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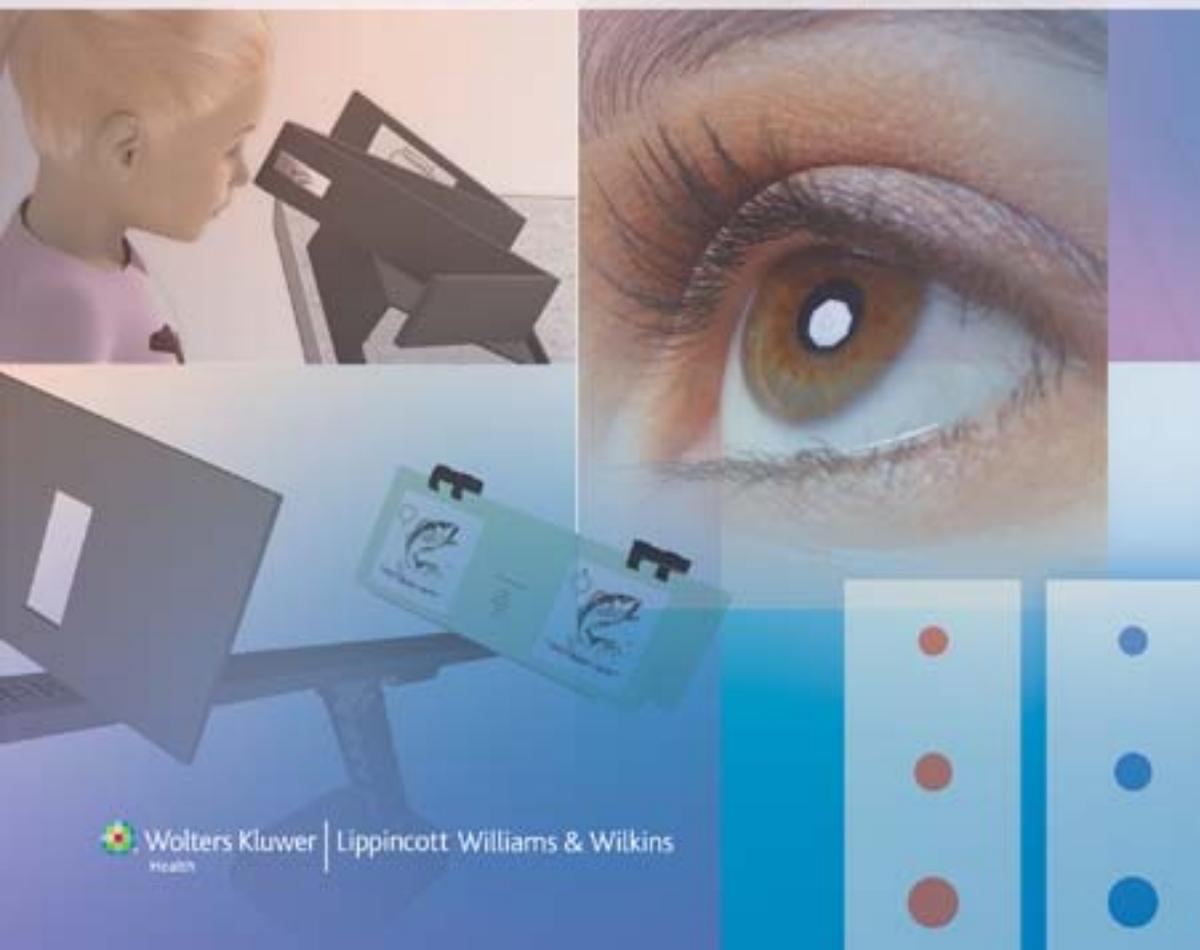
CLINICAL MANAGEMENT OF

Binocular Vision

Heterophoric, Accommodative, and
Eye Movement Disorders

FOURTH EDITION

Mitchell Scheiman | Bruce Wick



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Fourth Edition

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To Maxine, for her love, patience, and understanding.

—M.S.

Preface

Over the past 19 years we have received very positive feedback from colleagues and students about the first three editions of this book. They have remarked that this book is easy to read and understand, and that it provides valuable information about the diagnosis and treatment of binocular vision. We have also continued to receive excellent constructive criticism and suggestions and as in the past we have tried to respond to these suggestions in this new edition.

In both editions 2 and 3, it was necessary to add new chapters to respond to reader suggestions. For this edition, however, we have not added any new chapters. Rather, the main purpose of this new edition is to refresh the book with the latest research and evidence supporting the evaluation and treatment protocols suggested. Over the course of 5 years there have been new research studies and other new literature that are relevant to the topics covered in this text. We have carefully reviewed this new literature and have incorporated information from these studies when appropriate.

One of the other important changes has been the introduction of new technology and equipment for vision therapy. We have tried to include information about new vision therapy equipment in this new edition in Chapters 6–8. Finally, all of the illustrations in the book have been updated and a majority of the illustrations are now in color.

We hope that the updated material will make this fourth edition even more useful than the previous editions for faculty designing courses, students studying these topics for the first time, and established practitioners looking for a practical, easy-to-use reference on accommodative, ocular motility, and non-strabismic vision anomalies.

*Mitchell Scheiman, O.D.
Bruce Wick, O.D., Ph.D.*

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O

ne of the authors (M.S.) acknowledges individuals who have had a strong influence on his professional development and the field of binocular vision and vision therapy:

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Contents

Preface	vi
Acknowledgments	vii

SECTION I Diagnosis and General Treatment Approach

1	Diagnostic Testing	2
2	Case Analysis and Classification	49
3	General Treatment Modalities, Guidelines, and Prognosis.	89
4	Primary Care of Binocular Vision, Accommodative, and Eye Movement Disorders.	112

SECTION II Vision Therapy Procedures and Instrumentation

5	Introduction and General Concepts	138
6	Fusional Vergence, Voluntary Convergence, and Antisuppression.	160
7	Accommodative Techniques.	209
8	Ocular Motility Procedures.	221

SECTION III Management

9	Low AC/A Conditions: Convergence Insufficiency and Divergence Insufficiency	234
10	High AC/A Conditions: Convergence Excess and Divergence Excess.	273
11	Normal AC/A Conditions: Fusional Vergence Dysfunction, Basic Esophoria, and Basic Exophoria.	307
12	Accommodative Dysfunction	335
13	Eye Movement Disorders	368
14	Cyclovertical Heterophoria	389
15	Fixation Disparity	429

SECTION IV Advanced Diagnostic and Management Issues

16	Interactions between Accommodation and Vergence.	451
17	Refractive Amblyopia.	471

18 Nystagmus 491

19 Aniseikonia 517

20 Binocular and Accommodative Problems
Associated with Computer Use 547

21 Binocular and Accommodative Problems Associated with
Acquired Brain Injury 571

22 Binocular and Accommodative Problems Associated
with Learning Problems 593

23 Development and Management of Refractive Error:
Binocular Vision-based Treatment 616

24 Binocular Vision Problems Associated with Refractive Surgery 655

SECTION V Vision Therapy and Optometric Practice

25 Patient and Practice Management Issues in Vision Therapy 674

Appendices 686

Index 705

SECTION

I

Diagnosis and General Treatment Approach

Diagnostic Testing

A After a thorough case history and determination of the refractive error, the first important step in the management of accommodative, ocular motor, and nonstrabismic binocular vision problems is the diagnostic testing routine. In this chapter we discuss testing procedures for assessing accommodation, binocular vision, and ocular motor skills. The emphasis is on presentation of important issues, considerations, and expected values for the various tests. The setup and administration of these tests is summarized in the Appendix to this chapter.

Determination of Refractive Error

All measures of alignment and accommodation require an accurate full-plus refraction with a binocular balance. It is useful to perform a binocular refraction technique that yields a maximum plus refraction. Such an examination often requires an initial objective determination of the refractive error. This can be accomplished with static retinoscopy, autorefraction, or even starting with the patient's previous refractive correction. To perform a modified binocular refraction, we recommend the following procedure:

1. Use a 20/30 line (or an acuity line two lines above threshold).
2. With the left eye occluded, add plus (0.25 diopter [D] at a time) to the objective findings until the right eye is barely able to read the 20/30 threshold line. If too much plus is used, the next step will be difficult, so you may want to back off slightly (add -0.25 D, at most).
3. Perform Jackson cross-cylinder (JCC) testing. Adding plus in the step above allows the patient to make more accurate JCC responses.
4. Repeat for left eye, with right occluded.
5. Add prism (3 Δ up before the right eye; 3 Δ down before the left) and $+0.75$ D to each eye.
6. Perform a dissociated balance by adding plus to the clearer target, until both are reported to be equally blurred.
7. Remove the dissociating prism and slowly add minus, until the patient can just read 20/20. *Do not* arbitrarily add some amount of minus!
8. Place the vectographic slide in the projector with analyzers in the phoropter. Place "I" target with letters on each side in the patient's view and ask if both sides are equally clear. If not, add $+0.25$ D to the clearer side. This is a binocular balance, but not a true binocular refraction where the JCC would be performed under these conditions as well; it is generally not necessary to perform a JCC here unless the patient has a significant astigmatism (>1.00 DC) and a torsional phoria is suspected.
9. Perform associated phoria measures and stereopsis testing.
10. Return to the standard slide and check visual acuity. If the patient cannot see 20/15, check whether -0.25 more OU improves the acuity. It is virtually never necessary to add more than -0.50 OU total. *Do not* arbitrarily add some amount of minus!

The maximum plus refraction technique breaks down when acuity is very unequal (e.g., amblyopia). In these instances, where often no refractive technique works well, use retinoscopy to determine balance after attempting to achieve maximum plus on the "good" eye (make the retinoscopic reflexes appear equal for the two eyes).

Assessment of Nonstrabismic Binocular Vision Disorders

GENERAL CONSIDERATIONS

The evaluation of binocular vision involves several distinct steps (Table 1.1). The first phase of testing is the measurement of the magnitude and direction of the phoria at a distance and near, along with the accommodative convergence to accommodation (AC/A) ratio. Conventional procedures to accomplish this include tests such as cover testing, the von Graefe phoria test, and the modified Thorington test. Fixation disparity testing represents a more recent method of assessing binocular vision and provides additional information that should be considered in the evaluation of binocular vision status. The primary advantage of fixation disparity testing is that it is performed under binocular or associated conditions, in contrast to other tests that are performed under dissociated conditions.

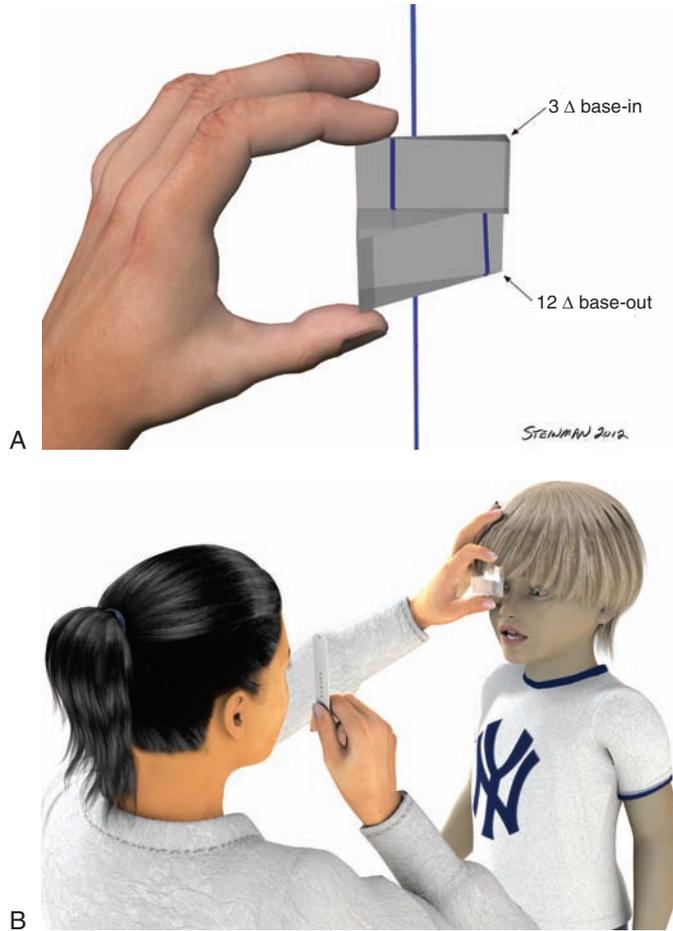
The second step is the assessment of positive and negative fusional vergence using both direct and indirect measures. *Direct measures* refer to tests such as smooth and step vergence testing, whose primary objective is to assess fusional vergence. *Indirect measures* refer to tests such as the negative relative accommodation (NRA), positive relative accommodation (PRA), fused cross-cylinder, binocular accommodative facility (BAF), and monocular estimation method (MEM) retinoscopy that are generally thought of as tests of accommodative function. Because these procedures are performed under binocular conditions, however, they indirectly evaluate binocular function as well. The results of such testing, therefore, can be used to confirm or deny a particular clinical hypothesis of a binocular vision disorder. Chapter 2 describes the analysis of these indirect measures in detail.

The traditional evaluation of fusional vergence involves only measurement of smooth vergence ranges or vergence amplitude using a Risley prism in the phoropter. In recent years, additional ways of evaluating fusional vergence have been suggested. One method is step vergence testing, which is done outside the phoropter, using a prism bar (1,2). Another addition to the traditional approach to assessing fusional vergence is vergence facility testing (3–9). This test is also performed outside the phoropter, using a specially designed vergence facility prism (Fig. 1.1). The patient's ability to make large rapid changes in fusional vergence is assessed with this procedure over a specific period of time.

An important distinction among different methods of evaluating fusional vergence is the assessment of vergence amplitude versus vergence facility. Smooth and step vergence testing are designed to assess the patient's vergence amplitude, whereas vergence facility testing measures vergence dynamics. Grisham (6) found a relationship between vergence dynamics and symptoms in subjects he studied. His research indicated that vergence latency and vergence velocity are of diagnostic importance in a binocular evaluation. It is possible for a patient to have normal fusional vergence amplitudes and still have a problem in the area of facility or vergence dynamics. Using only the traditional smooth vergence evaluation approach would fail to detect

TABLE 1.1 IMPORTANT STEPS IN THE EVALUATION OF BINOCULAR VISION

Measurement of the phorias	Cover test
AC/A and CA/C ratios	von Graefe phoria Modified Thorington Fixation disparity
Assessment of positive and negative fusional vergence	
<i>Direct measures</i>	Smooth vergence testing Step vergence testing Vergence facility testing
<i>Indirect measures</i>	Negative relative accommodation Positive relative accommodation Fused cross-cylinder Binocular accommodative facility Monocular estimation method retinoscopy
Convergence amplitude	Near point of convergence
Sensory status	Worth four-dot Stereopsis testing



■ **Figure 1.1** **A:** Vergence facility prism (3 Δ base-in/12 Δ base-out). **B:** Vergence facility prism clinical procedure.

such a problem. Gall et al. (7) found that the use of 3 Δ base-in/12 Δ base-out for vergence facility testing can differentiate symptomatic from nonsymptomatic patients.

Another consideration in testing fusional vergence amplitude or facility is the issue of performance over time (3). The underlying question is whether the patient is able to compensate for a given amount of prism over an extended period of time. Traditionally, fusional vergence amplitude is measured just once. Research suggests that this may not be sufficient (6,7). Rather, these tests should be repeated several times, and testing that probes facility and ability to respond over time should be incorporated into the evaluation.

The third area that should be evaluated is convergence amplitude. Generally referred to as the near point of convergence (NPC), this test is particularly important in the diagnosis of one of the most common binocular vision disorders—convergence insufficiency. Important issues include the type of target or targets to be used and the issue of performance over time (10,11).

The last aspect of the binocular evaluation is sensory status. Suppression and stereopsis are the primary areas to evaluate. Information about sensory status can also be obtained from many of the other tests discussed above. On several of these tests, suppression can be monitored. A specific test that can be used to assess suppression is the Worth four-dot test. As a general rule, clinical measures of stereopsis are either not affected or only minimally affected in nonstrabismic binocular vision disorders. Intermittent mild suppression, however, is a common finding.

A complete assessment of binocular vision should include all four of the components just described. A suggested minimum database would include the NPC, the cover test at distance and near, step vergence ranges at distance and near, and stereopsis testing. If a patient presents with symptoms and the minimum

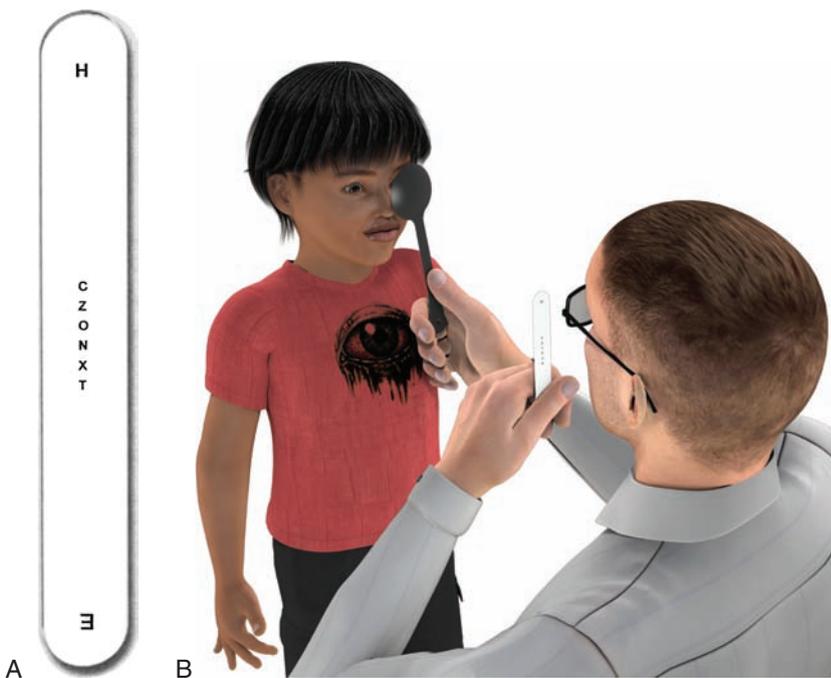
database does not yield conclusive information, additional testing using indirect measures of binocular function, along with facility testing and fixation disparity assessment, should be utilized.

ASSESSMENT OF SIZE AND DIRECTION OF THE PHORIA OR FIXATION DISPARITY

Cover Test (in the Absence of Strabismus)

1. **Purpose** The cover test is an objective method of evaluating the presence, direction, and the magnitude of the phoria.
2. **Important issues**
 - (a) **Controlling accommodation** The most important aspect of the cover test procedure, or any other test of binocular alignment, is control of accommodation. A study by Howarth and Heron (12) reaffirmed the significance of the accommodative system as a potential source of variability in clinical heterophoria measurement. Underaccommodation will result in an overestimation of the degree of exophoria or an underestimation of the esophoria. Overaccommodation will yield the opposite results. There are two techniques that can be used to maximize control of accommodation during the cover test procedure. These refinements to the basic procedure tend to increase attention on the task. The examiner can use multiple fixation targets to maintain attention and accommodation on the task. This can easily be accomplished using Gulden fixation sticks that have 20/30 targets on both sides of the stick (Fig. 1.2). Periodically, the fixation stick is turned around to change targets. The patient is asked to identify the target during the cover test.

Another useful procedure is to move the target left to right very slightly (1 to 3 cm) between movements of the cover paddle. The examiner looks for a small pursuit movement in the uncovered eye. If a pursuit movement occurs when the target is moved left to right, it suggests that the patient is attending to the target. Attention on the target tends to encourage accommodation.
 - (b) **Objectivity** Because the cover test is an objective technique, it is one of the most valuable methods for assessing the motor characteristics of binocularity. It becomes particularly valuable when working with young children.
 - (c) **Repeatability** Johns et al. (13) found that the alternate cover test with prism neutralization has high intraexaminer and interexaminer repeatability.



■ **Figure 1.2** A: Gulden fixation stick. B: Gulden fixation sticks with small targets used as a fixation target.

TABLE 1.2 REVISED NEWCASTLE CONTROL SCORE

Home Control	
XT or monocular eye closure seen	
0	Never
1	<50% of time fixing at distance
2	<50% of time fixing at distance
3	50% of time fixing in distance + seen at near
Clinic Control	
<i>Near</i>	
0	Immediate realignment after dissociation
1	Realignment with aid of blink or refixation
2	Remains manifest after dissociation/prolonged fixation
3	Manifest spontaneously
<i>Distance</i>	
0	Immediate realignment after dissociation
1	Realignment with aid of blink or refixation
2	Remains manifest after dissociation/prolonged fixation
3	Manifest spontaneously

Total Newcastle Scale Score: (Home + Near + Distance).

- (d) **Assessing frequency and control of the deviation** When an intermittent strabismus is detected using the cover test an additional assessment must be made of the proportion of time the eye is deviated, or the frequency of the deviation. This can also be referred to as control of the deviation. It is commonly believed that a worsening of control in intermittent exotropia is an indication for vision therapy or surgical intervention. The problem is that until recently precise criteria for progression have not been established.

Haggerty et al. (14) described the Newcastle Control Score that they developed as a tool to assess control of an intermittent exotropia deviation. The scale incorporates both objective (office assessment) and subjective measures (home assessment by parents) of control into a grading system that differentiates and quantifies the various levels of severity in intermittent exotropia. The authors suggest that the scale is a consistent and robust method of rating severity that can be used accurately in clinical practice. Hatt et al. (15), however, questioned the reliability of parental observations. The revised Newcastle Control Score (16) is illustrated in Table 1.2.

Mohney and Holmes (17) developed an office-based scale that can describe the wide range of control in patients with intermittent exotropia and avoids many of the weaknesses of prior systems. It provides a quantitative measure of the severity and duration of the manifest component of the exodeviation and is useful for the longitudinal evaluation of patients with intermittent exotropia. Hatt et al. (18) used this scale with 12 children with intermittent XT and they were evaluated during 4 sessions (2 hours apart) over a day on 2 separate days (8 sessions per child). Control was standardized using the scoring system and quantified three times during each examination. They found that the mean of three assessments of control during a clinic examination better represents overall control than a single measure. This scale is illustrated in Table 1.3.

TABLE 1.3 INTERMITTENT EXOTROPIA CONTROL SCALE

Control Score	Control Score Description
5	Constant exotropia during a 30-sec observation period (before dissociation)
4	Exotropia 50% of the time during a 30-sec observation period (before dissociation)
3	Exotropia 50% of the time during a 30-sec observation period (before dissociation)
2	No exotropia unless dissociated (10 sec): recovery in 5 sec
1	No exotropia unless dissociated (10 sec): recovery in 1–5 sec
0	Pure phoria: 1-sec recovery after 10-sec dissociation

3. **Expected values** Although the expected finding for the cover test has not been specifically studied, we expect it to be similar to the values found during phoria testing. At distance, the expected value is 1 exophoria, with a standard deviation of $\pm 1 \Delta$. The mean expected value at near is 3 exophoria, with a standard deviation of $\pm 3 \Delta$ (19).

Phoria Measured Using the von Graefe Technique

1. **Purpose** The von Graefe phoria test is a subjective method of evaluating the presence, direction, and the magnitude of the phoria.

2. **Important issues**

- (a) **Controlling accommodation** Controlling accommodation is also important when evaluating the phoria using the von Graefe procedure. It is vital to emphasize this in the instructional set to the patient. Often clinicians merely ask the patient to look at one image and report when the other is right above or below. To ensure more accurate accommodation, the clinician should state

I want you to look at the lower image, and it is very important to *keep it clear at all times*. While you keep it clear, tell me when the upper image moves directly above the lower image.

Although the instruction to keep the target clear is not always included in phoria testing, a lack of attention to this issue may lead to variability and poor reliability.

Another issue that should be considered, particularly in young children, is whether the patient understands the task. Clinicians often use the following instructional set to try to explain the objective of the test:

Look at the bottom line and tell me when the top line moves directly above it, like buttons on a shirt.

Although this may be helpful for older children and adults, we have found that children who are 7 years old and younger do not perform well with this analogy. To promote an understanding in young children, we suggest an actual simple demonstration outside the phoropter using one's fingers. The young child is asked to look at the examiner's fingers, which are held one directly over the other. We use the following instructional set:

Look at the finger on the bottom and tell me when my top finger is right over my bottom finger. (Demonstrate by misaligning your fingers and then bringing them back to alignment.) Now let's try it; tell me when to stop.

Using this method allows the examiner to determine whether the child has an understanding of what is expected.

Although the von Graefe procedure is commonly used in clinical practice, a study by Rainey et al. (20) indicated that this procedure is the least repeatable of the various tests used to measure the phoria.

- (b) **Reliability** Rouse et al. (21) reported a high level of intraexaminer reliability, both within and between sessions, using the von Graefe method of assessing the phoria in children 10 to 11 years old.
3. **Expected values** At distance, the expected value is 1 exophoria, with a standard deviation of $\pm 1 \Delta$ (Table 1.4). The mean expected value at near is 3 exophoria, with a standard deviation of $\pm 3 \Delta$ (19) for children and young adults; for presbyopes, the mean expected values are 1 esophoria, with a standard deviation of $\pm 1 \Delta$ at distance, and 8 exophoria with a standard deviation of $\pm 3 \Delta$ at near.

Phoria Measured Using the Modified Thorington Technique

1. **Purpose** This technique is a subjective method of evaluating the presence, direction, and the magnitude of the phoria.

2. **Important issues**

- (a) **Controlling accommodation** With the modified Thorington test, it is important for the clinician to emphasize that the patient keep the letters on the chart clear during the test procedure. In a study by Rainey et al. (20), the results of seven different procedures of assessing the phoria were compared to determine the repeatability of the clinical tests. The authors compared the estimated cover test, prism-neutralized objective cover test, prism-neutralized subjective cover test, von Graefe continuous

TABLE 1.4 TABLE OF EXPECTED VALUES: BINOCULAR VISION TESTING

Test		Mean Value	Standard Deviation
Cover test			
Distance		1 exophoria	$\pm 2 \Delta$
Near		3 exophoria	$\pm 3 \Delta$
Distance lateral phoria		1 exophoria	$\pm 2 \Delta$
Near lateral phoria		3 exophoria	$\pm 3 \Delta$
AC/A ratio		4:1	$\pm 2 \Delta$
Smooth vergence testing			
Base-out (distance)	Blur:	9	± 4
	Break:	19	± 8
	Recovery:	10	± 4
Base-in (distance)	Break:	7	± 3
	Recovery:	4	± 2
Base-out (near)	Blur:	17	± 5
	Break:	21	± 6
	Recovery:	11	± 7
Base-in (near)	Blur:	13	± 4
	Break:	21	± 4
	Recovery:	13	± 5
Step vergence testing			
<i>Children 7–12 year old</i>			
Base-out (near)	Break:	23	± 8
	Recovery:	16	± 6
Base-in (near)	Break:	12	± 5
	Recovery:	7	± 4
<i>Adults</i>			
Base-out (distance)	Break:	11	± 7
	Recovery:	7	± 2
Base-in (distance)	Break:	7	± 3
	Recovery:	4	± 2
Base-out (near)	Break:	19	± 9
	Recovery:	14	± 7
Base-in (near)	Break:	13	± 6
	Recovery:	10	± 5
Vergence facility testing			
<i>(12 base-out/3 base-in)</i>		15.0 cpm	± 3
Near point of convergence			
Accommodative target	Break:	2.5 cm	± 2.5
	Recovery:	4.5 cm	± 3.0
Penlight and red/green glasses	Break:	2.5 cm	± 4.0
	Recovery:	4.5 cm	± 5.0

presentation, von Graefe flash presentation, the Thorington method, and the modified Thorington method. They found that the modified Thorington procedure was the most repeatable method, whereas the von Graefe methods had the poorest repeatability.

- (b) **Testing outside the phoropter** An important advantage of this technique is that it can be used for patients who are difficult to test with a phoropter. For this reason, the modified Thorington technique has value with children younger than 7 or 8 years. As indicated above, it has also been shown to be the most repeatable method of assessing the phoria.
3. **Expected values** At distance, the expected value is 1 exophoria with a standard deviation of $\pm 1 \Delta$ (Table 1.4). The mean expected value at near is 3 exophoria, with a standard deviation of $\pm 3 \Delta$ (19).

Fixation Disparity Assessment

1. **Purpose** Fixation disparity testing is designed to evaluate binocular vision under associated conditions. This is in contrast to cover testing, the von Graefe phoria test, and the modified Thorington techniques, which are done under conditions in which either one eye is covered or the eyes are dissociated.
2. **Important issues**
 - (a) **Fixation disparity testing is performed under binocular conditions** The main deficiency of the typical phoria measurement is that the evaluation occurs under dissociated conditions. Wick (22) states that “the vergence error under binocular conditions is often not the same as it is under monocular conditions.” As a result, there are situations in which a patient may be symptomatic, but the conventional phoria/vergence analysis does not produce a clear understanding of the cause of the patient’s symptoms. Although some clinicians suggest the routine use of fixation disparity testing, we have found that in the majority of cases, phoria/vergence testing is sufficient to reach a tentative diagnosis and management plan. In those situations in which the diagnosis is unclear or a prism prescription is being considered, fixation disparity testing is a useful addition to the examination procedure.
 - (b) **Associated phoria versus forced vergence fixation disparity assessment** Various instruments are available for the evaluation of fixation disparity. Instruments, such as the Mallett unit, the American Optical vectographic slide, the Borish card, the Bernell lantern, the Wesson Card, the Sheedy Disparometer, and some computerized distance visual acuity charts (Chapter 15) can all be used to determine the associated phoria. The associated phoria is the amount of prism necessary to neutralize any perceived misalignment of the lines.
 Studies suggest, however, that the use of forced vergence fixation disparity testing is more likely to yield data that are useful for determining those patients who are likely to have symptoms (23,24). The Wesson card is currently the only commercially available instrument for measuring the actual fixation disparity. Based on current information, forced vergence fixation disparity testing should be used when assessing a horizontal deviation. For a vertical deviation, associated phoria testing is sufficient.
 - (c) **Determination of prism correction** Fixation disparity is currently considered the method of choice for determining the amount of prism to prescribe for binocular disorders. Other methods tend to yield higher amounts of prism than fixation disparity analysis.
3. **Expected values** Refer to Chapter 15.

AC/A Ratio

1. **Purpose** To determine the change in accommodative convergence that occurs when the patient accommodates or relaxes accommodation by a given amount.
2. **Important issues**
 - (a) **Significance in diagnosis and treatment** Determination of the AC/A ratio is important in analysis of optometric data. The AC/A finding is a key characteristic in the final determination of the diagnosis. It is also one of the most important findings used to determine the appropriate management sequence for any given condition. For example, esophoria at near associated with a high AC/A ratio would generally respond well to plus lenses. If the same degree of esophoria were associated with a normal or low AC/A ratio, the recommended treatment approach would include prism correction or vision therapy or both.
 - (b) **Calculated versus gradient AC/A ratio** There are two methods for determining a patient’s AC/A ratio. The first, referred to as the *calculated AC/A ratio*, is determined using the following formula:

$$AC/A = IPD \text{ (cm)} + NFD \text{ (m)} (H_n - H_f)$$

where

IPD = interpupillary distance in centimeters

NFD = near fixation distance in meters

H_n = near phoria (eso is plus and exo is minus)

Hf = far phoria (eso is plus and exo is minus)

Example: IPD = 60 mm, the patient is 2 exophoric at distance and 10 exophoric at near (40 cm).

$$\begin{aligned} AC/A &= 6 + 0.4(-10 + 2) \\ &= 6 + 0.4(-8) = 6 + (-3.2) \\ &= 2.8 \end{aligned}$$

When using this formula, one should remember to use the correct signs for esophoria and exophoria. A rule of thumb is that a high AC/A ratio will result in more eso or less exo at near, and a low AC/A ratio will lead to less eso or more exo at near.

The second method, called the *gradient AC/A*, is determined by measuring the phoria a second time using -1.00 or -2.00 lenses. The change in the phoria, with the additional minus, is the AC/A ratio. For example, if the near phoria is 2 esophoria through the subjective finding and, with -1.00 , it is 7 esophoria, the AC/A ratio is 5:1.

There may be significant differences between the two methods of determining the AC/A ratio. For instance, divergence excess and convergence excess patients both have high calculated AC/A ratios, but many of these patients have approximately normal gradient AC/A ratios (20). The same phenomenon may occur with convergence insufficiency. The calculated AC/A ratio will be low, but the gradient AC/A may be normal (22). The reason for these differences is the effect of proximal convergence and the lag of accommodation. The calculated AC/A ratio is usually larger than the gradient because of the effect of proximal vergence, which affects the near phoria measurement. Because the gradient ratio is measured by testing the near phoria twice at a fixed distance, proximal vergence is held constant and theoretically does not alter the final result. The lag of accommodation also accounts for differences between the calculated and gradient AC/A ratio measurements. Although the stimulus to accommodation is 2.50 D at near, the accommodative response is typically less than the stimulus. This difference between the stimulus and response of the accommodative system is called the *lag of accommodation*. The lag of accommodation is generally $+0.25$ to $+0.75$ D. Because the patient will tend to underaccommodate for any given stimulus, the gradient AC/A tends to be lower than the calculated AC/A ratio.

- (c) **Controlling accommodation** A source of measurement error in the AC/A evaluation is failure to control accommodation. The clinician should emphasize, in the instructional set, that clarity of the target is essential. It is easy to understand how variation in accommodative response from one measurement to another would adversely affect results. The gradient AC/A requires two measurements of the near phoria, first with only the subjective in place and then with -1.00 over the subjective. If a patient accurately accommodates for the first measurement, but underaccommodates for the second, the result will be an underestimation of the true AC/A ratio. It is, therefore, critical to ask the patient to maintain clarity, and it is advisable to ask the patient to read the letters periodically.
- (d) **Response versus stimulus AC/A ratio** When evaluating the accommodative or binocular systems, we usually present the stimulus at 40 cm. This creates an accommodative demand of 2.50 D. This is referred to as the *stimulus to accommodation*. Although the stimulus to accommodation is 2.50 D, the accommodative response will generally be about 10% less than the stimulus (25). The expected finding for MEM retinoscopy, for example, which assesses the accommodative response, is a lag of accommodation of about $+0.25$ to $+0.50$ D. It is important to be aware of the difference between the response and stimulus to accommodation, realizing that most patients will underaccommodate by about 10%. An instance where this becomes important is when comparing the calculated AC/A ratio to the gradient AC/A ratio. The gradient AC/A ratio will tend to underestimate the AC/A ratio. For example, suppose the phoria is measured as 10 exophoria at near and, when repeated with -1.00 lenses, the phoria is 6 exophoria. Based on this information, the gradient AC/A ratio would be 4:1. However, if we assume that the patient underaccommodates by 10%, the phoria has changed by 4Δ while accommodation has changed by 0.75 D. This would be an AC/A ratio of about 4.45:1.
3. **Expected values** The expected AC/A ratio is 4:1, with a standard deviation of ± 2 .

CA/C Ratio

1. **Purpose** To determine the change in accommodation that occurs when the patient converges or relaxes convergence by a given amount.

2. Important issues

- (a) **Significance in diagnosis and treatment** The convergence accommodation to convergence (CA/C) ratio is still not commonly assessed in the clinical situation. Determination of the CA/C ratio is important in analysis of optometric data. The CA/C finding is sometimes an important characteristic in the final determination of the diagnosis. It may also play a key role when one determines appropriate management. For example, divergence excess and other cases of high exophoria at distance may benefit from the use of added minus lenses. Analysis of the CA/C ratio helps in this determination.
 - (b) **Clinical determination of the CA/C ratio** To measure the CA/C ratio clinically, one has to use either a blur-free target or pinholes to eliminate blur as a stimulus. There is still no widely accepted method for determining the CA/C ratio. One possible approach is to use a target called the Wesson DOG (difference of gaussian) card (26) along with dynamic retinoscopy. To use this technique, ask the patient to view this target at four different distances as you perform retinoscopy. You can determine the amount of accommodation with different vergence levels.
 - (c) **Stimulus versus response CA/C** Unlike the accommodative system, in which there may be a significant difference between the stimulus and response, the vergence stimulus and vergence response are generally identical. There is, therefore, no need to differentiate between a stimulus and response CA/C ratio (27).
3. **Expected values** The expected CA/C value for young adults is 0.50 D per meter (m) angle. In vision research, 1 m angle equals 10% of the distance IPD in millimeters (mm); thus, for a patient with a 50 mm distance IPD, 1 m angle is 5 Δ , and for a patient with a 69 mm distance IPD, 1 m angle is 6.9 Δ . For clinical purposes, it is satisfactory to consider 1 m angle to be about 6 Δ . Because there is little difference between vergence stimulus and vergence response, there is very little difference between the stimulus and response CA/C ratio. The CA/C ratio is inversely related to age.

DIRECT ASSESSMENT OF POSITIVE AND NEGATIVE FUSIONAL VERGENCE

Smooth Vergence Testing

1. **Purpose** Smooth vergence testing is designed to assess the fusional vergence amplitude and recovery at both distance and near. This is considered a direct measure of fusional vergence.
2. **Important issues**
 - (a) **Amplitude versus facility** Smooth vergence testing is the most common method used for assessing the amplitude of the fusional vergence response for both positive and negative fusional vergence. The blur finding is a measure of the amount of fusional vergence free of accommodation. The break indicates the amount of fusional vergence and accommodative vergence. The recovery finding provides information about the patient's ability to regain single binocular vision after diplopia occurs. Although smooth vergence testing provides important information about the amplitude of fusional vergence, studies (6) have shown that it is possible to have normal fusional amplitudes and still have a problem referred to as fusion vergence dysfunction. Additional testing must be performed to assess fusional facility.
 - (b) **Reliability** Rouse et al. (21) reported only fair intraexaminer reliability, both within and between sessions using the von Graefe smooth vergence testing procedure in children aged 10 to 11 years. Their results suggest that differences up to 12 Δ occur with follow-up visits even without intervention. Thus, when evaluating the effects of treatment such as vision therapy, a change of greater than 12 Δ is needed to be confident that the change is real and not the result of measurement variability.
 - (c) **Smooth versus step vergence** Smooth and step vergence testing are both designed to evaluate fusional vergence amplitude. The primary value of step vergence testing is that it is administered outside the phoropter. This is an important advantage when examining young children. Before the age of 8 or 9, children tire quickly and may move around, making testing with a phoropter difficult. Because it is impossible to see the child's eyes behind the phoropter, the clinician cannot be sure whether the patient is responding appropriately. Studies (1,2) have demonstrated that expected findings are different for smooth versus step vergence. Two studies have also compared fusional vergence ranges with rotary prism (smooth) versus step vergence with a prism bar (28,29). Antona et al. (28) compared phoropter rotary prism vergence ranges with phoropter prism bar fusional vergence ranges

for 61 optometry students in Spain. The results suggested that the two tests should not be used interchangeably. Goss and Becker (29) did a similar study and also concluded that fusional vergence ranges determined by prism bars out of the phoropter cannot be used interchangeably with those determined by phoropter rotary prisms for the purpose of follow-up on individual patients or for the purpose of comparison with norms. Thus, clinicians should use one method or the other in the initial examination and when following the patient's progress, reevaluate using the same method.

- 3. Expected values** Table 1.4 lists the expected values for the blur, break, and recovery for positive and negative fusional vergence using smooth vergence testing.

Step Vergence Testing

- 1. Purpose** Step vergence is a method of evaluating fusional vergence amplitude outside the phoropter.
- 2. Important issues** Testing is done outside the phoropter. When a young child is evaluated who is either very active or not responding reliably, step vergence testing represents a useful alternative. The child's eyes can be seen because testing is done with a prism bar, and the test becomes more objective. Instead of relying on the patient's responses, the examiner can observe when the child loses binocularity.
- 3. Expected values** The expected values have been determined to be different for adults and children (1,2). Table 1.4 lists the break and recovery values for positive and negative fusional vergence testing for both children and adults.

Vergence Facility Testing

- 1. Purpose** Vergence facility testing is designed to assess the dynamics of the fusional vergence system and the ability to respond over a period of time. This ability to make rapid repetitive vergence changes over an extended period of time can be referred to as a measure of stamina and is the characteristic that we assess clinically. Another characteristic that we indirectly evaluate using vergence facility testing is sustaining ability. This refers to the ability of the individual to maintain vergence at a particular level for a sustained period of time, rather than to rapidly alter the level.
- 2. Important issues**
 - (a) Amplitude versus facility** Melville and Firth (30) investigated the relationship between positive fusional vergence ranges and vergence facility. They found no correlation between these values and suggest that this indicates that the two tests assess different aspects of the vergence system. A more recent study by McDaniel and Fogt (31) also found a lack of correlation between the two test findings and concluded that patients with vision-related asthenopic symptoms who have normal compensating disparity vergence ranges should undergo vergence facility testing. Because it is possible to have normal fusional vergence amplitudes and vergence facility problems, both aspects should be evaluated with a symptomatic patient. We suggest using vergence facility testing when a patient presents with symptoms characteristic of a binocular disorder and other testing does not reveal any problems. Such a patient may have normal fusional vergence amplitudes but reduced facility.
 - (b) Strength of prism to use and target to use** Until fairly recently, there had been a lack of systematically gathered normative data and little consensus in literature about the strength of the prism that should be used for this test. Buzzelli (4) recommended the use of 16 base-out and 4 base-in. Another common recommendation (3) was 8 base-out and 8 base-in. Gall et al. (7) performed the first systematic study of vergence facility and found that the magnitude of choice is 3 Δ base-in/12 Δ base-out. This combination of prisms yielded the highest significance for separating symptomatic from nonsymptomatic subjects. They also found that this combination of prisms produced repeatable results ($R = 0.85$) when used for near vergence facility testing.

In another study, Gall et al. (8) compared the use of three different vertically oriented targets for vergence facility testing. The targets tested were a vertical column of 20/30 letters, a back-illuminated anaglyphic target, and the Wirt circles oriented vertically. The study was designed to determine whether it is important to use a target with a suppression control for vergence facility testing. They found that vergence facility is nearly independent of the target and that a simple vertical row of 20/30 letters is an appropriate target.

- 3. Expected values** Based on the work of Gall et al. (7), the expected finding for vergence facility, using values of 3 Δ base-in/12 Δ base-out, is 15 cpm at near (Table 1.4).

INDIRECT ASSESSMENT OF POSITIVE AND NEGATIVE FUSIONAL VERGENCE

Near Point of Convergence

1. **Purpose** The purpose of the NPC is to assess the convergence amplitude. A remote NPC was found to be the most frequently used criterion by optometrists for diagnosing convergence insufficiency (32).

2. Important issues

(a) **Target to be used** Different targets have been suggested for NPC testing. Recommendations vary, including an accommodative target, a light, a light with a red glass before one eye, and a light with red/green glasses. Some suggest that a variety of targets should be used to determine whether there are differences with various targets. We recommend repeating the NPC twice—first using an accommodative target and then using a transilluminator or penlight with red/green glasses.

(b) **Does repetition yield additional useful clinical data?** The NPC test traditionally is performed by slowly moving a target toward the eyes until the patient reports diplopia or the examiner notices a break in fusion (33). This is recorded as the breakpoint. The target is then slowly moved away from the patient until fusion is reported or the examiner notices realignment of the eyes, signaling recovery of fusion.

Several modifications to this traditional approach have been suggested in the literature to make the test more sensitive. Wick (22) and Mohindra and Molinari (34) recommend that the NPC test be repeated four to five times. Their suggestions are based on the claim of Davies (35) that asymptomatic patients manifest little change in the near point with repeated testing, whereas symptomatic patients have significantly less convergence with repeated testing. Thus, this recommendation is designed to improve the diagnostic sensitivity of the break of the NPC test. Scheiman et al. (11) found a recession of the NPC after repetition in both normal subjects and convergence insufficiency patients. In the subjects with normal binocular vision, however, the amount of recession was small, less than 1 cm. In the convergence insufficiency group, the amount of recession was 1.5 cm after 5 repetitions and about 4 cm after 10 repetitions (11). These findings suggest that the NPC test would have to be repeated about 10 times to yield useful clinical information. Maples and Hoenes (36) also investigated the changes in the NPC after repetition and found that the NPC break and recovery do not change appreciably with multiple repetitions of the test.

(c) **Does the use of the red glass or red/green glasses yield any additional useful clinical data?** Another criterion utilized for assessment of convergence ability is the recovery point, or the point at which an individual regains fusion (after fusion has been lost) during the push-up convergence testing. Capobianco (37) reported that a recovery point greatly different from the break indicates greater convergence problems. She also suggested repeating the test with a red glass before one eye. She stated that greater recession with the red glass suggests a more significant convergence problem. Several authors (22,34,38,39) have suggested that this procedure be part of the standard assessment of convergence amplitude.

Scheiman et al. (11) found a statistically significant difference between the break and recovery with an accommodative target and the results with a penlight and red/green glasses in patients with convergence insufficiency. For convergence insufficiency subjects, the mean break with an accommodative target was 9.3 cm and, with a penlight and red/green glasses, the mean break was 14.8 cm. The recovery finding with the accommodative target was 12.2 cm, and with a penlight and red/green glasses it was 17.6 cm. For both the break and recovery, therefore, there was a difference of about 5.5 cm between the accommodative target and penlight and red/green glasses. Statistically significant differences were not found for an accommodative target compared to a penlight or a penlight compared to a penlight and red/green glasses.

In the subjects with normal binocular vision, there were no significant differences for any of the conditions just described. The mean break was between 2.4 cm and 2.9 cm, and the mean recovery was between 4.2 cm and 5 cm.

(d) **The value of assessing convergence ability using a jump convergence format** Pickwell and Stephens (40) described another method of assessing convergence ability, which they termed *jump convergence*. In this procedure, the subject first fixates a target at 6 cm and then changes fixation to a target at 15 cm. Pickwell and Stephens (40) and Pickwell (41) reported that this jump convergence test appears to have more clinical significance and is a more sensitive way of determining the presence of convergence problems than the NPC. In the original study (41), the authors compared the effectiveness of the standard near point test (pursuit convergence) and the jump convergence procedure in a group of 74 subjects with inadequate convergence; 50 of the 74 showed normal pursuit

convergence but reduced jump convergence. Only five subjects passing the jump convergence test failed the pursuit convergence procedure. The authors concluded that “this evidence clearly suggests that the jump convergence test is more likely to detect inadequacy of convergence than the measurement of the NPC.” In a second study, Pickwell and Hampshire (10) found that in a sample of 110 subjects with inadequate convergence, poor jump convergence was more frequently associated with symptoms than was poor pursuit convergence. One problem with the jump convergence test is the lack of expected values for this test. In their 2003 study, Scheiman et al. (11) found a mean of 30 cpm (standard deviation = 10) for subjects with normal binocular vision and 23 cpm (standard deviation = 11) for subjects with convergence insufficiency (11).

- 3. Expected values** Although this test is commonly used to diagnose convergence insufficiency, there had been no normative data for children or adults until recently. Hayes et al. (42) studied 297 schoolchildren and recommended a clinical cutoff value of 6 cm. Maples and Hoenes (36) reported a similar value with a cutoff value of 5 cm. Scheiman et al. (11) studied an adult population and suggested that when using an accommodative target, a 5-cm cutoff value should be used for the break and a 7-cm cutoff value should be used for the recovery. Using a penlight and red/green glasses, the cutoff value for the break is 7 cm and that for the recovery 10 cm.

Negative Relative Accommodation and Positive Relative Accommodation

- 1. Purpose** NRA and PRA tests were designed to be used as part of the near point evaluation of accommodation and binocular vision. The primary objective of these tests is to determine whether the patient requires an add for near work. In a presbyopic patient, the two findings should be approximately balanced (NRA = +2.50, PRA = -2.50). An NRA value higher than the PRA suggests that a patient may benefit from an add (Chapter 10). The test is also used with the presbyopic population in the same manner to determine if an add is necessary and to finalize the magnitude of the required add. The NRA can also be used to determine whether a patient has been overminused during the subjective examination. The NRA is performed through the subjective prescription, which should eliminate all accommodation at distance. Because the test distance is 40 cm, the patient will accommodate approximately 2.5 D to see the target clearly. Therefore, the maximum amount of accommodation that can be relaxed is 2.50 D. Thus, an NRA finding greater than +2.50 suggests that the patient was overminused.

In this text, we stress another use for the NRA and PRA tests. These tests can be used to indirectly analyze both accommodation and vergence. This is explained in detail in Chapter 2.

2. Important issues

- (a) Instructional set** It is important to ask the patient to keep the target clear and single during these tests. Traditionally, the instructional set is, “As I add lenses in front of your eyes, keep these letters clear for as long as you can. Tell me when the letters are blurry.” We believe it is important to also ask the patient to report diplopia, because these tests also indirectly probe the ability to maintain fusion using positive and negative fusional vergence.
- (b) High NRA finding** A high NRA finding indicates that the patient has been overminused during the subjective.
- (c) At what level should the PRA be discontinued?** The maximum value that should be expected with the NRA is +2.50, for the reasons explained above. However, there is no consistent endpoint for the PRA. The endpoint for the PRA will vary depending on the patient’s amplitude of accommodation, AC/A ratio, and the negative fusional vergence. The following examples illustrate the variables that determine the endpoint for the PRA.

In the first patient, we would expect the patient to be able to keep the target single and clear until about -6.00. As we add minus lenses binocularly, the patient must accommodate to maintain clarity.

Test	Patient 1	Patient 2	Patient 3	Patient 4
Amplitude of accommodation	12 D	12 D	12 D	2 D
AC/A ratio	2:1	4:1	8:1	2:1
Base-in vergence (near)	12/20/12	10/20/10	8/12/8	12/20/12
Expected PRA finding	-6.00	-2.50	-1.00	-2.00

This is not a problem because the amplitude of accommodation is 12 D. At the same time, the patient must maintain single binocular vision. As the patient accommodates, the AC/A ratio causes convergence that must be counteracted using negative fusional vergence. For every 1 Δ of accommodation, the patient must use 2 Δ of negative fusional vergence. Because patient 1 has 12 D of accommodation and 12 Δ of negative fusional vergence, he or she will be able to maintain clear single binocular vision until about -6.00 D. Using the same reasoning, the PRA endpoint will decrease as the AC/A increases, as demonstrated above for patients 2 and 3, who have higher AC/A ratios and lower negative fusional vergence ranges. Patient 4 has findings identical to patient 1, except that the amplitude of accommodation is only 2 D. Even though this patient has a low AC/A ratio and normal negative fusional vergence, blur would be expected at -2.00 because of the low amplitude of accommodation.

In contrast to the NRA, where the maximum expected endpoint is always $+2.50$, the maximum endpoint for the PRA varies with multiple factors. Because the primary objective of the NRA and PRA tests is to determine whether the two values are balanced, it makes sense to stop the PRA test after reaching a value of -2.50 .

3. **Expected values** The expected values for NRA are $+2.00, \pm 0.50$; for PRA, the expected values are $-2.37, \pm 1.00$.

Evaluation of Sensory Status

GENERAL CONSIDERATIONS

Although sensory fusion anomalies can be very dramatic in cases of strabismus, in cases of nonstrabismic binocular vision disorders, sensory anomalies are much less severe. Most patients with nonstrabismic binocular anomalies have normal or only mildly reduced stereopsis. Intermittent mild suppression is common in heterophoria, but is less intense and the size of the suppression scotoma smaller than in strabismus.

Although sensory status is not as significant an issue in heterophoria, the presence of suppression or loss of stereopsis is still important in determining the prognosis and sequence of treatment. In many cases, the presence of suppression can be determined by performing the binocular vision testing described earlier. During the NPC, near lateral phoria, and fusional vergence testing, patients may be unable to appreciate diplopia in spite of misalignment of the visual axes, indicating suppression.

EVALUATION OF SUPPRESSION

Worth Four-dot Test

1. **Purpose** The Worth four-dot test is a subjective test designed to evaluate the presence and size of the suppression scotoma. It is considered one of the most accurate methods of evaluating suppression (43).
2. **Important issues**
 - (a) **Determining the size of the suppression scotoma** The size of the suppression scotoma can be determined by moving the Worth four-dot flashlight away from the patient. As the flashlight is moved away from the patient, the target subtends a smaller angle. For instance, at 33 cm, the target subtends an angle of approximately 4.5 degrees. At 1 m, the angle subtended is approximately 1.5 degrees. When performing the Worth four-dot test, the flashlight is initially held at 33 cm, and the patient, wearing red/green glasses, is asked to report the number of dots seen. If the patient reports four dots, the clinician should slowly move the flashlight from 33 cm to about 1 m. If the patient reports four dots at 33 cm, but two or three dots at 1 m, a small suppression scotoma is present. If a three- or two dot-response is present, even at 33 cm, the suppression scotoma is larger. The size of the suppression scotoma is important because there is an inverse relationship between the size of the suppression scotoma and the level of stereopsis. As the suppression scotoma becomes larger, the stereopsis decreases (3).
 - (b) **Determining the intensity or depth of the suppression** It is important to evaluate the intensity of the suppression scotoma. It is possible to have a small suppression scotoma that is more intense and, therefore, more difficult to treat than a larger, less intense, suppression scotoma. To assess the depth of the suppression, the clinician can perform the Worth four-dot test with normal room illumination and again with the room lights turned off. Normal illumination simulates the patient's normal visual

conditions and is more likely to yield a suppression response. As the conditions are made artificial, the patient has more difficulty maintaining the suppression. The suppression is considered more intense, therefore, if it is present even with the room lights off.

3. **Expected values** The expected response with the Worth four-dot test is four dots at both 33 cm and 1 m.

Other Tests for Evaluating Suppression

Many other tests are available for testing suppression; these include both subjective and objective tests. Commonly used subjective tests include the AO (American Optical) vectographic chart, the near Mallett unit, Bagolini striated lenses, and cheirosopic tracings. The 4 base-out test is an objective method of assessing suppression. We suggest the use of the Worth four-dot test because of its availability, low cost, ease of administration, and accuracy in detecting suppression. A complete discussion of instrumentation and specific clinical procedures is available in other texts (44,45).

EVALUATION OF STEREOPSIS

Randot Stereotest

1. **Purpose** The Randot Stereotest is a subjective test designed to evaluate the presence and degree of stereopsis at near using both global and contour (local) stereopsis targets.

2. **Important issues**

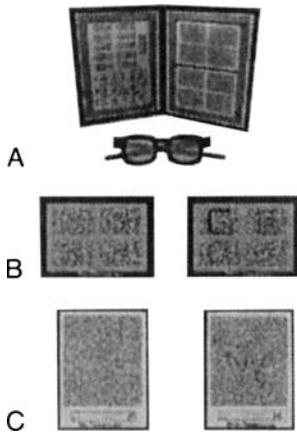
(a) **Global versus contour targets** Two techniques are commonly used for the assessment of stereopsis. The first, called *contour* or *local stereopsis*, uses two similar targets that are laterally displaced. The Titmus stereofly, Wirt rings, and animals (Fig. 1.3) are examples of this type of target. A shortcoming of this type of stereopsis target is that patients with no stereopsis may be able to guess the “correct” answer using monocular cues. Cooper and Warshowsky (46) found that the correct response for the first four Wirt rings could be determined by looking for monocular displacement of one of the circles. Clinically this may be significant when a clinician is examining a child who is trying to give the “right answer” to please the examiner. Of course, with a patient giving accurate responses and not trying to fool the examiner, this test works well.

The second type of stereopsis technique, called *global targets*, eliminates this problem. Global targets contain random dot stereopsis targets and have no monocular cues. As a result, the guessing that can occur with contour stereopsis is not a problem with global stereopsis.

Another important distinction between contour and global targets is their value in detecting the presence of a constant strabismus. Cooper and Feldman (47) investigated the use of stereopsis tests to detect strabismus and found that with a random dot stereogram of 660 seconds of arc disparity, no

■ **Figure 1.3 A:** Titmus stereofly. **B:** Child reaching for “fly” that appears to be floating in front of the page.





■ **Figure 1.4** Examples of random dot stereopsis. **A:** Randot Stereotest. **B:** The Synthetic Optics circle, square. **C:** The Synthetic Optics butterfly target.

constant strabismic could pass the test. Thus, even a gross random dot stereopsis target is effective at detecting the presence of a constant strabismus. With contour stereopsis targets, a constant strabismic can occasionally appreciate up to 70 seconds of arc stereopsis (43). Random dot targets can be used to rule out the presence of a constant strabismus, whereas contour stereopsis targets can be used to determine whether peripheral stereopsis is present. Peripheral stereopsis is considered to be any value greater than 60 seconds of arc. Both types of stereopsis targets, therefore, have value and it is best to use both in the clinical evaluation of stereopsis. This can be accomplished using one test, such as the Randot Stereotest (Fig. 1.4A), or by using two tests, such as the Synthetic Optics^a circle, square, and E targets (Fig. 1.4B) or butterfly (Fig. 1.4C) and the Titmus Stereotest or the Synthetic Optics animals and circles.¹

- (b) **Polaroid versus anaglyphic targets** The traditional evaluation of stereopsis includes measurement by stimulation of retinal disparity using polarized targets and polarized glasses. Targets not requiring the use of any glasses have also been developed, and stereopsis measurements with these targets have been shown to correlate well with those requiring polarized glasses (48). Another format for measuring stereopsis involves the use of red/green cancellation to induce exclusive, disparate images to the right and left eyes. Thus, red/green testing is often referred to as *anaglyphic testing*. These targets have been developed so that other target properties, such as disparity, shape, and size, are similar to those found in the polarized equivalents. Yamada et al. (49) found that the red/green method yields results comparable to the polarized equivalent, especially for testing the presence of random dot or global stereopsis in patients. The red/green version of the random dot butterfly/butterfly stereopsis test and the random dot letter “E”/RDE tests (Synthetic Optics^a) offer a cost-effective alternative for clinicians when attempting to rule out the presence of constant strabismus. To measure the level of contour stereopsis, their data suggest lower agreement between red/green and polarized methods. Therefore, if the objective is to quantify improvement of contour stereopsis after treatment, polarized versions of stereopsis tests may be more useful.
- (c) **Near versus distance stereopsis testing** Most clinicians routinely evaluate stereopsis using targets designed for use at 33 cm or 40 cm. In most cases this is sufficient because if stereopsis is present at 40 cm it should be present at distance as well. The exception would be a case in which there is an intermittent or constant strabismus at distance. In such cases the clinician should consider testing stereopsis at distance as well. Currently there are both noncomputer- and computer-based tests for distance stereopsis. An example of a computer-based assessment is the M&S[®] Technologies Vision Testing System that has a distance stereopsis test which uses LCD Shutter Glasses. It is likely that other computerized systems will also incorporate distance stereopsis testing. A new noncomputer-based distance stereo assessment is the Distance Randot Test (Stereo Optical). Wang et al. (50) reported that the Distance Randot scores from normal subjects have low variability and high test–retest reliability. They concluded that the Distance Randot Stereotest is a sensitive measurement of binocular sensory status that may be useful in monitoring progression of strabismus and/or recovery following strabismus surgery.

¹Throughout the book, see end-of-chapter lists for sources of equipment identified by superscript letters in the text.

3. **Expected values** A patient with normal binocular function should be able to achieve 20 seconds of stereopsis with the contour stimuli and appreciate stereopsis with the gross random dot targets.

Assessment of Accommodative Disorders

GENERAL CONSIDERATIONS

The traditional evaluation of accommodative function (Table 1.5) involves measurement of the amplitude of accommodation using either Donder's push-up method or the Optometric Extension Program (OEP) minus lens procedure. There are shortcomings to this limited approach, however. In recent years, many authors have reported the clinical significance of testing accommodative response and facility as well as amplitude (22,51–56). An important concept is that an individual may experience asthenopic symptoms and have an accommodative disorder even when the accommodative amplitude is normal (53,55). Several studies have investigated the relationship between accommodative facility and the presence of symptoms. Both Hennessey et al. (55) and Levine et al. (56) reported that symptomatic subjects perform significantly poorer than asymptomatic subjects on both monocular accommodative facility (MAF) and BAF testing.

Liu et al. (53) and Cooper and Feldman (47) were able to objectively measure changes in latency and velocity of accommodative response before and after vision therapy. They found that accommodative dynamics changed significantly after vision therapy. The fact that accommodative facility results are related to symptoms, and that changes can be demonstrated after therapy, suggests that it is a valuable assessment technique. It should be part of the routine evaluation of accommodative function.

The third aspect of the evaluation, accommodative response, has also been studied (57–60). It has been demonstrated that the accommodative response is generally not equal to the stimulus. Because most optometric testing relies on stimulus measures and assumes equality between stimulus and response, a clinician might be misled when managing binocular or accommodative anomalies. It is, therefore, important to actually measure the accommodative response. MEM retinoscopy is a widely used procedure that can be utilized for this assessment. Rouse et al. (59,60) have demonstrated the validity of MEM retinoscopy and established normative data.

Another clinical method of assessing accommodative response is Nott retinoscopy (61,62). In contrast to MEM retinoscopy, in which lenses are used to neutralize the reflex, in Nott retinoscopy the examiner moves the retinoscope toward or away from the patient until neutrality is observed. Goss et al. (63) studied the interexaminer reliability of MEM and Nott retinoscopy on 50 young adult subjects. The results of their study indicated close agreement of the means for MEM and Nott. There was a wider range of measurements with MEM retinoscopy than with Nott retinoscopy.

Wick and Hall (64) studied the relationships among the three areas of accommodation (amplitude, facility, and response) that are usually tested. They screened 200 children and, after eliminating those who had strabismus or significant uncorrected refractive error, found that only 4% had deficits in all three of the accommodative functions. Their results suggest that it is impossible to predict the results of one test based on the results of another. Therefore, when accommodative dysfunction is suspected, all aspects of accommodation, amplitude, facility, and response must be considered.

A complete assessment of accommodation should include all three components just described. A suggested minimum database would include the amplitude of accommodation, accommodative facility, and MEM retinoscopy. Table 1.6 lists the expected findings for all accommodative testing described next.

TABLE 1.5 IMPORTANT ASPECTS OF ACCOMMODATIVE TESTING

Accommodative amplitude	Push-up test Minus lens test
Accommodative facility	Accommodative facility Testing with ± 2.00 lenses
Accommodative response	Monocular estimation method retinoscopy

TABLE 1.6 TABLE OF EXPECTED VALUES: ACCOMMODATIVE TESTING

Test	Expected Finding	Standard Deviation
Amplitude of accommodation		
Push-up test	18 – 1/3 age	±2 D
Minus lens test	2 D < push-up	
Monocular accommodative facility		
<i>Children</i>		
(±2.00 flippers, calling out numbers or letters on Accommodative Rock Cards)		
6 year old	5.5 cpm	±2.5 cpm
7 year old	6.5 cpm	±2.0 cpm
8–12 year old	7.0 cpm	±2.5 cpm
<i>Adults</i>		
(±2.00 flipper lenses, saying now when clear)		
13–30 year old	11.0 cpm	±5.0 cpm
30–40 year old	Not available	
Binocular accommodative facility		
<i>Children</i>		
(±2.00 flippers, calling out numbers or letters on Accommodative Rock Cards)		
6 year old	3.0 cpm	±2.5 cpm
7 year old	3.5 cpm	±2.5 cpm
8–12 year old	5.0 cpm	±2.5 cpm
<i>Adults (Use lens power based on amplitude scaled testing—refer to Table 1.7)</i>		
	10.0 cpm	±5.0 cpm
Monocular estimation method retinoscopy	+0.50 D	±0.25 D
Fused cross-cylinder	+0.50 D	±0.50 D
Negative relative accommodation	+2.00 D	±0.50 D
Positive relative accommodation	–2.37 D	±1.00 D

ASSESSMENT OF ACCOMMODATIVE AMPLITUDE

Push-up Amplitude

- Purpose** To subjectively measure the amplitude of accommodation under monocular conditions.
- Important issues**
 - Careful measurement of distance** It is critical to accurately measure the distance at which the patient reports a blur. Even small errors in measurement can lead to large differences in results. For example, an endpoint at 5 cm (2 in.) suggests a 20 Δ amplitude, whereas a blur at 6 cm (2.5 in.) suggests an amplitude of 16 Δ. To reduce this problem, the push-up amplitude can be measured through –4.00 D lenses. This modification moves the endpoint further away from the patient and allows more exact measurement of the endpoint.
 - Monitor patient response** With young children, it is important periodically to ask the child to read the letters to be sure that the print is not blurred. One modification in procedure that can be used is to begin the test with the chart very close to the child. Instead of asking when the print blurs, pull the chart away from the child until he/she can first read the letters. A study comparing the results of using the traditional push-up method of assessing the amplitude of accommodation to the pull-away method found no significant difference in the measurement (65).
 - Relative distance magnification** A problem associated with the push-up method is that the letters no longer subtend the angle expected for a 20/30 letter because of relative distance magnification. A 20/30 letter at 40 cm becomes equivalent to a 20/60 letter at 20 cm and a 20/120 letter at 10 cm. The push-up test, therefore, overestimates the accommodative amplitude. Hamasaki et al. (66) found that the overestimation is about 2 D. A possible solution to this problem is to change the size of the letters at 20 cm and again at 10 cm.

3. **Expected values** A variety of norms can be used for monocular accommodative amplitude. Tables developed by Duane and Donders provide expected findings by general age (33). A more commonly used system is Hofstetter's formula, which is based on Duane's figures (67). The average amplitude at any age can be calculated using this formula: $18.5 - 1/3 \text{ age}$. The minimum amplitude expected for a given age can be calculated using $15 - 1/4 \text{ age}$.

Minus Lens Amplitude

1. **Purpose** To subjectively measure the amplitude of accommodation under monocular conditions.
2. **Important issues**
 - (a) **Avoid relative magnification that affects results of push-up amplitude** A concern about push-up amplitude is that it might overestimate accommodative amplitude—because of relative magnification of the target—as the chart is moved toward the patient's eye. In the minus lens method, the testing distance remains stable as minus lenses are added in 0.25 D increments.
 - (b) **Concern about minification** Whereas the push-up method might overestimate the amplitude due to magnification of the target, the minus lens method may underestimate the amplitude because of minification of the target. Minification occurs when the patient views the target through increasingly greater amounts of minus lenses. To compensate for this concern, the test distance is 33 cm, but the working distance adjustment used is still 2.50 D.
3. **Expected values** The expected value for minus lens amplitude is about 2 D less than that for the push-up method (44).

ASSESSMENT OF ACCOMMODATIVE FACILITY

Accommodative Facility Testing

1. **Purpose** To evaluate the stamina and dynamics of the accommodative response. The objectives of this test are similar to those discussed relative to fusional facility testing.
2. **Important issues**
 - (a) **Age** The norms for these tests were initially developed using young adult subjects. Questions have been raised about the validity of applying these norms to other populations, such as schoolchildren and older adults between the ages of 30 to 40. Because the test is subjective, the results with young children may not always be reliable. A study by Scheiman et al. (51) indicated that accommodative facility testing has questionable value with children younger than 8 years. This same study demonstrated that the expected values for accommodative facility testing are different for schoolchildren.

More recently, Siderov and DiGuglielmo (68) investigated accommodative facility testing in adults from 30 to 42 years of age. They found a significant reduction in the expected values for this age group from the values expected for young adults. Yothers et al. (69) felt that the difference between the responses of schoolchildren and adults is related to the decrease in accommodative amplitude with age. They point out that standard accommodative facility testing is much different for a 10-year-old patient with a binocular accommodative amplitude of 12 D (where the test distance of 40 cm is 16% $[2.5/12]$ of the binocular amplitude and the ± 2.00 D lenses represent 33% $[4/12]$ of amplitude) and a 30-year-old patient with a binocular amplitude of 5 D (where the test distance of 40 cm is 50% $[2.5/5]$ of the binocular amplitude and the ± 2.00 D lenses represent 80% $[4/5]$ of amplitude). As a result of these issues, they suggest altering BAF testing in response to measurement of the push-up accommodative amplitude—that is, amplitude scaled facility (Table 1.7). In their investigation, Yothers et al. (69) found that amplitude scaled testing differentiates symptomatic from nonsymptomatic children and adults better than the traditional test using ± 2.00 lenses at 40 cm.
 - (b) **Instructional set** When testing adults, the clinician can simply ask the patient to report when the target is clear. With elementary schoolchildren, this may not be a reliable method (51). Rather, with young children, a target such as the Accommodative Rock Cards should be used (Fig. 1.5). Using this target, the clinician can ask the child to call out the number, picture, or letter after each flip of the lenses. If the child can accurately call out the number, this suggests accurate accommodation. When using this instructional set, different expected values must be used.

TABLE 1.7 AMPLITUDE SCALED FACILITY

Test distance = 45% of amplitude^a
 Lens power range = 30% of amplitude^b

Amplitude	Distance from Nose (cm)	Test Distance (cm)	Flip Lens Power ^c
22.25	4.5	10.0	±3.25
20.00	5.0	11.0	±3.00
18.25	5.5	12.0	±2.75
16.75	6.0	13.5	±2.50
15.50	6.5	14.5	±2.25
14.25	7.0	15.5	±2.25
13.25	7.5	16.5	±2.00
12.50	8.0	18.0	±2.00
11.75	8.5	19.0	±1.75
11.00	9.0	20.0	±1.75
10.50	9.5	21.0	±1.50
10.00	10.0	22.0	±1.50
9.50	10.5	23.5	±1.50
9.00	11.0	24.5	±1.50
8.75	11.5	25.5	±1.25
8.25	12.0	26.5	±1.25
8.00	12.5	28.0	±1.25
7.75	13.0	29.0	±1.25
7.50	13.5	30.0	±1.00
7.25	14.0	31.0	±1.00
7.00	14.5	32.0	±1.00
6.75	15.0	33.5	±1.00
6.50	15.5	34.0	±1.00
6.25	16.0	35.5	±1.00
6.00	16.5	37.0	±1.00
5.75	17.5	38.5	±1.00
5.50	18.0	40.5	±0.75
5.25	19.0	42.5	±0.75
5.00	20.0	44.5	±0.75
4.75	21.0	47.0	±0.75
4.50	22.0	49.5	±0.75

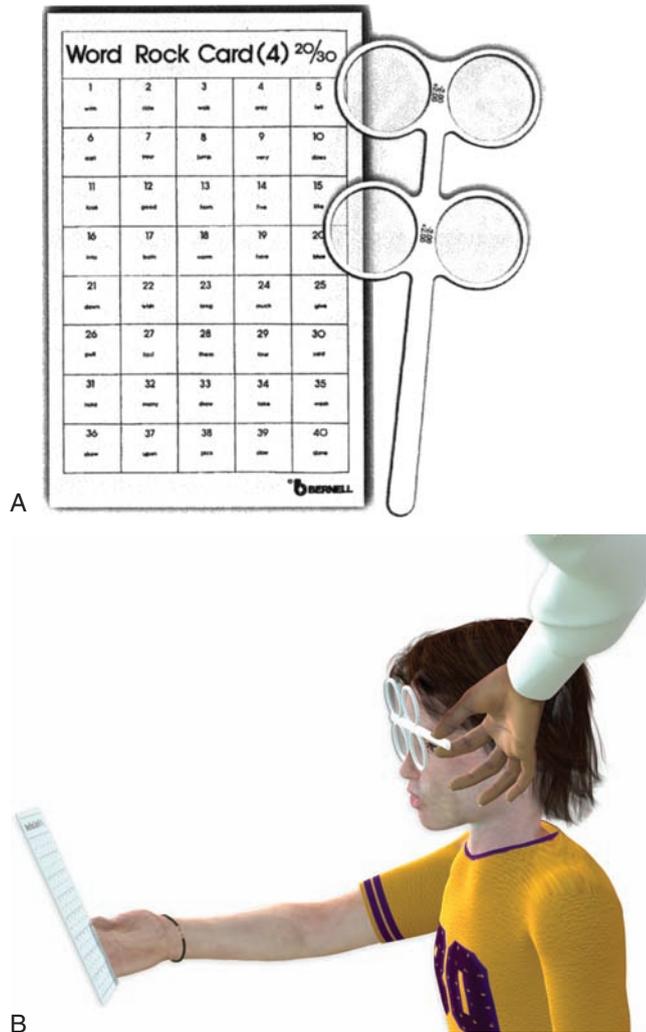
Scoring criteria: Patients scoring less than 10 cpm are likely to be symptomatic.

^aRounded to nearest 0.5 cm.

^bRounded to nearest 0.25 D.

^cRange divided by 2.

- (c) **Monocular versus binocular testing** Should testing be done monocularly and binocularly? This would require repetition of the test three times, which can be time consuming in a routine examination. Binocular testing is an assessment of the interactions between accommodation and vergence and is not a pure measurement of accommodative facility. If a patient is binocular, the introduction of minus lenses, for instance, will require the patient to stimulate accommodation to maintain clarity. As the patient accommodates, accommodative convergence will be stimulated as well and the patient



■ **Figure 1.5 A:** The Accommodative Rock Cards. **B:** The Accommodative Rock Cards being used for accommodative facility testing.

will lose binocularity unless he or she makes a compensatory response. To prevent the loss of binocularity, the patient must use negative fusional vergence to compensate for the accommodative convergence. Thus, as minus lenses are introduced, the ability to stimulate accommodation and negative fusional vergence are both being assessed. A problem in either area could result in poor performance.

We recommend routine use of BAF testing. A normal response on BAF testing suggests normal function in both areas. If a patient experiences difficulty with binocular testing, then monocular testing can be administered. Monocular testing, in this case, would be diagnostic. If the patient cannot clear minus lenses binocularly or monocularly, an accommodative problem is present. If, however, the patient fails binocularly and passes monocularly, a binocular vision problem is more likely.

- (d) **Target for binocular testing** The importance of using a suppression control when performing BAF testing has been stressed in the literature (51,54–56). The target that is generally used is the Bernell No. 9 vectogram. This is a Polaroid target (Fig. 1.6) that has one line seen by the right eye, one by the left eye, and one by both. This target has also been used in studies that developed expected values for adults. As a result, the No. 9 vectogram is the target of choice. Other binocular targets with suppression controls could be used, but it is important to remember that the expected values for this test were developed using the No. 9 vectogram.



■ **Figure 1.6** Bernell No. 9 vectogram used for binocular accommodative facility testing.

3. **Expected values** Table 1.6 lists expected values for schoolchildren. For adults, we suggest using amplitude scaled testing and Table 1.7. In the remainder of this text, we discuss diagnosis using ± 2.00 lenses at 40 cm.

ASSESSMENT OF ACCOMMODATIVE RESPONSE

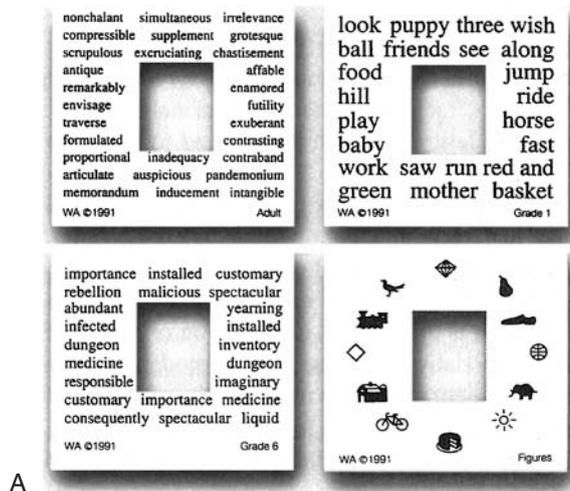
Monocular Estimation Method Retinoscopy

1. **Purpose** An objective method to evaluate the accuracy of the accommodative response.
2. **Important issues**
 - (a) **Testing must be done with the subjective** MEM retinoscopy is a form of near point retinoscopy. MEM cards (Fig. 1.7) are available for the Welch Allyn retinoscope and magnetically attach to the retinoscope head. The working distance should be at 40 cm for adults or at the Harmon distance (the distance from the patient's elbow to the middle knuckle) for children. Select an MEM card that is appropriate for the age and grade level of the patient. While the patient reads the words on the card, perform retinoscopy along the horizontal axis and estimate the amount of plus or minus necessary to neutralize the motion of the retinoscopic reflex observed. A lens can be quickly placed before the eye being evaluated to confirm the estimate. It is important, however, not to leave the lens in place too long because it can alter the accommodative response.

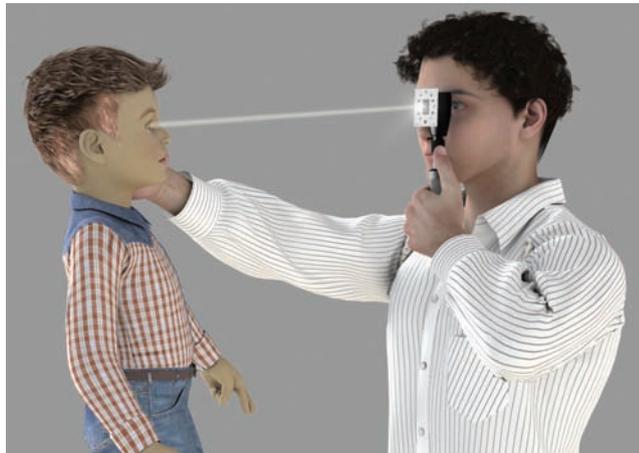
Interpretation of the results of MEM testing is based on the assumption that the accommodative stimulus at distance has been reduced to zero. If the patient is not wearing the subjective or has been overcorrected or undercorrected, interpretation of the MEM result will be affected. For example, an MEM finding of +1.25 D is considered to represent underaccommodation. If, however, the patient is a hyperope and is not wearing his or her glasses, the MEM finding in this case would simply reflect the presence of this uncorrected hyperopia. Similarly, an uncorrected myope might exhibit less plus than expected on MEM retinoscopy.
 - (b) **The results of MEM testing reflect both accommodative and binocular function** Any testing performed under binocular conditions is affected by both accommodative and binocular function. Thus, although MEM is considered a test of accommodative function, binocular vision is also being assessed. For example, a finding of less plus than expected may reflect overaccommodation secondary to accommodative excess or high exophoria and decreased positive fusional vergence.

A patient with high exophoria and inadequate positive fusional vergence may use accommodative convergence to supplement the inadequate fusional vergence. This would enable the individual to maintain binocularity, although it may lead to blurred vision secondary to the overaccommodation.

The same reasoning applies to a finding of more plus than expected on MEM retinoscopy. This could suggest either underaccommodation secondary to accommodative insufficiency or high esophoria and reduced negative fusional vergence.



A



B

■ **Figure 1.7** **A:** Monocular estimation method (MEM) cards used for MEM retinoscopy. **B:** MEM retinoscopy—clinical procedure.

- (c) **Lighting** When performing MEM retinoscopy, it is important to use normal room illumination. Accommodation is affected by illumination (e.g., dark focus), and dim illumination will alter the accommodative response. Accommodation should therefore be tested under illumination that the patient habitually uses.
3. **Expected values** The expected value for MEM retinoscopy is +0.25 D to +0.50 D, with a standard deviation of +0.25 D. A finding below plano or above +0.75 D should therefore raise suspicion.

Fused Cross-cylinder Test

1. **Purpose** A subjective method to evaluate the accuracy of the accommodative response.
2. **Important issues** Because the fused cross-cylinder test is a subjective method, it is difficult to use with children younger than 8 to 9 years. It is generally easier and faster to perform MEM retinoscopy. This test is also not as repeatable as MEM retinoscopy.
3. **Expected values** The expected value for the binocular fused cross-cylinder test is +0.50 D with a standard deviation of ± 0.50 D (19).

Evaluation of Eye Movements

Examination of eye movements involves three distinct steps: assessment of stability of fixation, saccadic function, and pursuit function (Table 1.7). Ocular motor disorders can reflect serious underlying central nervous system disease or functional or developmental problems. It is always important to consider the possibility that abnormalities in fixation stability, saccades, and pursuits may require a neurologic consultation. This is discussed in detail in Chapter 13 (Table 1.8).

The main reason for clinically assessing eye movement function is that reading consists of a series of saccades and fixations. Research has demonstrated that poor readers read more slowly and exhibit smaller and more numerous fixations and regressions. Although more research is necessary to firmly establish the causal relationship between eye movements and reading, the fact that poor readers do behave differently has prompted a great deal of interest in assessing these skills (Chapter 13).

EVALUATION OF FIXATION STABILITY

This test evaluates the ability of the patient to maintain steady fixation on a fixation object. The most important issue to keep in mind is that assessment of fixation is often overlooked in a routine examination. Asking the patient to fixate on a target during the initial external evaluation or during cover testing is sufficient to evaluate fixation status. A variety of disorders of fixation can occur and may represent organic or functional anomalies (Table 1.9).

All patients, except the very young, anxious, hyperactive, or inattentive, should be able to sustain precise fixation, with no observable movement of the eyes, for 10 seconds (70,71).

Saccades

The purpose of saccadic testing is to assess the quality and accuracy of saccadic function.

TABLE 1.8 IMPORTANT ASPECTS OF OCULAR MOTOR TESTING

Fixation ability	Observation of fixation for 10 sec
Saccadic eye movements	Developmental eye movement Readalyzer or Visagraph II NSUCO oculomotor test
Pursuit eye movements	NSUCO oculomotor test

NSUCO, Northeastern State University College of Optometry.

TABLE 1.9 PATHOLOGIC CONDITIONS ASSOCIATED WITH EYE MOVEMENT DISORDERS

Disorders of fixation	
Peripheral microneystagmus	Congenital nystagmus
Ocular flutter	Latent nystagmus
Opsoclonus	Acquired nystagmus
Square wave jerks	Spasmus nutans
Ocular myoclonus	Superior oblique myokymia
Ocular bobbing	
Disorders of saccadic movements	
Congenital ocular motor apraxia	Progressive supranuclear palsy
Acquired ocular motor apraxia	Dysmetria
Huntington chorea	Disconjugate saccades (internuclear ophthalmoplegia)
Disorders of pursuit movements	
Unilateral pursuit paresis	Progressive supranuclear palsy
Cogwheeling	

Testing Format

A variety of assessment procedures have been developed to evaluate saccades. Tests may involve direct observation by the clinician, timed/standardized tests involving a visual–verbal format, and objective eye movement recording using electrooculographic instruments. However, there are advantages and disadvantages associated with all three of these methods. Infrared limbal sensing procedures such as the Readalyzer and the Visagraph II are expensive and may be difficult to use with elementary schoolchildren. Subjective techniques involving observation of the patient’s eye movements have been developed along with rating scales. These rating scales are subjective, and inexperienced clinicians may have difficulty learning to use them effectively. Another problem with this approach is that the gross eye movements observed using these procedures may not correspond well to the eye movements used when reading. Although some questions have been raised in the past about the reliability and repeatability of subjective rating scales, a study by Maples (72) showed that the rating scale used for the NSUCO (Northeastern State University College of Optometry) oculomotor test is reliable and repeatable.

Direct Observation Tests

The test we recommend in this category is the NSUCO oculomotor test, which is the first standardized direct observation test that has been developed. The test includes a standardized instructional set, a description of the appropriate targets, instructions about target placement, a standardized scoring system, and normative data. Direct observation tests require the subject to look from one object to another while the clinician observes the patient’s saccades.

For the saccadic testing portion of the NSUCO oculomotor test, the patient is asked to stand directly in front of the examiner. Two targets are used and held at the Harmon distance or no farther than 40 cm from the patient. The examiner holds the targets so that each target is about 10 cm from the midline of the patient and asks the patient to look from one target to another on command. This is repeated until the patient makes five round-trips or 10 fixation movements from one target to another. No instructions are given to the patient to move or not to move his or her head.

The examiner observes the saccadic eye movements and rates the performance in four categories: head movement, body movement, ability, and accuracy (Table 1.10). Although several rating scales have been developed to create better uniformity in observation (3,73,74), only the NSUCO oculomotor test has been shown to be both reliable and repeatable (74). Table 1.11 shows normative data for this test.

TABLE 1.10 NSUCO SCORING CRITERIA: DIRECT OBSERVATION OF SACCADES

Ability	
Points	Observation
1	Completes less than two round-trips
2	Completes two round-trips
3	Completes three round-trips
4	Completes four round-trips
5	Completes five round-trips
Accuracy (Can the patient accurately and consistently fixate so that no noticeable correction is needed?)	
Points	Observation
1	Large overshooting or undershooting is noted 1 or more times
2	Moderate overshooting or undershooting noted 1 or more times
3	Constant slight overshooting or undershooting noted (>50% of time)
4	Intermittent slight overshooting or undershooting noted (<50% of time)
5	No overshooting or undershooting noted
Head and body movement (Can the patient accomplish the saccade without moving his or her head?)	
Points	Observation
1	Large movement of the head or body at any time
2	Moderate movement of the head or body at any time
3	Slight movement of the head or body (>50% of time)
4	Slight movement of the head or body (<50% of time)
5	No movement of head or body

TABLE 1.11 NSUCO SACCADE TEST MINIMAL ACCEPTABLE SCORE BY AGE AND SEX (>1 STANDARD DEVIATION FROM MEAN)

Age	Ability		Accuracy		Head Movement		Body Movement	
	Male	Female	Male	Female	Male	Female	Male	Female
5	5	5	3	3	2	2	3	4
6	5	5	3	3	2	3	3	4
7	5	5	3	3	3	3	3	4
8	5	5	3	3	3	3	4	4
9	5	5	3	3	3	3	4	4
10	5	5	3	3	3	4	4	4
11	5	5	3	3	3	4	4	5
12	5	5	3	3	3	4	4	5
13	5	5	3	3	3	4	5	5
14 or >	5	5	4	3	3	4	5	5

Direct observation testing is a useful starting point in the evaluation of saccades. Maples (72) suggests that if the patient fails this test, a clinician can feel comfortable suspecting an oculomotor dysfunction. However, if a patient passes the test, this does not rule out an oculomotor dysfunction. If the history suggests an eye movement disorder, additional testing such as visual–verbal format testing or objective eye movement recording should be performed.

Visual–Verbal Format

Another alternative is the use of tests using a visual–verbal format. These tests are inexpensive, easily administered, and provide a quantitative evaluation of eye movements in a simulated reading environment (75). They assess oculomotor function on the basis of the speed with which a series of numbers can be seen, recognized, and verbalized with accuracy. Richman et al. (75) have raised questions about the validity of such assessment techniques because they do not account for automaticity of number naming. They devised a new test called the developmental eye movement (DEM) test that does account for this variable (76).

A second method is the use of timed and standardized tests. Several are available, including the Pierce saccade, King-Devick, and DEM tests. All three of these tests are designed on the same principle. The patient is asked to call off a series of numbers as quickly as possible without using a finger or pointer as a guide. The response times and number of errors are then compared to tables of expected values.

A potential problem with these tests is that young children may call off the numbers slowly, simply because they have difficulty with naming numbers. Both the Pierce and King-Devick tests fail to differentiate between a saccadic problem and difficulty with naming numbers (automaticity of letter naming). The DEM test is the procedure of choice because it does consider this issue (Fig. 1.8).

Another problem associated with the use of tests using the visual–verbal format is reliability. This question is important because the DEM is commonly used to evaluate progress during vision therapy. Of particular concern is the issue of variation and improvement due to learning effects. Oride et al. (77) have shown a significant learning effect with the Pierce saccade and King-Devick tests. Although Garzia et al. (76) reported that the DEM is a reliable and repeatable test, Rouse et al. (78) have reported conflicting results. Rouse et al. examined 30 third-grade students using the DEM and retested them 2 weeks later. They found a very low correlation for the DEM ratio score, which is an important finding for diagnosis. Orlansky et al. evaluated the repeatability of the DEM test with three consecutive administrations on two separate visits to 181 children between the ages of 6 years and 11 years 11 months. The within-session repeatability for vertical- and horizontal-adjusted time were good to excellent but were poor to good for ratio, and poor to fair for errors. The between-session intraclass correlation coefficients were fair to good for both the vertical and horizontal scores but poor for the ratio and error scores. The repeatability of the pass-fail diagnostic classification within a single session for each subject on test and retest was also compared. The percentage of patients who remained in the same classification ranged from 71% to 100% for both vertical and horizontal scores. Wider variability was seen with the ratio and error scores showing between 47% and 100% of the children remaining classified as pass or fail with repeated administrations of the DEM. Such findings suggest that children

TEST A

3	4
7	5
5	2
9	1
8	7
2	5
5	3
7	7
4	4
6	8
1	7
4	4
7	6
6	5
3	2
7	9
9	2
3	3
9	6
2	4

TEST C

3	7	5	9	8
2	5	7	4	6
1	4	7	6	3
7	9	3	9	2
4	5	2	1	7
5	3	7	4	8
7	4	6	5	2
9	2	3	6	4
6	3	2	9	1
7	4	6	5	2
5	3	7	4	8
4	5	2	1	7
7	9	3	9	2
1	4	7	6	3
2	5	7	4	6
3	7	5	9	8

■ **Figure 1.8** The developmental eye movement test.

in this age range may show improvements in all four test scores without any intervention. The authors concluded that clinicians should be cautious about using the DEM test in isolation for reaching a diagnosis or monitoring the effectiveness of treatment for saccadic dysfunction. More recently, Tassinari and DeLand (79) investigated the DEM test-retest reliability in patients undergoing vision therapy. They reported good to excellent intrasubject test-retest reliability. This study is important because it is the first study to evaluate the

reliability of the DEM with vision therapy patients. It is apparent that there are issues with the repeatability of the ratio and error scores for the DEM. The horizontal-adjusted time has the best repeatability and seems to be the most appropriate way to follow progress during therapy. As a clinical guideline, Orlansky et al. (80) found that when monitoring for treatment effect, differences in the horizontal-adjusted time must show more than 64 s of change for 6-year-olds, more than 39 s for 7-year-olds, more than 24 s for 8-year-olds, and more than 19 s for 9- to 11-year-olds.

Several studies have investigated the use of the DEM with adults subjects (81–83). Sampedro and colleagues (83) developed an adult version called the Adult Developmental Eye Movement Test (A-DEM). This version was developed with norms for Spanish speakers aged 14 to 68 years. The A-DEM is similar to the DEM with two exceptions: First, the A-DEM uses double-digit numbers as test stimuli rather than the single-digit numbers on the DEM. Second, the numbers used for the horizontal array are not the same as those in the vertical array as they are on the DEM. It is not clear whether the norms developed for the Spanish-speaking population can be used for English-speaking patients. Given the high prevalence of eye movement problems after traumatic brain injury in adults (84–87), it would be valuable to further develop an adult version of the DEM for this population.

Objective Eye Movement Recording

The third approach to the assessment of saccades is objective eye movement recording. The clinical devices available for this purpose are the Readalyzer and the Visagraph II. These systems consist of infrared monitoring eyeglasses and a recording unit (Fig. 1.9), both of which are attached to a PC-compatible computer.



■ **Figure 1.9** **A:** Visagraph II instrument, goggles, and reading selections. **B:** Visagraph II used for assessment of eye movements.

Objective eye movement recording has several advantages over direct observation and timed/standardized tests. It is an objective procedure that does not depend on the skill of the examiner, and the Readalyzer and Visagraph II provide a permanent recording of the evaluation. The information gained from objective recording is also more sophisticated. It provides information about number of fixations, regressions, duration of fixations, reading rate, relative efficiency, and grade equivalence. All of this information can be compared to established norms for elementary schoolchildren through adulthood.

The disadvantage of both the Readalyzer and Visagraph II is the expense of the instruments. The test is also difficult to use with patients who are inattentive, hyperactive, or have poor fixation. The testing procedure and interpretation of results are discussed in detail elsewhere (88). Although these instruments are commonly used in optometric practice, until recently there had been no universally accepted standard protocol. Colby et al. (89) demonstrated that the Visagraph II worked very well with a group of 50 first-year optometry students and produced data that seemed to be reliable indicators of reading skill; they suggested at least one practice trial before the actual reading baseline measurements are obtained. A more recent study (90) reported that at least three practice paragraphs should be administered prior to formal testing with the Visagraph II to ensure a valid and stable baseline determination in adult patients. Ciuffreda et al. (90) also suggested an explicit set of procedural guidelines to obtain reliable, valid, and stable baseline reading levels. They stress the proper setup of the goggles and text materials as well as a full, clear, and consistent instructional set. Dixon et al. (91) compared the use of 100- versus 800-word reading passages with the Readalyzer. They found that both symptomatic and asymptomatic subjects had more difficulty on longer reading passages. They suggest that the use of the longer reading passages is a more sensitive method for assessing reading eye movements.

In the only study evaluating the repeatability of the Visagraph II in children, Borsting et al. (92) recruited 22 children from a clinical population in grades 3 to 8 (mean grade 5.1). Four Visagraph trials were performed (the first was a practice session) at the first visit and again about 1 week later. They reported repeatability of data that can help clinicians determine whether changes in reading eye movements made during vision therapy are real or accounted for by normal variability. They suggested using absolute values (i.e., fixations, regressions, reading duration of fixation, span of recognition, rate) rather than grade equivalents when making decisions about changes in the Visagraph results after treatment.

Recommendations

We suggest that clinicians working in a primary care setting use a combination of direct observation, using the rating scale and normative data in Tables 1.8 and 1.9, along with the DEM test. This should provide sufficient information for making both diagnostic and therapeutic decisions. For those clinicians who intend to devote a considerable percentage of their practices dealing with oculomotor problems, the Readalyzer or Visagraph II should be considered because of its ability to provide objective documentation of progress during therapy.

Expected Values

Refer to Table 1.11 for expected findings for the NSUCO oculomotor test. For the DEM, any score below the 15th percentile is considered significant.

Pursuit

The purpose of pursuit testing is to assess the quality and accuracy of pursuit function.

Testing Format

There are not as many testing alternatives for pursuits as there are for saccades. Direct observation of the patient following a moving target is the most commonly used clinical technique. Several rating scales have been developed for direct observation of pursuit movements. We recommend use of the NSUCO oculomotor test for the reasons just described.

For the pursuit portion of the NSUCO oculomotor test, the patient is asked to stand directly in front of the examiner. One target is used and held at the Harmon distance or no farther than 40 cm from the patient. The examiner holds the target at the midline of the patient's body and moves it in a circle of no more than 20 cm diameter. The patient is asked to follow the target as it goes around. Two clockwise rotations and two

TABLE 1.12 NSUCO SCORING CRITERIA: DIRECT OBSERVATION OF PURSUITS

Ability	
Points	Observation
1	Cannot complete 1/2 rotation in either clockwise or counterclockwise direction
2	Completes 1/2 rotation in either direction
3	Completes one rotation in either direction but not two rotations
4	Completes two rotations in one direction but less than two rotations in the other direction
5	Completes two rotations in each direction
Accuracy (Can the patient accurately and consistently fixate so that no noticeable refixation is needed when doing pursuits?)	
Points	Observation
1	No attempt to follow the target or requires greater than 10 refixations
2	Refixations 5 to 10 times
3	Refixations 3 to 4 times
4	Refixations 2 times or less
5	No refixations
Head and body movement (Can the patient accomplish the pursuit without moving his or her head?)	
Points	Observation
1	Large movement of the head or body at any time
2	Moderate movement of the head or body at any time
3	Slight movement of the head or body (>50% of time)
4	Slight movement of the head or body (<50% of time)
5	No movement of head or body

counterclockwise rotations are made. A sweep horizontally through the midline of the body is made when switching from clockwise to counterclockwise rotation. No instructions are given to the patient to move or not to move his or her head. The examiner observes the pursuit eye movements and rates the performance in four categories: head movement, body movement, ability, and accuracy (Table 1.12).

Although several rating scales have been developed to create better uniformity in observation (3,73,74), only the NSUCO oculomotor test has been shown to be both reliable and repeatable (72,74). Table 1.13 shows normative data for this test.

Direct observation for the evaluation of pursuits suffers from the same shortcomings as direct observation for saccades. Although the technique is rather easy to teach to an inexperienced clinician, the observations that must be made are more difficult to teach.

Another testing format that has been available for some time is Groffman tracings (93). Unfortunately, there has been no research to demonstrate either the validity or reliability of this test.

TABLE 1.13 NSUCO PURSUIT TEST MINIMAL ACCEPTABLE SCORE BY AGE AND SEX (>1 STANDARD DEVIATION FROM MEAN)

Age	Ability		Accuracy		Head Movement		Body Movement	
	Male	Female	Male	Female	Male	Female	Male	Female
5	4	5	2	3	2	3	3	4
6	4	5	2	3	2	3	3	4
7	5	5	3	3	3	3	3	4
8	5	5	3	3	3	3	4	4
9	5	5	3	4	3	3	4	4
10	5	5	4	4	4	4	4	5
11	5	5	4	4	4	4	4	5
12	5	5	4	4	4	4	5	5
13	5	5	4	4	4	4	5	5
14 or >	5	5	5	4	4	4	5	5

Expected Values

Refer to Table 1.13 for expected findings.

Summary

We have emphasized the important general issues that must be considered when assessing accommodative, ocular motor, and binocular vision skills. We have also provided a recommended sequence of testing for all three areas, along with expected findings. A comprehensive assessment of these areas can be accomplished in a short period of time using very simple equipment. Given the high prevalence of accommodative, ocular motor, and binocular vision disorders in the general population, it is critical for clinicians to incorporate a battery of tests that can adequately assess these areas.

Study Questions

1. What are the advantages of the cover test compared to the von Graefe phoria?
2. Name two methods that tend to increase the validity and reliability of cover testing.
3. What are the advantages of the step vergence compared to the vergences measured in the phoropter?
4. How can you increase the reliability and repeatability of vergence testing?
5. Explain the importance of vergence facility testing. How is vergence facility testing different from step vergence or smooth vergence testing?
6. Why are smooth and step vergences alone an incomplete assessment of fusional vergence?
7. Describe two modifications to the NPC test that make it more sensitive.
8. Why is accommodative amplitude testing alone an incomplete assessment of accommodation?
9. What are the three aspects of accommodation that should be evaluated?
10. How can you increase the reliability and validity of accommodative amplitude testing in children?
11. What is the appropriate testing distance and target for the various binocular vision and accommodative tests discussed in the text?
12. What is the maximum amount of plus you can add during NRA testing? Why did you choose this value?
13. At what level should you stop the PRA test? Why did you choose this value?

SOURCE OF EQUIPMENT

(a) Synthetic Optics: 747 Butternut Drive, Franklin Lakes, NJ 07417.

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Appendix

Setup and Administration of Binocular Vision and Accommodation Tests

Cover Test

EQUIPMENT NEEDED

- Gulden fixation stick
- 20/30 target for distance (or two lines above threshold if acuity is not 20/30)
- Occluder

SETUP

1. If the patient wears glasses for close work, these should be used.
2. For distance testing, isolate a 20/30 letter on the distance visual acuity chart.
3. For near testing, hold Gulden fixation stick 40 cm from patient's face and direct the patient's attention to the isolated 20/30 letter.

PROCEDURE: UNILATERAL AND ALTERNATE COVER TEST

1. Instruct the patient to fixate the letter and to "keep it clear" throughout testing.
2. Cover the subject's right eye (RE) and watch left eye (LE) as RE is covered.
3. Cover the subject's LE and watch RE as LE is covered.
4. Allow the subject adequate time to regain fixation.
5. Neutralize the alternate cover test (ACT) according to the following procedure:
 - (a) Select a loose prism nearest in power to the estimated magnitude.
 - (b) Cover one eye with the occluder, interposing the prism behind the occluder. (Uncovered eye is therefore fixating.)
 - (c) Switch the occluder and observe the eye movement behind the prism. (Only observe eye behind prism during ACT.)
 - (d) Interpose different magnitudes of prism until neutrality is obtained by a bracketing method.
 - (e) Record the amount and base of prism.
 - (f) Repeat the procedure at 40 cm using a single 20/30 letter on the Gulden fixation stick.

If an intermittent strabismus is present, use the intermittent exotropia scale (Table 1.3) and follow the directions below:

- (a) The control scale is for both distance (3 m) and near (0.33 m) fixation.
- (b) The fixation objects are accommodative and age appropriate, such as small stickers and videos for younger children and letters for older children and adults.
- (c) Levels 5 to 3 are assessed during a 30-second observation period. If exotropia is observed, testing stops and the control score is recorded as 5, 4, or 3 at that distance.

- (d) If no exotropia is observed during the 30-second observation period, testing continues.
- (e) Levels 2 to 0 are then assessed and graded as the worst of three successive 10-second periods of occlusion. An occluder is placed over the *right* eye for 10 seconds, and on removal, the time required to re-fuse is noted.
- (f) This process is repeated for the *left* eye, and then a third occlusion trial is performed on the eye that required the longest time to re-fuse.
- (g) The worst of these three 10-second trials is recorded, resulting in a control score of 2, 1, or 0 at that distance.

IMPORTANT POINTS

1. Control accommodation using
 - (a) 20/30 target
 - (b) Occasional movement of target
2. The cover test is objective and can be used with young children.
3. Watch for small horizontal movements and small movements of the upper lashes, if a vertical phoria is suspected. With practice, clinicians can detect less than 1 Δ heterophoria on the cover test.

Measurement of Horizontal Phoria: von Graefe Technique

EQUIPMENT NEEDED

Phoropter
Isolated 20/30 target

SETUP

1. Seat the patient comfortably behind the phoropter with the patient's distance correction in place.
2. Use a single 20/30 letter on the distance chart.
3. Place the Risley prisms before both eyes and set the prism before the left eye at about 10 to 12 base-in. Set the prism before the right eye at 6 base-down.

PROCEDURE

1. Instruct the patient to open both eyes and ask how many targets he or she sees.
2. Ask the patient to look at the lower target (seen by right eye) and keep it clear at all times.
3. Instructions: "I will be moving the upper target from side to side until it is directly above the lower target. Look at the lower target, keep it clear, and tell me when the upper target moves directly above the lower target."
4. Move the Risley prisms at about a rate of 2 Δ per second.
5. Record the amount and direction of prism when the patient reports alignment.
6. Repeat the procedure again, using an isolated 20/30 letter or vertical line of 20/30 print positioned at 40 cm.

IMPORTANT POINTS

1. Control accommodation by stressing the importance of keeping the target clear.
2. This test tends to have the poorest repeatability of the various tests used to assess motor alignment.

Measurement of Vertical Phoria: von Graefe Technique

EQUIPMENT NEEDED

Phoropter
Isolated 20/30 target

SETUP

1. Seat the patient comfortably behind the phoropter with the patient's distance correction in place.
2. Use a single 20/30 letter on the distance chart.
3. Place the Risley prisms before both eyes and set the prism before the left eye at about 10 to 12 base-in. Set the prism before the right eye at 6 base-down.

PROCEDURE

1. Instruct the patient to open both eyes and ask how many targets he or she sees. Two targets should be seen.
2. Ask the patient to look at the upper target (seen by the left eye) and keep it clear at all times.
3. Instructions: "I will be moving the lower target up until it is lined up side by side with the upper target. Look at the upper target, keep it clear, and tell me when the lower target moves directly side by side with the upper target."
4. Move the Risley prisms at about a rate of 2 Δ per second.
5. Record the amount and direction of prism when the patient reports alignment.
6. Repeat the procedure again, using an isolated 20/30 letter or horizontal line of 20/30 print positioned at 40 cm.

IMPORTANT POINTS

1. If the patient does not understand the instructional set, demonstrate the type of alignment you expect using your fingers or a drawing.

Modified Thorington Test: Near Point Horizontal and Vertical Phoria

EQUIPMENT NEEDED

Penlight
Maddox rod
Thorington card

SETUP

1. The patient should wear his or her distance glasses.
2. The patient holds the Maddox rod before the right eye with the striations of the Maddox rod oriented horizontally (patient sees red vertical streak of light).
3. Hold the Thorington card at 40 cm with a penlight behind the center hole of the card.

PROCEDURE

1. Instruct the patient to look directly at the center of the card.
2. The patient should see a red vertical line.
3. Ask the patient to report the number through which the line is passing and whether it is to the right or left of the zero.
4. For measurement of the vertical phoria, the Maddox rod is held so that the striations are oriented vertically (patient sees horizontal line).
5. Ask the patient to report the number through which the line is passing and whether it is above or below the zero.

IMPORTANT POINTS

1. Control accommodation by reminding the patient to keep the letters on the card clear at all times.
2. This test has been shown to have the best repeatability of the various subjective tests of motor alignment.
3. This test can be valuable for patients who cannot be tested with a phoropter.

AC/A Measurement Using the von Graefe Method

EQUIPMENT NEEDED

Phoropter
Isolated 20/30 target

SETUP

1. Seat the patient comfortably behind the phoropter with the patient's distance correction in place.
2. Use an isolated 20/30 letter or vertical line of 20/30 print positioned at 40 cm.
3. Place the Risley prisms before both eyes and set the prism before the left eye at about 10 to 12 base-in. Set the prism before the right eye at 6 base-down.

PROCEDURE

1. Instruct the patient to open both eyes and ask how many targets he or she sees.
2. Ask the patient to look at the lower target (seen by the right eye) and keep it clear at all times.
3. Instructions: "I will be moving the upper target from side to side until it is directly above the lower target. Look at the lower target, keep it clear, and tell me when the upper target moves directly above the lower target."
4. Move the Risley prisms at about a rate of 2 Δ per second.
5. Record the amount and direction of prism when the patient reports alignment.
6. Repeat the procedure, but first add -1.00 lenses OU, in addition to the distance prescription.

IMPORTANT POINTS

1. It is critical to control accommodation for both measurements by stressing the importance of keeping the target clear.

AC/A Measurement Using the Modified Thorington Test

EQUIPMENT NEEDED

Penlight
Maddox rod
Thorington card

SETUP

1. The patient should wear his or her distance glasses.
2. The patient holds the Maddox rod before the right eye, with the striations of the Maddox rod oriented horizontally (patient sees red vertical streak of light).
3. Hold the Thorington card at 40 cm with a penlight behind the center hole of the card.

PROCEDURE

1. Instruct the patient to look directly at the center of the card.
2. The patient should see a red vertical line.
3. Ask the patient to report the number through which the line is passing and whether it is to the right or left of the zero.
4. Repeat the procedure, but first add -1.00 lenses OU, in addition to the distance prescription.

IMPORTANT POINTS

1. It is critical to control accommodation for both measurements by stressing the importance of keeping the target clear.

Horizontal Smooth Vergence Testing

EQUIPMENT NEEDED

Phoropter
Near point card with a vertical line of 20/30 letters

SETUP

1. Seat the patient comfortably behind the phoropter, with the patient's distance correction in place.
2. Place the near point card at a 40 cm distance from the patient, with good illumination.
3. Place the Risley prisms before both eyes and set both Risley prisms at zero; position the Risley prism so that you can introduce horizontal prism.

PROCEDURE

1. Instruct the patient to open both eyes and ask how many targets he or she sees. The patient should see one target. If the patient reports diplopia, add either base-in or base-out until fusion occurs. This will be the starting point for the test.
2. Ask the patient to look at the target and keep it clear and single.
3. Instructions: "I will be changing the lenses in front of your eyes. Try to keep the line of letters single and clear for as long as you can. Tell me as soon as the letters become blurry or double."
4. Introduce base-in at about a rate of 2 Δ per second.
5. Record the amount of prism when the patient reports blur (blur).
6. Continue to add base-in prism until the patient reports double vision (break).
7. Continue 2 to 4 Δ past the breakpoint and then begin reducing the base-in prism until the patient reports single vision again (recovery).
8. Repeat steps 4 to 7 with base-out prism.
9. This sequence can also be repeated at distance, if there is concern about a distance binocular vision disorder. Repeat steps 1 to 8 using an isolated 20/30 target set at 20 ft.

IMPORTANT POINTS

1. Control accommodation by stressing the importance of keeping the target clear.
2. Stress the importance of trying to keep the target clear and single for as long as possible.

Vertical Smooth Vergence Testing

EQUIPMENT NEEDED

Phoropter
Near point card with a horizontal line of 20/30 letters

SETUP

1. Seat the patient comfortably behind the phoropter, with the patient's distance correction in place.
2. Place the near point card at a 40-cm distance from the patient, with good illumination.
3. Place the Risley prisms before both eyes and set both Risley prisms at zero; position the Risley prism so that you can introduce vertical prism.

PROCEDURE

1. Instruct the patient to open both eyes and ask how many targets he or she sees. The patient should see one target. If the patient reports diplopia, add either base-in or base-out until fusion occurs. This will be the starting point for the test.
2. Ask the patient to look at the target and keep it clear and single.
3. Instructions: "I will be changing the lenses in front of your eyes. Try to keep the line of letters single for as long as you can. Tell me as soon as the letters double."
4. Introduce base-up before the right eye only (right infravergence) at about a rate of 2 Δ per second.
5. Record the amount of prism in place when the patient reports double vision (break).
6. Continue 1 to 2 Δ past the breakpoint and then begin reducing the base-up prism until the patient reports single vision again (recovery).
7. Repeat steps 4 to 7 with base-down (right supravergence) prism.
8. This sequence can also be repeated at distance, if there is concern about a distance binocular vision disorder. Repeat steps 1 to 8 using an isolated 20/30 target set at 20 ft.

IMPORTANT POINTS

1. Stress the importance of trying to keep the target single for as long as possible.

Step Vergence Testing

EQUIPMENT NEEDED

- Prism bar
- Gulden fixation stick (20/30 target)

SETUP

1. If the patient wears glasses for close work, these should be used.
2. Hold Gulden fixation stick tongue depressor 40 cm from patient's face at eye level.

PROCEDURE

1. Say the following: "I want you to look at the letter on this stick. When I place this measuring device in front of your eye, you might see blurry or double. Keep looking at the letter; try to keep it single and clear, but tell me when it becomes blurry or double."
2. Begin with base-in prism in front of the right eye. Increase the amount of prism in front of the right eye at approximately 2 Δ per second, stopping when the target moves laterally or breaks.
3. Always begin with the prism bar above the eyes and slowly move the prism bar down, increasing the base-in or base-out demand. When the patient reports blurred vision, mentally record the prism value.
4. Continue adding prism until the patient reports double vision and mentally record the prism value.
5. Continue to increase the base-in demand by about five more prism diopters and then, at a rate of about 2 Δ per second, reduce the base-in prism until the patient regains single vision (it does not have to be clear). Mentally record the prism value.
6. Record as a blur finding, a break finding, and a recovery finding. Example: 6/12/8. This means that the patient reported blurred vision at 6 Δ , double vision at 12 Δ , and single vision at 8 Δ .
7. Now repeat with base-out prism.

IMPORTANT POINTS

1. Control accommodation by stressing the importance of keeping the target clear.
2. Stress the importance of trying to keep the target clear and single for as long as possible.

Vergence Facility Testing

EQUIPMENT NEEDED

- Gulden vergence facility prism (12 base-out/3 base-in combination)
- Gulden fixation stick (20/30 target)

SETUP

1. If the patient wears glasses for close work, these should be used.
2. Hold Gulden fixation stick tongue depressor 40 cm from patient's face at eye level.

PROCEDURE

1. Say the following: "I want you to look at the letter on this stick. When I place this measuring device in front of your eye, you will see double. Try to get the target to be clear and one as soon as possible. Say 'now' as soon as it is clear and one."
2. Begin with either base-out or base-in and count how many cpm the patient can complete in 60 seconds (one cycle equals successful completion of both base-out and base-in).
3. Record the number of cpm.
4. If the patient cannot do either base-in or base-out, record as 0 cpm, fails base-out or base-in.
5. If the patient cannot do both, record as 0 cpm, cannot do base-in or base-out.

EXAMPLES

1. The patient can complete 18 flips in 1 minute. This equals 9 cpm.
2. If the patient cannot regain single and clear vision at all, record as 0 cpm, fails both base-in and base-out.
3. If the patient cannot regain single and clear vision with base-in, record as 0 cpm, fails base-in.
4. If the patient cannot regain single and clear vision with base-out, record as 0 cpm, fails base-out.

IMPORTANT POINTS

1. Control accommodation by stressing the importance of keeping the target clear.
2. Stress the importance of trying to regain clear and single vision as quickly as possible.

Negative Relative Accommodation and Positive Relative Accommodation Measurement

EQUIPMENT NEEDED

- Phoropter
- Near point card with vertical line of 20/30 letters

SETUP

1. Seat the patient comfortably behind the phoropter with the patient's distance correction in place.
2. Place the near point card at a 40-cm distance from the patient, with good illumination.

PROCEDURE

1. Instruct the patient to look at the target and keep it clear and single.
2. Instructions: "I will be changing the lenses in front of your eyes. Try to keep the line of letters clear and single for as long as you can. Tell me as soon as the letters become blurry or double."

3. Add plus lenses in +0.25 D increments until the patient reports the first sustained blur or diplopia.
4. Record the amount of plus added above the distance prescription as the NRA.
5. Remove the plus lenses and return to the distance prescription.
6. Add minus lenses in -0.25 D increments until the patient reports the first sustained blur or diplopia.
7. Record the amount of minus added above the distance prescription as the PRA.
8. Stop the PRA test when you reach -2.50 D above the distance prescription.

IMPORTANT POINTS

1. Stress the importance of reporting both blur and diplopia.
2. Discontinue the PRA at -2.50 D.

Near Point of Convergence

EQUIPMENT NEEDED

Penlight
 Gulden fixation stick
 Red/green glasses

SETUP

1. If the patient wears glasses for close work, these should be used.
2. Hold Gulden fixation stick tongue depressor 40 cm from patient's face at eye level.
3. Ask the patient to look at the isolated 20/50 target on the Gulden fixation stick.

PROCEDURE

1. Slowly move the fixation stick toward the patient at eye level and between the two eyes.
2. Ask the patient to keep the target one for as long as possible.
3. Ask the patient to tell you when he or she sees two targets.
4. Once diplopia occurs, move the fixation stick in another inch or two and then begin to move it away from the patient.
5. Ask the patient to try and see "one" again.
6. Also watch the eyes carefully and observe whether the eyes stop working together as a team (one eye will usually drift out).
7. Record the distance at which the patient reports double vision and when the patient reports recovery of single vision.
8. Repeat the test using a penlight and red/green glasses if you suspect that dissociation may reveal a more receded NPC.

IMPORTANT POINTS

1. Repeat the test several times if results are not definitive.
2. Watch the patient's eyes and try to objectively determine when the break and recovery occur.

Stereopsis

EQUIPMENT NEEDED

Randot stereopsis test
 Polaroid glasses

SETUP

1. The patient should wear Polaroid glasses over his or her appropriate prescription.
2. The plates should be well illuminated, glare free, and upright to ensure proper axis of polarization. Do not allow the patient to do any head tilting or turning.

PROCEDURE

1. The test plates are presented in order, at 40 cm.
2. The plates should be well illuminated, glare free, and upright to ensure proper axis of polarization. Do not allow the patient to do any head tilting or turning.
3. Present plate 1 (random dot stereo target) and say, “Do you see any pictures in these boxes? Tell me what you see.”
4. The examiner may ask the patient to identify the box in plate 1 with no form in it, or may ask a young patient to point to the matching figure on the instruction card.
5. Present plate 2 (similar to Titmus animals) and say, “There is a rabbit, a cat, a squirrel, a monkey, and a chicken [point to row A]. Does one of those animals look closer to you than any of the other animals or float or come out of the page?”
6. Repeat for rows B and C.
7. Present the third plate. Similar to Wirt circles, say, “Look at box number 1. There are three circles in the box. Do any of the circles come out of the page toward you (or float out) or do they look like they are flat on the page? Which one? Left, middle, or right?” Young children are encouraged to “push the magic button or door bell that is popping out.”
8. If no stereopsis is noted, point to the correct answer and one alongside it for comparison. Ask if either one “pops out.”
9. The same procedure is carried out for each of the 10 boxes.
10. Stop when the patient cannot identify (or incorrectly identifies) two in a row. If the patient misses one but can continue through with correct responses, recheck the one missed.
11. Reliability can be checked by inverting the test booklet. The “floating” forms will be seen as recessed.

IMPORTANT POINTS

1. Hold target at 40 cm.
2. Book should be well illuminated, glare free, and upright to ensure proper axis of polarization.
3. Do not allow the patient to do any head tilting or turning.

Worth Four-dot Test

EQUIPMENT NEEDED

Worth four-dot flashlight
Red/green glasses

SETUP

1. The patient should be wearing red/green glasses and distance correction in place.
2. Hold the Worth four-dot flashlight at 33 cm.

PROCEDURE

1. Cover the patient’s left eye and ask, “How many lights do you see?”
2. Now cover the right eye and ask, “How many lights do you see?”
3. Now with both eyes open ask, “How many lights do you see?”
4. Repeat step 3 at 1 m.

IMPORTANT POINTS

1. It is not necessary to ask about the color of the lights. Simply ask how many lights are seen with the right eye, left eye, and both eyes.
2. It is important to perform the test at 33 cm and 1 m.

Accommodative Amplitude: Pull-away Method

EQUIPMENT NEEDED

Gulden fixation stick
Occluder

SETUP

1. Ambient and overhead lighting should provide good illumination.
2. The 20/30 single letter on the Gulden fixation stick is used as the target.
3. The examiner should hold the target very close to the eye to begin the test.
4. If the patient wears glasses, these should be used.
5. Occlude the patient's left eye.

PROCEDURE

1. To begin the test, slowly move the target away from the patient's eye at approximately 1 to 2 cm/sec.
2. The target will be moved away from the subject until the subject can just report the letter on the stick. This will be considered the endpoint.
3. Measure the distance from the eye to the stick.
4. The accommodative amplitude will be measured to the nearest centimeter.

IMPORTANT POINTS

1. Stress the importance of trying as hard as possible to clear the target.

Accommodative Amplitude: Minus Lens Method

EQUIPMENT NEEDED

Phoropter
Distance prescription
Near point card (reduced Snellen)

SETUP

1. Patient is seated comfortably behind the phoropter viewing through his or her distance prescription.
2. A well-illuminated near target (one line of letters larger than the patient's near visual acuity) is set at 40 cm.
3. Testing is done monocularly only.

PROCEDURE

1. Instructions to patient: "I will be changing the lenses in front of your eyes. Try to clear the print after each lens change. Tell me when you notice that the letters [examiner indicates appropriate print] are slightly blurred, still readable, but cannot be cleared by further effort."

2. Minus lenses are added in 0.25 D increments. When the patient reports first sustained blur, the lens power is noted.
3. To obtain the amplitude in diopters, add 2.50 D for working distance to the amount of minus added.

EXAMPLE

Minus added until first sustained blur	−6.00 D
Working distance (40 cm)	−2.50 D
Accommodative amplitude	−8.50 D

IMPORTANT POINTS

1. Stress the importance of trying as hard as possible to clear the target.

Accommodative Facility Testing

EQUIPMENT NEEDED

Gulden fixation stick
+2.00/−2.00 flip lenses

SETUP

1. If the patient wears glasses for close work, these should be used.
2. Hold Gulden fixation stick 40 cm from the patient's face at eye level and place the +2.00 lens in front of the patient's eyes.
3. The test is initially performed binocularly.

PROCEDURE: CHILD OR YOUNG ADULT

1. Ask the patient to try to get the letters clear and single as quickly as possible.
2. Instruct the subject to report (say "clear") as soon as the letters are clear.
3. When the letters are reported to be clear, quickly flip the flipper so the minus side is before the same eye, again instructing the subject to read the letters and report when the letters appear clear or if they disappear.
4. Continue alternating sides of the flipper lenses for 1 minute, calculating the cycles per minute achieved (1 cycle = plus and minus).
5. Repeat the procedure monocularly if the patient is unable to pass binocularly. The only difference in monocular testing is that the patient only has to report when the target is clear (diplopia is no longer an issue).
6. Record the cycles per minute. Record if one side (plus or minus) of the flippers was more difficult, or if neither side was more difficult.

PROCEDURE: 30 YEARS AND OLDER

1. The differences in this age group are the working distance and the lens power to be used.
2. We suggest using the amplitude scaled facility approach discussed earlier in this chapter (Table 1.7).
3. When using this method, select the lens power and working distance based on the amplitude of accommodation.
4. For example, if you are working with a 32-year-old patient with an amplitude of accommodation of 7.0 D, you would use ± 1.00 D lenses and the target would be placed 32 cm from the patient.

EXAMPLES

1. The patient can complete 18 flips in 1 minute. This equals 9 cpm.
2. If the patient cannot clear −2.00 at all, record as 0 cpm, fails minus.

3. If the patient cannot clear +2.00 at all, record as 0 cpm, fails plus.
4. If the patient reports diplopia, record as 0 cpm, diplopia with +2.00 or diplopia with -2.00.

IMPORTANT POINTS

1. Stress the importance of trying to keep the target both clear and single.

Monocular Estimation Method Retinoscopy

EQUIPMENT NEEDED

Appropriate prescription (habitual or proposed near prescription)
 Retinoscope
 Age-appropriate MEM graded cards (preschool to adult) affixed to retinoscope
 Loose lenses (+0.50, +0.75, +1.00, +1.25, etc.)

SETUP

1. Patient is out of the phoropter, wearing his or her prescription.
2. The examiner sits opposite the patient, at eye level with the target, at either the patient's habitual reading distance (ask the patient) or Harmon distance.
3. Illumination must be sufficient so that the patient can easily see the words or pictures on the MEM card.
4. Select the appropriate MEM card corresponding to a grade or reading level closest to that of the patient. Card selected can be low demand (large print) or high demand (small print).

PROCEDURE

1. Instructions: "With both eyes open, please read the words (or name the pictures) on the card out loud."
2. Make a sweep with the retinoscope and try to estimate the amount of "with" or "against" motion for each meridian. Repeat the sweeping motion as many times as needed. Repeat the measurements for the other eye.
3. To verify the estimation, a neutralizing trial lens is interposed very briefly, in front of one eye at a time, as the retinoscope light passes across the eye. If the motion is "with," interpose a plus lens. If the motion is "against," interpose a minus lens. When the true amount of lead or lag is measured in that meridian, a neutral response will be seen with the lens in place.

IMPORTANT POINTS

1. Try to estimate the lens needed to neutralize the motion.
2. When using lenses, try to minimize the amount of time the lens is placed in front of the eye.

NSUCO Oculomotor Test: Saccades

EQUIPMENT NEEDED

Two Gulden fixation sticks (place a green circular sticker on one and a red circular sticker on the other)

SETUP

1. Have the patient stand directly in front of the examiner.
2. No instructions are given to the patient to move or not to move his or her head.
3. Two modified Gulden fixation targets are used and held at the Harmon distance (the distance from the patient's elbow to the middle knuckle) or no farther than 40 cm from the patient.
4. The examiner holds the targets so that each target is about 10 cm from the midline of the patient.

PROCEDURE

1. Instructions to patient: “When I say ‘red,’ look at the red sticker, and when I say ‘green,’ look at the green sticker. Remember, don’t look until I tell you.”
2. The examiner begins calling out “red” and “green” and repeats this so that the patient has to make 10 saccades (five to the red target and five to the green target).
3. The examiner observes the saccadic eye movements and rates the performance in four categories: head movement, body movement, ability, and accuracy (Table 1.10).

IMPORTANT POINTS

1. Do not make any statement in the instructions about head or body movement.
2. Have the patient stand during the procedure.
3. Keep the targets a maximum of 10 cm from the midline of the patient.

NSUCO Oculomotor Test: Pursuits

EQUIPMENT NEEDED

Gulden fixation sticks (place a red circular sticker on stick)

SETUP

1. Have the patient stand directly in front of the examiner.
2. No instructions are given to the patient to move or not to move his or her head.
3. One modified Gulden fixation target is used and held at the Harmon distance or no farther than 40 cm from the patient.

PROCEDURE

1. Instructions to patient: “Watch the red sticker as it goes around. Don’t ever take your eyes off the ball.”
2. The examiner moves the fixation target in a path no more than 20 cm in diameter, performed at the midline of the patient.
3. The examiner observes the pursuit eye movements and rates the performance in four categories: head movement, body movement, ability, and accuracy (Table 1.12).

IMPORTANT POINTS

1. Do not give any instructions about head or body movement.
2. Have the patient stand during the procedure.
3. Move the target in a path no more than 20 cm in diameter, performed at the midline of the patient.

Case Analysis and Classification

Several analytical approaches are presented in the optometric literature. Each has its own unique characteristics, advantages, and disadvantages. Each of these systems also has shortcomings that are significant enough to have prevented wide acceptance of any one approach by the profession. Rather, it is common for optometrists, during their early years of practice, to develop their own personal approach to case analysis that is often a combination of the various systems they have been taught during their education.

The four approaches that are most widely discussed in our literature are graphical analysis, the Optometric Extension Program (OEP) analytical analysis approach, Morgan's system of normative analysis, and fixation disparity analysis. This chapter briefly describes these four case analysis approaches. This discussion leads directly to a detailed presentation of the case analysis approach that is used throughout this text.

Review of Currently Available Analytical Approaches

GRAPHICAL ANALYSIS

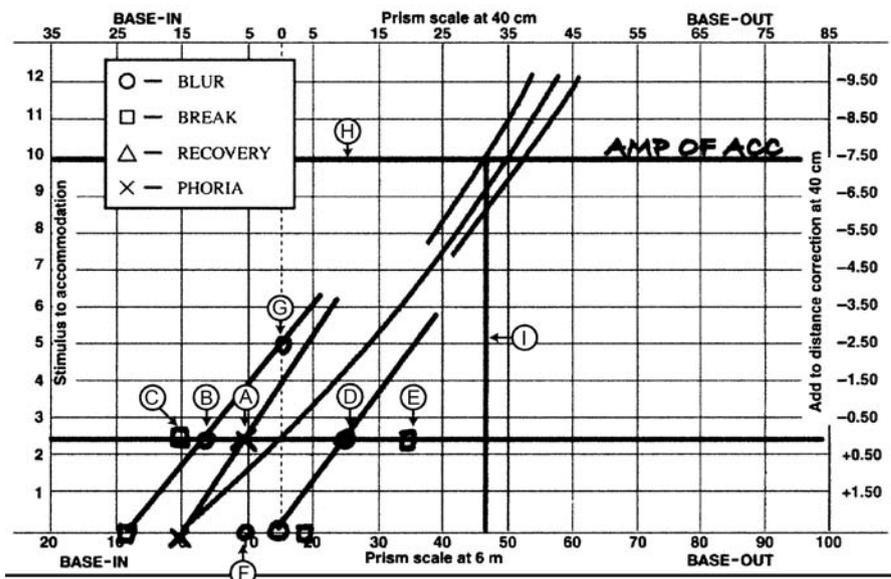
Graphical analysis is a method of plotting clinical accommodation and binocular findings to determine whether a patient can be expected to have clear, single, and comfortable binocular vision (1). The test findings that are commonly plotted include the dissociated phoria; base-in to blur, break, and recovery; base-out to blur, break, and recovery; negative relative accommodation (NRA); positive relative accommodation (PRA); amplitude of accommodation; and near point of convergence (Fig. 2.1).

Advantages

The primary advantage of the graphical analysis system is that it allows one to visualize the relationship among several optometric findings and is, therefore, an excellent system to introduce the concepts of case analysis. The width of the zone of clear single binocular vision, the relationship between the phoria and fusional vergence, the accommodative convergence to accommodation (AC/A) ratio, and the relationship of the NRA and PRA findings to fusional vergence and/or accommodation are all clearly portrayed on the graph. For the student learning about accommodation and binocular vision for the first time, the ability to view a visual representation can be a very powerful learning tool. Over the years, graphical analysis has become a standard teaching approach in many optometric curricula.

Graphical analysis also facilitates identification of erroneous findings. When data are plotted on the graph, a characteristic pattern becomes evident. If an individual finding deviates from this typical pattern, it may indicate that it is erroneous and unreliable.

Although the primary purpose of graphical analysis is simply the visual representation of accommodative and binocular data (2), various guidelines for analyzing these findings have developed over the years. The most popular of these guidelines has been Sheard's criterion. Sheard (3,4) postulated that for an individual to be comfortable, the fusional reserve should be twice the demand (phoria). For example, in the case of a 10 Δ exophoria, the positive fusional convergence should be 20 Δ to meet Sheard's criterion. This postulate also can be used to determine the amount of prism necessary to make the patient comfortable or to determine whether lenses or vision therapy would be appropriate.



■ **Figure 2.1** Sample graphical analysis worksheet showing the test findings that are commonly plotted: **A:** the dissociated phoria, **B:** base-in to blur, **C:** base-in to break, **D:** base-out to blur, **E:** base-out to break, **F:** NRA, **G:** PRA, **H:** amplitude of accommodation, and **I:** near point of convergence.

Disadvantages

The system does have shortcomings, however, which, for the most part, have relegated graphical analysis to the classroom.

- The graphical system fails to identify some binocular vision, accommodation, and oculomotor problems. When using the graphical analysis approach, important data such as accommodative facility, fusion facility, fixation disparity, and monocular estimation method (MEM) retinoscopy findings are not included in the analysis. This is significant because, of the 15 most common accommodative, ocular motor, and binocular vision anomalies discussed in later chapters, five (accommodative excess, accommodative infacility, ill-sustained accommodation, fusional vergence dysfunction, and ocular motor dysfunction) cannot be identified using graphical analysis. For example, an individual with a condition called accommodative infacility may have a normal amplitude of accommodation, NRA, and PRA. When the data are plotted according to established graphical analysis guidelines and analyzed according to Sheard's criterion, the result is a normal graph and failure to identify a problem. Accommodative infacility can only be diagnosed when facility testing is performed and analyzed. This type of information, however, is not part of the routine in the graphical system. A condition such as accommodative infacility would, therefore, not be diagnosed using a traditional graphical analysis approach.
- Graphical analysis relies heavily upon criteria—such as those by Sheard (3,4) and by Percival (5)—to determine whether a problem exists. These criteria, however, can only be considered guidelines. Although Sheard's criterion has been readily accepted by optometry since its introduction, there has been little research evidence, until recently, to support its validity. A study by Dalziel (6) found that a vision therapy program that was effective in improving fusional vergence to meet Sheard's criterion was effective in relieving symptoms. Sheedy and Saladin (7,8) studied the relationship between asthenopia and various clinical analysis measures of oculomotor balance. The objective was to determine which measures would best discriminate symptomatic from asymptomatic patients. Sheard's criterion was found to be the best for the entire population and exophoria, but the slope of the fixation disparity curve was found to be best for esophores. Worrell et al. (9) evaluated patient acceptance of prism prescribed by Sheard's criterion. They prescribed two pairs of glasses for each subject. The glasses were identical in every way except that one contained a prism based on Sheard's criterion. The results of this study showed that patients with esophoria preferred the glasses with the prism, whereas those with exophoria preferred the glasses without

the prism. Although these studies are somewhat supportive of Sheard's criterion, there are certainly suggestions that, in some cases, it fails to identify patients who are symptomatic and may not always be the most effective method for determining appropriate management.

- Another shortcoming of graphical analysis is that it may be too precise a method for clinical purposes and is cumbersome to use. Although most optometry students begin their study of case analysis with a presentation of graphical analysis, few continue to graph data throughout their careers. The actual mechanics of plotting the data are cumbersome and time consuming. An experienced clinician rarely needs to actually plot optometric data to reach a decision about diagnosis and management.

ANALYTICAL ANALYSIS

The second case analysis approach is referred to as the analytical analysis system. Developed by the OEP, this approach has several rigid requirements and steps (10):

- Administration of a 21-point examination using precise instructional sets
- Checking (comparison of data to a table of expected findings)
- Chaining (grouping the data)
- Case typing (identifying the condition)

In the analytical analysis approach, the specific 21 tests (points) as described by the OEP must be used and the instructional sets must be precisely followed. Any deviation from the suggested routine invalidates the results and the analytical system.

Results of the examination must then be compared to a table of expected values developed by the OEP (Table 2.1). This is followed by a procedure referred to as *chaining*, or grouping of the data. Chaining simply means that those findings found to be high are entered above a horizontal line, while data that are low are placed below the horizontal line. The data are also grouped together according to specific rules. The following illustrates an example of chaining:

$$\frac{7(5) 14-16A-19}{(9-11-16B) 15A 17A-20}$$

The results of this chaining or grouping of all the high and low data are then analyzed. This process is referred to as *case typing*. Two basic types or classifications exist in the OEP system, the B-type (accommodative problem) and the C-type (convergence problem). The B-type case is further divided into seven stages or subtypes.

TABLE 2.1 OPTOMETRIC EXTENSION PROGRAM EXPECTED FINDINGS

Distance lateral phoria	Ortho -0.5 exophoria
Near lateral phoria	6.0 exophoria
Base-out (distance)	Blur: 7 Break: 19 Recovery: 10
Base-in (distance)	Break: 9 Recovery: 5
Base-out (near)	Blur: 15 Break: 21 Recovery: 15
Base-in (near)	Blur: 14 Break: 22 Recovery: 18
Negative relative accommodation	+2.00
Positive relative accommodation	-2.25
Fused cross-cylinder	+0.50

Advantages

Analytical analysis incorporates several unique concepts into its system that are derived from the underlying philosophy of vision of the OEP. Two examples are described below.

- **Concept 1: The status of the visual system can deteriorate over time.** The OEP stresses the concept that vision problems develop over time and that the deterioration occurs as an adaptation to a stressful condition (e.g., excessive reading or near work) (11). Analytical analysis allows one to evaluate the current stage or deterioration of the vision problem, and the therapy prescribed depends on this determination. If this treatment using lenses or vision therapy is not instituted, continued reading can be expected to result in adaptations that take the form of fusional vergence and accommodative problems, refractive error, and strabismus. This concept is dramatically different from traditional thinking, which suggests that vision disorders occur as random variations or as a failure in development (12).
- **Concept 2: Vision problems can be prevented.** OEP philosophy postulates that vision problems develop as an adaptation to near point demands (11). Because analysis of the data can indicate the current stage of development of a vision problem, subtle changes can be detected early. With appropriate intervention using lenses, prism, and vision therapy, many vision problems can be prevented, according to OEP philosophy.

Disadvantages

The analytical approach is mainly used by members of the OEP and has not gained widespread use for several reasons.

- A major problem with this system is that the student or practitioner must be familiar with specific OEP testing protocols. Unless these protocols are precisely followed, the system becomes unusable. Because most schools of optometry do not teach this system of testing, students are generally unfamiliar with the instructional sets.
- An understanding and acceptance of OEP philosophy is a basic requirement. The OEP is primarily a postgraduate education organization. Students at the various schools and colleges of optometry generally receive only introductory information about the OEP. It is not difficult to understand, therefore, why so few students feel comfortable with this approach.
- The OEP literature is written using a basic language that is often very different from the classic optometric language taught in optometry schools. Basic definitions of terms such as *accommodation*, *convergence*, *blur*, *break*, *recovery*, and *phoria* are all significantly different. For example, Manas (13) defines exophoria as “[a] developmental relationship within the visual behavior pattern, between areas of that pattern, operationally active to preserve the integrity of performance of the convergence pattern.” If an optometrist wants to use analytical analysis, it requires a period of time learning this new language. For a student or practitioner who has just spent several years learning one optometric language, the additional effort required is an obstacle that must be overcome before involvement with the OEP analysis system is possible.

MORGAN’S SYSTEM OF CLINICAL ANALYSIS (NORMATIVE ANALYSIS)

Morgan’s system is based on his 1944 study, in which he presented the concept that it is important to analyze the results of groups of data (14). In Morgan’s approach, little significance is attributed to variation from the norm on any one given test. Morgan found that he was able to divide all data into groups based on the direction in which the tests tend to vary. To analyze optometric data using Morgan’s analytical approach, one must first compare findings to Morgan’s table of expected findings (Table 2.2) and then look for a trend in the group A and group B findings (Table 2.3). The important concept in this system is that no single finding is considered significant by itself. However, when a group as a whole varies in a given direction, it is considered clinically significant. If the group A findings are high and the group B data are low, a convergence problem is present. If the group B data are high and the group A findings are low, an accommodative fatigue problem is indicated (15). The data in group C are used to suggest whether lenses, prism, or vision therapy should be recommended as treatment.

Morgan’s approach, therefore, is an attempt to present an analytical system that is easily applied and that does not go beyond the exactness and significance of the data involved (15).

TABLE 2.2 MORGAN'S TABLE OF EXPECTED FINDINGS

Test	Expected Finding	Standard Deviation
Distance lateral phoria	1 exophoria	$\pm 2 \Delta$
Near lateral phoria	3 exophoria	$\pm 3 \Delta$
AC/A ratio	4:1	$\pm 2 \Delta$
Base-out (distance)	Blur: 9	$\pm 4 \Delta$
	Break: 19	$\pm 8 \Delta$
	Recovery: 10	$\pm 4 \Delta$
Base-in (distance)	Break: 7	$\pm 3 \Delta$
	Recovery: 4	$\pm 2 \Delta$
Base-out (near)	Blur: 17	$\pm 5 \Delta$
	Break: 21	$\pm 6 \Delta$
	Recovery: 11	$\pm 7 \Delta$
Base-in (near)	Blur: 13	$\pm 4 \Delta$
	Break: 21	$\pm 4 \Delta$
	Recovery: 13	$\pm 5 \Delta$
Amplitude of accommodation		
Push-up	18 – 1/3 age	± 2.00 D
Fused cross-cylinder	+0.50	± 0.50 D
Negative relative accommodation	+2.00	± 0.50 D
Positive relative accommodation	-2.37	± 1.00 D

Advantages

- The primary advantage of this approach is the concept that it is important to look at groups of findings rather than individual data. Morgan (15) stresses that if one finding falls outside the “normal range” it does not necessarily indicate that the patient has a problem. He states that “statistical data applies to populations and not necessarily to individuals.”
- Another advantage of this system is its flexibility and ease of use, compared to the complexity and rigidity associated with graphical and analytical analyses.

TABLE 2.3 MORGAN'S THREE GROUPS

Group A data
Negative fusional vergence at distance—break
Negative fusional vergence at near—blur
Negative fusional vergence at near—break
Positive relative accommodation
Amplitude
Group B data
Positive fusional vergence at distance—blur and break
Positive fusional vergence at distance—blur and break
Binocular cross-cylinder
Monocular cross-cylinder
Near retinoscopy
Negative relative accommodation
Group C data
Phoria
AC/A ratio

Disadvantages

The primary limitation of Morgan's approach is that the groups developed by Morgan in the 1940s have not been updated to include some of the more recent optometric tests that have been shown to be important clinical findings. As a result, it fails to identify some binocular vision, accommodation, and oculomotor problems. When using Morgan's analysis, important data, such as accommodative facility, fusion facility, fixation disparity, MEM retinoscopy, and ocular motility findings, are not included in the analysis.

FIXATION DISPARITY ANALYSIS

Fixation disparity is a small misalignment of the eyes under binocular conditions (16). This misalignment from exact bifoveal fixation is very small, with a magnitude of only a few minutes of arc. Several clinical methods have been developed to evaluate fixation disparity at near, including the Mallett unit, the Bernell lantern slide, the Wesson card, the disparometer, and the Borish card. For fixation disparity testing at distance the Mallett unit (distance unit) and the American Optical vectographic slide were the only primary commercially available instruments for many years. Today, many of the computer-based visual acuity testing instruments include a distance fixation disparity target (17). The associated phoria, or the amount of prism necessary to neutralize the fixation disparity, is determined using the Mallett unit, American Optical vectographic slide, the Bernell lantern slide, the Borish card, and computer-based visual acuity testing instruments. The Wesson card and the disparometer permit a more complete analysis of the fixation disparity. Using these instruments, a fixation disparity curve can be generated and four diagnostic characteristics of the curve can be analyzed. These four characteristics are the type, slope, x-intercept, and y-intercept. However, the disparometer is no longer commercially available. Chapter 15 presents an in-depth discussion of fixation disparity.

The use of fixation disparity data has been suggested as a useful method for the analysis and diagnosis of problems of the oculomotor system (16–19). The primary advantage of fixation disparity analysis is that the assessment takes place under binocular and, therefore, more natural conditions. Studies have indicated that analyzing binocular vision using fixation disparity is useful in determining those patients who are likely to have symptoms (18). Some authors (16–19) have suggested that fixation disparity data may be the most effective method for determining the amount of prism to prescribe for binocular vision disorders.

Advantages

- The primary advantage of fixation disparity analysis is that the data are gathered under binocular vision conditions. Other analytical systems depend on phoria vergence testing performed under dissociated conditions that may not truly reflect the way the system operates under binocular conditions. For example, in about one-third of patients, a condition referred to as paradoxical fixation disparity is present (19). This is a condition in which the fixation disparity is in the direction opposite to the phoria.
- Studies have shown that fixation disparity provides the most effective method of determining the amount of prism necessary for the treatment of certain binocular vision disorders (7,8).

Disadvantages

- Fixation disparity testing is a technique for evaluating binocular vision and does not provide direct information about accommodation or ocular motor disorders.

All of the systems described above have failed to gain widespread acceptance by the profession because of the limitations described. The rest of this chapter is devoted to the presentation of the case analysis system that is utilized throughout this text. This approach draws from the major contributions of the four systems described, while it attempts to eliminate most of their disadvantages. Its use allows the optometrist to operate with much more flexibility than available with strict adherence to any of the other approaches.

INTEGRATIVE ANALYSIS APPROACH

The integrative analysis approach is an analysis system that attempts to make use of the most positive aspects of other case analysis approaches while avoiding the problems associated with them.

It requires three distinct steps:

1. Comparing the individual tests to a table of expected findings
2. Grouping the findings that deviate from expected findings
3. Identifying the syndrome based on steps 1 and 2.

This format uses the concepts of the OEP analytical analysis system: checking, chaining, and typing. However, the primary disadvantages of analytical analysis—that is, the rigidity of the 21-point examination and the OEP language problems—are avoided. The integrative analysis approach also makes use of the following important characteristics of other systems:

- Some of the unique concepts of the OEP system are utilized, including the following:
 - The status of the visual system can deteriorate over time.
 - Vision problems can be prevented.
- Morgan's suggestion that it is important to look at groups of findings rather than individual data is a key element in the integrative analysis approach.
- Fixation disparity data performed under binocular conditions are included.
- The integrative analysis approach includes an analysis of ocular motor, accommodative facility, vergence facility, MEM retinoscopy, and fixation disparity data. No other analysis system makes use of all of this data.

Specifics

To utilize this case analysis system, the optometrist must be knowledgeable about the following:

- Expected findings for each optometric test administered
- The relationship of one finding to another or how to group the data that are gathered
- A classification system that categorizes the most commonly encountered vision problems or syndromes.

Expected Findings for Optometric Tests

Tables 1.2, 1.4, 1.5, 1.9, and 1.11 list various commonly administered optometric tests and expected findings. These tables are a compilation of data from Morgan's table of expected findings along with newer data for accommodative facility, ocular motor, vergence facility, step vergence, MEM retinoscopy, and fixation disparity testing.

Grouping Optometric Data

The concept of the importance of looking for trends comes from both the OEP analysis and Morgan's system. The integrative analysis approach is simply an expansion of this concept and divides optometric data into six groups, rather than the three proposed by Morgan (Table 2.3). Tests or data are placed in a group if they directly or indirectly evaluate the same function.

TESTS EVALUATING POSITIVE FUSIONAL VERGENCE

- Positive fusional vergence (PFV)—smooth vergence testing
- PFV—step vergence testing
- PFV—vergence facility testing
- NRA
- Binocular accommodative facility with plus lenses
- Near point of convergence
- MEM retinoscopy and fused cross-cylinder

TESTS EVALUATING NEGATIVE FUSIONAL VERGENCE

- Negative fusional vergence (NFV)—smooth vergence testing
- NFV—step vergence testing
- NFV—vergence facility testing
- PRA

- Binocular accommodative facility with minus lenses
- MEM retinoscopy and fused cross-cylinder

TESTS EVALUATING THE ACCOMMODATIVE SYSTEM

- Monocular accommodative amplitude
- Monocular accommodative facility with plus and minus lenses
- MEM retinoscopy
- Fused cross-cylinder
- NRA/PRA
- Binocular accommodative facility testing
- Binocular accommodative amplitude

TESTS EVALUATING VERTICAL FUSIONAL VERGENCE

- Supravergence and infravergence
- Fixation disparity

TESTS EVALUATING THE OCULAR MOTOR SYSTEM

- Fixation status
- Subjective assessment of saccades using grading scales
- Developmental eye movement (DEM) test
- Visagraph
- Subjective assessment of pursuits using grading scales

MOTOR ALIGNMENT AND INTERACTION TESTS (MAIT)

- Cover test at distance
- Cover test at near
- Phoria at distance
- Phoria at near
- Fixation disparity
- AC/A ratio
- CA/C ratio

Classification System of Common Accommodative and Nonstrabismic Binocular Vision Problems

Once the test findings are grouped and a trend is identified, the specific syndrome can be selected from the list of the 15 common accommodative, ocular motility, and binocular vision problems described in this section. This classification is a modification of the well-known Duane-White classification (20) suggested by Wick (18). The rationale for this classification is described in detail later in this chapter.

BINOCULAR ANOMALIES

Heterophoria with Low AC/A Ratio

- Orthophoria at distance and exophoria at near—convergence insufficiency
- Exophoria at distance, greater exophoria at near—convergence insufficiency
- Esophoria at distance, orthophoria at near—divergence insufficiency

Heterophoria with Normal AC/A Ratio

- Orthophoria at distance, orthophoria at near—fusional vergence dysfunction
- Esophoria at distance, same degree of esophoria at near—basic esophoria
- Exophoria at distance, same degree of exophoria at near—basic exophoria

Heterophoria with High AC/A Ratio

- Orthophoria at distance and esophoria at near—convergence excess
- Esophoria at distance, greater esophoria at near—convergence excess
- Exophoria at distance, less exophoria at near—divergence excess

Vertical Heterophoria

- Right or left hyperphoria

Accommodative Anomalies

- Accommodative insufficiency
- Ill-sustained accommodation
- Accommodative excess
- Accommodative infacility

Ocular Motor Problems

- Ocular motor dysfunction

Analysis of Specific Groups

POSITIVE FUSIONAL VERGENCE GROUP DATA

Optometric data that can be used to determine the status of a patient's PFV are included in this category. These include all data that directly or indirectly assess PFV at both distance and near.

Positive Fusional Vergence: Smooth Vergence Testing

As base-out prism is added, the patient is instructed to keep the target single and clear as long as possible and to report when the target blurs or becomes double. This requires the patient to converge to maintain bifoveal fixation and maintain accommodation at a given level (either distance or near). It is also important to realize that as prism is added and the patient converges, the accommodative response gradually increases due to increased vergence accommodation. The amount of vergence accommodation stimulated depends on the convergence accommodation to convergence (CA/C) ratio. (The CA/C ratio is discussed in depth in Chapter 16.) The patient must relax accommodation to counterbalance this increased vergence accommodation. When the patient can no longer do this, a blur occurs. As more base-out prism is added beyond the blur limit, diplopia occurs when fusion is no longer possible.

An important aspect of this test is that the prism is added in a slow, gradual manner. Because the technique requires the patient to maintain accommodation at a given level, accommodative convergence cannot be used to assist convergence. The patient must, therefore, use PFV. If the patient attempts to use accommodative convergence, he or she will report a blur.

Positive Fusional Vergence: Step Vergence Testing

Step vergence testing is similar to the smooth vergence testing described above, except it is performed outside the phoropter with a prism bar. Because a prism bar is used instead of Risley prisms, the actual prismatic demand is presented in a steplike manner. This is in contrast to the smooth demand introduced

using Risley prism. A study suggested that the expected findings for this test are different from smooth fusional vergence testing for children (21,22).

Positive Fusional Vergence: Vergence Facility Testing

The patient is instructed to keep a vertical line of 20/30 letters single and clear as base-out prism is suddenly introduced (12 base-out and 3 base-in). To accomplish this, the patient must maintain his or her accommodative level at 2.50 D, using 12 Δ of PFV to restore bifoveal fixation. Because of the lag of accommodation, the actual accommodative response will generally be less than 2.50 D. The usual accommodative response for a 2.50 D accommodative stimulus is about 1.75 to 2.00 D. If sufficient fusional vergence is available, the response will be a single clear image. A report of diplopia indicates that the patient cannot restore binocularity using PFV. Another possible response is a single but blurred target, suggesting the use of accommodative convergence to compensate for the inability to use the fusional vergence mechanism to restore bifoveal fixation.

The important differentiation between vergence facility testing and standard testing of PFV is that prism is introduced in large increments and over a longer period of time. A patient is forced to make rapid changes in fusional vergence to sustain these changes over time. A patient having adequate smooth fusional vergence ranges may experience difficulty on the vergence facility test.

Negative Relative Accommodation

This test evaluates PFV in an indirect manner. The NRA is comparable to the assessment of smooth fusional vergence ranges, because lenses are introduced in a slow, gradual manner. However, with the NRA, the patient is being asked to maintain convergence at a particular level while changing the accommodative response. As plus lenses are added in +0.25 D increments, the patient is instructed to keep the target *single* and *clear*. To accomplish this, he or she must relax accommodation. However, any relaxation of accommodation is accompanied by a decrease in accommodative convergence. The amount of accommodative convergence change depends on the AC/A ratio.

If the patient allows his or her eyes to diverge as accommodation is relaxed, he or she will report diplopia. To counteract this decrease in accommodative convergence, the patient must use an appropriate amount of PFV. Thus, the result obtained during the NRA test can depend on the status of the PFV system. Of course, the endpoint in the NRA also can be limited by the patient's ability to relax accommodation as plus lenses are introduced.

To determine which factor—accommodation or PFV—is causing the blur, the patient's accommodative status can be tested monocularly. If he or she can clear +2.50 monocularly but only +1.50 binocularly, PFV is the causative factor. Another way to differentiate is simply to cover one eye after the patient reports blur on the NRA test. If the target clears under monocular conditions, the fusional vergence system is at fault.

Binocular Accommodative Facility with Plus Lenses

This test is similar to the NRA, since it requires maintenance of convergence at a specific level while the accommodative response changes. As +2.00 lenses are introduced binocularly, the patient is instructed to maintain single and clear binocular vision. To accomplish this, the patient must relax about 2.00 D of accommodation to keep the target clear (the actual accommodative response will be about 10% less than the stimulus). The relaxation of 2.00 D of accommodation, however, causes a reflex decrease in accommodative convergence. The amount of divergence will be directly related to the AC/A ratio. Assuming a 5:1 AC/A ratio, if the patient relaxes 2.00 D of accommodation, his or her eyes will tend to diverge by 10 Δ . If this occurs, the patient will see two images.

Because the instructions require the patient to maintain single clear vision, he or she must use 10 Δ of PFV to compensate for the decrease in accommodative convergence. The endpoint of this test can be caused by one of two factors. Either the patient has inadequate PFV or is unable to relax his or her accommodative system (ACC). To differentiate, one simply needs to cover one eye. If the print clears under monocular conditions, the limiting factor is the fusional vergence system.

Near Point of Convergence

The patient is asked to maintain single vision as a target is moved toward his or her nose. To accomplish this, the patient can use a combination of various types of convergence, including accommodative convergence, PFV,

and proximal convergence. If PFV is deficient, it may affect the patient's ability to achieve the expected finding on this test. A receded near point of convergence is, therefore, an indirect measure of PFV.

Monocular Estimation Method Retinoscopy and Fused Cross-cylinder

Both tests are performed under binocular conditions and are designed to assess the accommodative response. The normal finding is approximately +0.25 to +0.50 for MEM retinoscopy and +0.50 to +0.75 for the fused cross-cylinder test. However, when a patient presents with exophoria and low PFV group findings, the MEM and fused cross-cylinder tests often yield less plus than expected.

Decreased plus on these tests is interpreted as overaccommodation for the particular stimulus. This is a common response in a patient with exophoria and reduced PFV. The individual is substituting accommodative convergence for the lack of PFV. By overaccommodating, the patient has additional accommodative convergence available to help overcome the exophoria.

SUMMARY

These seven tests constitute the PFV group. In the presence of exophoria and symptoms, the data in the PFV group will generally be lower than expected, and the MEM and the fused cross-cylinder tests will tend to show overaccommodation (less plus than expected). All of the findings in this group provide information about the patient's PFV system and the ability to compensate for exophoria. Occasionally only the *facility* findings will be low, while the amplitude findings are normal. This would be the type of situation missed with the graphical analysis approach.

NEGATIVE FUSIONAL VERGENCE GROUP DATA

This group includes optometric data that reflect the status of a patient's NFV. It includes tests that directly or indirectly assess NFV at both distance and near.

Negative Fusional Vergence: Smooth Vergence Testing

As base-in prism is gradually added, the patient is instructed to keep the target single and clear as long as possible and to report if the target blurs or becomes double. The test requires the patient to diverge to maintain bifoveal fixation and maintain accommodation at a given level. It is also important to realize that as prism is added and the patient diverges, the accommodative response gradually decreases as a result of decreased vergence accommodation. The amount of decrease in vergence accommodation depends on the CA/C ratio. The patient must stimulate accommodation to counterbalance this decreased vergence accommodation. When the patient can no longer do this, a blur occurs. By requiring clarity, we are forcing the patient to use NFV to compensate for the base-in prism.

An important aspect of this test is that the prism is added in a slow, gradual manner.

Negative Fusional Vergence: Step Vergence Testing

Although the introduction of the prism demand is different from smooth vergence testing, the instructional set and the explanation of the requirements of the test are similar to that described for smooth vergence testing.

Negative Fusional Vergence: Vergence Facility Testing

The patient is instructed to keep a vertical line of 20/30 letters *single* and *clear* as 12 Δ base-out and 3 Δ base-in prism is abruptly introduced. To accomplish this, the patient must maintain his or her accommodative level at 2.50, while using 3 Δ of NFV to restore bifoveal fixation. If sufficient fusional vergence is available, the response will be a single clear image. A report of diplopia would indicate that the patient could not restore binocularity using NFV. A report of a single blurred target indicates the use of a decrease in accommodative convergence to aid the fusional vergence mechanism.

Because this procedure is repeated several times and prism is introduced in large increments, it is an excellent method to evaluate a patient's stamina or ability to make a large number of rapid repetitive fusional vergence changes.

Positive Relative Accommodation

This test evaluates NFV in an indirect manner. Lenses are introduced slowly in 0.25 increments, making this procedure comparable to smooth vergence testing. However, with the PRA, the patient must maintain convergence at a particular level while changing the accommodative response. As minus lenses are added, the patient must maintain single and clear vision. To accomplish this, he or she must stimulate accommodation. This stimulation of accommodation is accompanied by an increase in accommodative convergence. The amount of additional accommodative convergence involved depends on the AC/A ratio.

The patient is faced with a dilemma. He or she must accommodate to maintain clarity, but the accommodation automatically causes additional convergence. This additional convergence, however, will result in diplopia because the target remains at 40 cm. To prevent diplopia, the patient must resort to use of NFV to offset the accommodative convergence. The amount of NFV required is related, again, to the AC/A ratio.

The PRA procedure, therefore, is not only an indication of the patient's ability to stimulate accommodation, but also a reflection of the status of NFV. The endpoint of the procedure is either an inability to stimulate additional accommodation or reduced NFV. When the endpoint is reached, a differentiation of the causative factor can be made by occluding one eye. If the print now clears, it indicates that the causative factor was reduced NFV.

Binocular Accommodative Facility with Minus Lenses

This procedure is similar to the PRA, since it requires maintenance of convergence at a specific level while the accommodative response changes. As -2.00 lenses are introduced binocularly, the patient is instructed to maintain *single* and *clear* vision. He or she must, therefore, stimulate 2.00 D of accommodation to restore clarity. This 2.00 D stimulation, however, causes a reflex increase in accommodative convergence. The amount of additional convergence is directly related to the AC/A ratio. Given a 5:1 AC/A ratio, if the patient stimulates 2.00 D of accommodation, his or her eyes will converge 10 Δ . If the patient permits this to occur, he or she will see two targets. Because the instructions require that the target be both single and clear, the patient must use 10 Δ of fusional divergence to compensate for the increase in accommodative convergence.

The endpoint of this test can be caused by one of two factors. Either the patient has inadequate NFV or is unable to stimulate 2.00 D of accommodation. To differentiate, simply cover one eye. If the print remains blurred, the difficulty is the ACC. If it clears, the limiting factor was NFV.

Monocular Estimation Method Retinoscopy and Fused Cross-cylinder Test

Both MEM retinoscopy and the fused cross-cylinder test tend to show more plus than normally expected when NFV is low. This type of response indicates an attempt by the patient to use as little accommodation as possible in order to maintain binocular vision. By decreasing the accommodative response, the demand on NFV is reduced.

SUMMARY

Given a patient presenting with near asthenopic symptoms and esophoria, the NFV group findings tend to be lower than expected, while the fused cross-cylinder and MEM show underaccommodation (more plus than expected). Occasionally, only the facility findings will be low, while the measures of amplitude are normal.

All of the findings in this group provide information about the status of the NFV system and the patient's ability to compensate for esophoria.

ACCOMMODATIVE SYSTEM GROUP DATA

Two factors must be kept in mind when evaluating the ACC. First, we can best assess accommodation under monocular conditions. This eliminates any contamination of test results due to the influence of binocular vision disorders. Some of the testing procedures that were included in the PFV and NFV groups are administered under binocular conditions. Several of these procedures also can yield information about the ACC. It is important, however, to realize that they are only indicative of the status of accommodation if the binocular system is unaffected. Tests in this category include the NRA, PRA, binocular accommodative facility, MEM retinoscopy, and the fused cross-cylinder test.

For instance, a low PRA finding can be indicative of an accommodative insufficiency or a problem with esophoria and low NFV. Accommodative insufficiency would only be indicated, however, if other testing revealed adequate NFV. As discussed previously, the endpoint for the PRA can either be an inability to stimulate accommodation or insufficient NFV.

The second important factor is that both the inhibition and stimulation of accommodation should be evaluated and the results interpreted individually.

Monocular Accommodative Amplitude

This procedure is comparable to measures of fusional vergence using the smooth vergence testing technique. It tells us the total amount of accommodation available. Standard procedure calls for one measurement of the accommodative amplitude for each eye. Under these conditions, we have little indication of how efficiently the patient is able to use the accommodative amplitude or if he or she can sustain over a reasonable period of time. To increase the diagnostic significance of this procedure, one needs to repeat the measurement three to four times or repeat the test at the end of the examination. Both of these variations in procedure will yield information about sustaining ability.

A finding of a lower than expected amplitude of accommodation in a prepresbyope is indicative of accommodative insufficiency. In such a case, all testing that requires the patient to stimulate accommodation will tend to be lower than expected. This includes the monocular accommodative facility test with minus lenses, binocular accommodative facility with minus lenses, and the PRA.

An adequate amplitude of accommodation does not eliminate the possibility of an accommodative anomaly. A facility problem, sustaining problem, or an inability to relax accommodation could coexist with a normal accommodative amplitude. As a result, additional testing is necessary.

Monocular Accommodative Facility with Plus and Minus Lenses

This procedure requires the patient to make rapid, large changes in the accommodative response. The stimulus to accommodation is changed from +2.00 D to -2.00 D with each fixation.

When a patient who presents with near point symptoms is tested, the procedure should be continued for 1 minute. The number of cycles performed in 1 minute can then be compared to the table of expected findings. This permits evaluation of the individual's ability to make rapid and large changes in accommodative level and to sustain over a long period of time.

There are four possible results:

- Adequate performance with both plus and minus lenses.
- Inadequate performance with both plus and minus lenses. This response is indicative of accommodative infacility. Other evidence would be lower than expected findings on the binocular accommodative facility test with both plus and minus lenses and a low PRA and NRA.
- Adequate performance with minus lenses, inadequate with plus. Such a response is indicative of overaccommodation, accommodative spasm, or accommodative excess. The problem can be an isolated accommodative anomaly. However, often a binocular vision anomaly is the underlying cause.

For example, a patient with a high exophoria, a receded near point of convergence, and reduced PFV will tend to overaccommodate and use accommodative convergence to assist his or her deficient PFV system. This allows the individual to compensate for the high exophoria. Constant overaccommodation may lead to an accommodative spasm and secondary myopia.

- Adequate performance with plus lenses, inadequate with minus. This patient has difficulty stimulating accommodation and will often have a reduced amplitude of accommodation. This is the response of an individual presenting with an accommodative insufficiency or ill-sustained accommodation problem. Other findings that confirm this diagnosis include a low PRA, high MEM, and fused cross-cylinder findings.

Monocular Estimation Method Retinoscopy

This procedure serves as an objective assessment of a patient's accommodative response. Other optometric procedures used to assess accommodation and binocularity fail to monitor the actual accommodative response.

We typically present a target at 40 cm that represents a 2.50 D accommodative stimulus. Expected findings for MEM retinoscopy are +0.25 to +0.50 D when viewing such a stimulus. The information obtained can be used to confirm the presence of an accommodative or a binocular anomaly, or both. A finding of more plus than expected tends to substantiate a diagnosis of accommodative insufficiency. Other relevant findings would include a low PRA, a high fused cross-cylinder, and difficulty with accommodative facility with minus lenses.

Less plus on MEM or the fused cross-cylinder than expected would indicate an accommodative spasm or accommodative excess. Other relevant findings would include a low NRA and difficulty with monocular accommodative facility with plus lenses.

Fused Cross-cylinder Test

More plus than expected indicates underaccommodation that occurs with accommodative insufficiency. Less plus is interpreted as overaccommodation and can be indicative of accommodative spasm or excess.

Binocular Accommodative Facility

If a patient has normal binocular findings (phoria, PFV, NFV), the results from tests such as the NRA, PRA, and binocular accommodative facility can be useful in confirming the presence of an accommodative anomaly and problems with interactions between accommodation and vergence.

For instance, if a normal phoria is present and NFV is adequate, the endpoint of the PRA procedure will generally be determined by the patient's ability to stimulate accommodation. The information obtained in such a case could be utilized—along with the results of other accommodative tests—to determine the nature of the accommodative anomaly.

SUMMARY

When evaluating the ACC, it is important to administer monocular tests. Given a patient, however, with adequate PFV and NFV, one can use the information obtained from other procedures to assess the ACC.

In terms of identifying accommodative anomalies, tests that assess a patient's ability to make rapid, large changes in accommodative level and to sustain over time are most sensitive. They provide the clinician with test conditions that more closely resemble the normal use of the ACC and may correlate better with reports of near point asthenopia.

VERTICAL FUSIONAL VERGENCE DATA

Optometric data that can be used to determine the status of a patient's vertical fusional vergence (VFV) are included in this category. Unlike the previous groups, which contain tests that directly and indirectly assess the function being evaluated, there are only direct tests of vertical vergence.

Supravergence and Infravergence

Right infravergence is the compensatory fusional vergence for a right hyperdeviation, whereas right supravergence is the compensatory fusional vergence for a right hypodeviation. When right supravergence is measured, base-down prism is added in front of the right eye as the patient is instructed to keep the target single as long as possible and to report when the target becomes double. This test measures the patient's ability to maintain bifoveal alignment as base-down prism is slowly added. When diplopia occurs, this is recorded as the break finding and then the prism is reduced until a recovery point is determined. Right infravergence is measured by adding base-up prism in front of the right eye.

Vertical Fixation Disparity Testing

In contrast to horizontal fixation disparity testing, forced vergence testing is not necessary. Rather, the amount of prism that reduces the associated phoria to zero is considered to be the most accurate and readily accepted method of prism correction for vertical deviations (23).

OCULAR MOTOR DATA

Optometric data that can be used to determine the status of a patient's ocular motor skills are included in this category. Unlike the previous groups that contain tests that directly and indirectly assess the function being evaluated, there are only direct tests of fixation, saccades, and pursuits.

Fixation Status

This is simply a test in which the patient is asked to maintain fixation for at least 10 seconds. The clinician subjectively evaluates the quality of fixation over this 10-second time period.

Saccadic Ability

The most common method for evaluating saccadic ability is to use the NSUCO oculomotor test described in Chapter 1 (Table 1.8). When a problem is suspected from this test or from the history, it is best to administer the DEM test. This test provides quantification of saccadic ability, along with expected findings by age and grade level. Recently an adult version of the DEM test was released; this adult version, the A-DEM, is appropriate for patients aged 18 years and older.

Pursuit Ability

The most common method for evaluating pursuit ability is to use the NSUCO oculomotor test described in Chapter 1 (Table 1.10).

MOTOR ALIGNMENT AND TESTS OF ACCOMMODATIVE CONVERGENCE INTERACTION

Tests that Assess the Direction and Magnitude of the Phoria

Tests such as the cover test and various methods of phoria testing are important because they represent the initial entry point—in this case, analysis approach. Examples of such tests are the distance and near phorias assessed using the Maddox rod, the modified Thorington test or the von Graefe technique, and the cover test at distance and near.

The two important pieces of information gained from this testing are the direction of the phoria and the magnitude at both distance and near. The classification system used in this text depends heavily on the distance and near phoria information. Most common binocular vision anomalies that are considered in this book are all partially defined by this near-to-distance relationship. The distance phoria is a reflection of tonic vergence and is measured when the patient is fixating on a distant object with fusion prevented, accommodation relaxed, and the refractive error corrected. Tonic vergence is the vergence response from some undeterminable divergent position of anatomic rest that is maintained by extraocular muscle tonus. The near phoria is based on the AC/A ratio.

Another important relationship that must be considered is that of the phoria to the compensating fusional vergence. The tendency of the eyes to deviate from bifoveal fixation (phoria) is controlled by fusional vergence. If there is an exophoria, the compensating vergence is PFV. In the presence of esophoria, the NFV is the compensating vergence. For a right hyperdeviation, right infravergence is the compensatory reserve.

When dealing with a patient with a heterophoria, we must consider not only the direct measure but the indirect data as well. The direct and indirect measures form the groups listed above. Thus, for example, with exophoria and asthenopic symptoms, we expect all or most of the findings in the PFV group to be lower than expected.

The presence of a significant exophoria on cover testing should direct initial attention to the PFV group findings; significant esophoria suggests a close examination of the NFV group data. In the absence of a significant phoria at distance or near, the optometrist would direct his or her attention to the ACC group findings.

Fixation Disparity

The primary advantage of fixation disparity analysis is that the assessment takes place under binocular and, therefore, more natural conditions. Phoria or vergence testing that is performed under dissociated conditions

may not truly reflect the way the system operates under binocular conditions. Studies have indicated that analyzing binocular vision using fixation disparity is useful in determining those patients who are likely to have symptoms (8).

Fixation disparity has its most significant value when other testing fails to reveal a basis for a patient's complaints. Fixation disparity may provide an understanding of the patient's problem in such cases (Chapter 15).

AC/A Ratio

The relationship between the distance and near deviations is an important part of case analysis. Because the AC/A ratio is a critical determinant of this relationship, it is a vital part of case analysis. The AC/A ratio is also the major factor that determines the *sequence* of management decisions in patients with heterophoria. This is discussed in detail in later chapters.

Classification of the Vision Disorder and Identification of the Syndrome

As optometrists, we are confronted by a finite number of accommodative, ocular motor, and nonstrabismic binocular vision anomalies in clinical care, and a number of classification systems are available to help categorize these disorders. Perhaps the most common is Duane classification (20):

- Convergence insufficiency
- Convergence excess
- Divergence insufficiency
- Divergence excess

This classification, originally developed by Duane for strabismus, was later extended to nonstrabismic binocular vision anomalies by Tait (24).

This is a descriptive classification and does not necessarily imply etiology. Binocular problems are described according to the type of heterophoria measured at distance and at near. The Duane classification has limitations, however. As illustrated in the list above, only four possible classifications are available. Clinically, however, we find that many other possible combinations exist that do not fit into Duane classification. For example, one problem with this classification, described by Wick (18), is that it does not have a category for a deviation in which the exodeviations or esodeviations are equal at distance and near. Another condition that is not included in Duane classification is fusional vergence dysfunction (25). This is a condition in which there is no significant phoria at either distance or near, but the horizontal fusional vergence ranges are reduced in both base-in and base-out directions.

Because of these and several other limitations, Wick (18) described an alternative classification system for binocular anomalies that represents an expansion of Duane classification and is based on consideration of the distance phoria (tonic vergence) and the AC/A ratio. This classification takes all possible combinations into consideration and is the system we use in this text for binocular vision disorders. In this system, there are nine possible diagnoses, rather than the four suggested by Duane.

The nine possible diagnoses can be divided into three main categories of binocular vision problems based on the AC/A ratio. The three categories are low AC/A ratio, normal AC/A ratio, and high AC/A ratio. Within each of these three categories there are three possible combinations: exophoria, orthophoria, or esophoria at distance (Table 2.4). Convergence excess and insufficiency and divergence excess and insufficiency are included, but a major difference is that our classification has two types of convergence excess and convergence insufficiency. In addition, fusional vergence dysfunction and basic esophoria and exophoria are possible diagnoses. Because the treatment differs for each of these various classifications, it is desirable to be as specific as possible when classifying binocular and accommodative disorders.

The nine binocular vision anomalies described in Table 2.4 are all horizontal heterophoria problems. Vertical heterophoria can also occur. Vertical heterophoria problems are either classified as right or left hyperphoria.

The accommodative classification system used in this text originated with Donders (26), was expanded by Duke-Elder and Abrams (27), and has been popularized by optometric authors (28–30). It includes the categories of accommodative insufficiency, ill-sustained accommodation, accommodative excess, and accommodative infacility (Table 2.4).

TABLE 2.4 CLASSIFICATION OF BINOCULAR, ACCOMMODATIVE, AND OCULAR MOTOR ANOMALIES

Binocular anomalies
<i>Low AC/A ratio</i>
1. Orthophoria at distance—convergence insufficiency
2. Exophoria at distance—convergence insufficiency
3. Esophoria at distance—divergence insufficiency
<i>Normal AC/A ratio</i>
1. Orthophoria at distance—fusional vergence dysfunction
2. Exophoria at distance—basic exophoria
3. Esophoria at distance—basic esophoria
<i>High AC/A ratio</i>
1. Orthophoria at distance—convergence excess
2. Esophoria at distance—convergence excess
3. Exophoria at distance—divergence excess
Vertical anomalies
1. Right or left hyperphoria
Accommodative anomalies
1. Accommodative insufficiency
2. Ill-sustained accommodation
3. Accommodative excess
4. Accommodative infacility
Ocular motor anomalies
1. Ocular motor dysfunction

In regard to ocular motor anomalies, we use only one diagnostic category, namely, ocular motor dysfunction. This diagnosis refers to a condition in which there are problems with fixation, saccades, and pursuits.

By becoming knowledgeable about this classification system and the different possible syndromes, the knowledge base necessary for analysis of optometric data becomes complete.

The characteristics of each of the 15 binocular, ocular motility, and accommodative disorders are briefly described in the following sections. In addition, Chapters 9 through 13 discuss these conditions in detail, including characteristics, differential diagnosis, and optometric management of each condition.

Classification of Binocular Vision Disorders

CATEGORY 1: BINOCULAR VISION DISORDERS WITH A LOW AC/A RATIO

Orthophoria at Distance: Convergence Insufficiency

This is a patient who has orthophoria at distance (normal tonic vergence), a low AC/A ratio, and moderate to high exophoria at near.

Characteristics

Symptoms

All of the following are associated with reading or other near tasks:

- Asthenopia and headaches
- Intermittent blur
- Intermittent diplopia
- Symptoms worse at end of day

- Burning and tearing
- Inability to sustain and concentrate
- Words move on the page
- Sleepiness when reading
- Decreased reading comprehension over time
- Slow reading

Signs

- Moderate to high exophoria or intermittent exotropia at near
- Reduced PFV at near
- Reduced vergence facility at near with base-out prism
- Intermittent suppression at near
- Receded near point of convergence
- Low AC/A ratio
- Fails binocular accommodative facility testing with +2.00
- Low MEM and fused cross-cylinder findings
- Low NRA
- Exofixation disparity

Exophoria at Distance: Convergence Insufficiency

This is a patient who has exophoria at distance (low tonic vergence) and low AC/A ratio, and thus the near phoria will be significantly greater than the distance phoria. This patient's exophoria differs from the previous type in which the phoria at distance is ortho.

Characteristics

Symptoms

All of the following are associated with reading or other near tasks:

- Asthenopia and headaches
- Intermittent blur
- Intermittent diplopia
- Symptoms worse at end of day
- Burning and tearing
- Inability to sustain and concentrate
- Words move on the page
- Sleepiness when reading
- Decreased reading comprehension over time
- Slow reading
- If the exophoria is large at distance, many of the above symptoms may be present at distance as well.

Signs

- Greater exophoria at near than at distance
- Reduced PFV at distance and near
- Reduced vergence facility at near and possibly at distance with base-out prism
- Intermittent suppression at near
- If the suppression is significant, stereopsis may be reduced
- Receded near point of convergence
- Low AC/A ratio
- Fails binocular accommodative facility testing with +2.00 D
- Low MEM and fused cross-cylinder findings
- Low NRA
- Exofixation disparity at distance and near

Esophoria at Distance: Divergence Insufficiency

This is a patient who has esophoria at distance (high tonic vergence) and low AC/A ratio, and thus the distance phoria will be significantly greater than the near phoria.

Characteristics

Symptoms

- Asthenopia associated with distance tasks
- Intermittent blur at distance
- Intermittent diplopia at distance
- Symptoms worse at end of day
- These symptoms will generally be long-standing, in contrast to a history of acute symptoms.

Signs

- Esophoria greater at distance than at near
- Reduced NFV at distance
- Reduced vergence facility at distance with base-in prism
- Esifixation disparity at distance

CATEGORY 2: NORMAL AC/A RATIO

Orthophoria at Distance: Fusional Vergence Dysfunction

This is a patient with orthophoria at distance and near or a low degree of esophoria or exophoria at distance and near. The important characteristic of this patient is not the phoria, but the fusional vergence findings. Fusional vergence dysfunction is a disorder in which the fusional vergence ranges are reduced in both the base-in and base-out directions. Other conditions that must be considered when a patient is symptomatic, in spite of an insignificant phoria, are aniseikonia, cyclophoria, latent hyperopia, and hyperphoria.

Characteristics

Symptoms

All of the following are associated with reading or other near tasks:

- Asthenopia and headaches
- Intermittent blur
- Symptoms worse at end of day
- Burning and tearing
- Inability to sustain and concentrate
- Sleepiness when reading
- Decreased reading comprehension over time
- Slow reading.

Signs

- Orthophoria or a low degree of esophoria or exophoria at distance and near
- Reduced NFV and PFV at distance and near
- Reduced vergence facility at near and possibly at distance, with both base-out and base-in prism
- Low PRA and NRA
- Fails binocular accommodative facility with both plus and minus lenses
- Normal monocular accommodative facility

Exophoria at Distance: Basic Exophoria

This is a patient who has exophoria at distance (low tonic vergence) and a normal AC/A ratio, and thus the near phoria will be approximately equal to the distance phoria.

Characteristics

Symptoms

- Asthenopia associated with distance and near tasks
- Intermittent blur at distance and near
- Intermittent diplopia at distance and near
- Symptoms worse at end of day.

Signs

- Exophoria of approximately equal magnitude at distance and near
- Reduced PFV at distance and near
- Reduced vergence facility at distance and near with base-out prism
- Low NRA
- Fails binocular accommodative facility with plus
- Low MEM and cross-cylinder findings
- Exofixation disparity at distance and at near
- Type III fixation disparity curve

Esophoria at Distance: Basic Esophoria

This is a patient who has esophoria at distance (high tonic vergence) and a normal AC/A ratio, and thus the near phoria will be approximately equal to the distance phoria.

Characteristics

Symptoms

- Asthenopia associated with distance and near tasks
- Intermittent blur at distance and near
- Intermittent diplopia at distance and near
- Symptoms worse at end of day.

Signs

- Esophoria of approximately equal magnitude at distance and near
- Reduced NFV at distance and near
- Reduced vergence facility at distance and near with base-in prism
- Low PRA
- Fails binocular accommodative facility with minus
- High MEM and cross-cylinder findings
- Esifixation disparity at distance and at near
- Type II fixation disparity curve

CATEGORY 3: BINOCULAR VISION DISORDERS WITH HIGH AC/A RATIO

Orthophoria at Distance: Convergence Excess

This is a patient with orthophoria at distance (normal tonic vergence) and a high AC/A ratio. There is, therefore, a significant amount of esophoria at near.

Characteristics

Symptoms

All of the following are associated with reading or other near tasks:

- Asthenopia and headaches
- Intermittent blur

- Intermittent diplopia
- Symptoms worse at end of day
- Burning and tearing
- Inability to sustain and concentrate
- Words move on the page
- Sleepiness when reading
- Decreased reading comprehension over time
- Slow reading.

Signs

- Significant esophoria at near
- Reduced NFV at near
- Reduced vergence facility at near with base-in prism
- Low PRA
- Fails binocular accommodative facility with minus lenses
- High MEM and cross-cylinder findings
- Esofixation disparity at near

Esophoria at Distance: Convergence Excess

This is a patient who has a low to moderate degree of esophoria at distance (high tonic vergence) and a high AC/A ratio as well. Thus, the degree of esophoria at near will be significantly greater than that at distance.

Characteristics

Symptoms

All of the following are associated with reading or other near tasks:

- Asthenopia and headaches
- Intermittent blur
- Intermittent diplopia
- Symptoms worse at end of day
- Burning and tearing
- Inability to sustain and concentrate
- Words move on the page
- Sleepiness when reading
- Decreased reading comprehension over time
- Slow reading
- If the esophoria is large enough at distance, there may be symptoms of intermittent diplopia, blur, and asthenopia at distance as well.

Signs

- Esophoria greater at distance and near
- Reduced NFV at distance and near
- Reduced vergence facility at distance and near with base-in prism
- Low PRA
- Fails binocular accommodative facility with minus
- High MEM and cross-cylinder findings
- Esifixation disparity at distance and at near

Exophoria at Distance: Divergence Excess

This is a patient who has a low to moderate degree of exophoria at distance (low tonic vergence) and a high AC/A ratio. Thus, the degree of exophoria at near will be significantly less than that at distance.

Characteristics

Symptoms

- Parents complain of eye turning out
- Occasional near point asthenopia
- Child closes one eye in bright light.

Signs

- Greater exophoria or intermittent exotropia at distance than at near
- High calculated AC/A ratio
- Suppression at distance
- Normal near point of convergence
- Limited NFV, adequate PFV
- Difficulty with first- and second-degree fusion
- Generally normal stereopsis at near.

CATEGORY 4: VERTICAL ANOMALIES

Vertical deviations can be described as either hyper or hypo. If the vertical deviation is a heterophoria, a right hyperphoria is the same as a left hypophoria. By convention, however, the deviation is classified as either a right or left hyperphoria.

Characteristics

Symptoms

- Blurred vision
- Headaches
- Asthenopia
- Diplopia
- Car and motion sickness
- Inability to attend and concentrate during sustained visual tasks
- Sleepiness
- Loses place when reading (returns to wrong line).

Signs

- Anomalous head position
- Hyperphoria
- Reduced horizontal fusional vergence (both PFV and NFV)
- Reduced vergence facility at distance and near with base-out and base-in prism
- VFV may be reduced or unusually large, depending on the duration of the vertical deviation.

Classification of Accommodative Anomalies

ACCOMMODATIVE INSUFFICIENCY

Characteristics

Symptoms

- Symptoms are very similar to those associated with presbyopia
- Blurred near vision
- Discomfort and strain associated with near tasks
- Fatigue associated with near point tasks
- Difficulty with attention and concentration when reading.

Signs

- Low accommodative amplitude
- Low PRA
- Fails monocular and binocular accommodative facility with minus lenses
- Esophoria at near
- High MEM and fused cross-cylinder

ILL-SUSTAINED ACCOMMODATION*Characteristics***Symptoms**

- Symptoms are very similar to those associated with accommodative insufficiency
- Blurred near vision
- Discomfort and strain associated with near tasks
- Fatigue associated with near point tasks
- Difficulty with attention and concentration when reading.

Signs

- Normal accommodative amplitude if administered just once; the amplitude decreases if repeated 5 to 10 times
- Low PRA
- Fails monocular and binocular accommodative facility with minus lenses; the performance will decrease over time
- Esophoria at near
- High MEM and fused cross-cylinder.

ACCOMMODATIVE EXCESS*Characteristics***Symptoms**

- Asthenopia and headaches associated with near tasks
- Intermittent blurred distance vision

Signs

- Variable visual acuity findings
- Variable static and subjective
- Low degree of against-the-rule cylinder
- Low MEM and fused cross-cylinder
- Low NRA
- Esophoria at near and possibly at distance
- Fails monocular and binocular accommodative facility with plus lenses.

ACCOMMODATIVE INFACILITY (INERTIA OF ACCOMMODATION)*Characteristics***Symptoms**

- Difficulty focusing from distance to near and near to distance
- Asthenopia associated with near tasks
- Difficulty with attention and concentration when reading
- Intermittent blur associated with near tasks.

Signs

- Fails binocular and monocular accommodative facility with plus and minus lenses
- Low PRA and NRA.

Classification of Ocular Motor Anomalies

Some clinicians classify ocular motor problems into saccadic and pursuit dysfunction. In our experience, it is rare to find difficulty in only one area. Generally, patients with ocular motor problems have problems with fixation, saccades, and pursuits. This text uses the term *ocular motor dysfunction* to refer to a condition in which all three areas are affected.

Characteristics

Symptoms

These symptoms are generally related to the use of the eyes for reading.

- Excessive head movement
- Frequent loss of place
- Omission of words
- Skipping lines
- Slow reading speed
- Poor comprehension
- Short attention span
- Difficulty copying from the chalkboard
- Difficulty solving arithmetic problems with columns of numbers
- Difficulty taking standardized psychological or educational tests with computer scan sheets
- Poor performance in sports.

Signs

- Below grade-level performance on the Visagraph
- Score below the 15th percentile on the DEM test
- Score below the 15th percentile NSUCO oculomotor test.

Table 2.5 provides a summary of the diagnostic findings for the accommodative and binocular vision disorders described above.

Case Analysis: Using the System

The use of the case analysis approach just presented can be illustrated by the branching diagnostic decision tree shown in Figure 2.2. The remainder of this chapter is devoted to a discussion of each section of this flowchart.

INITIAL TESTING: CASE HISTORY AND TESTING TO RULE OUT NONFUNCTIONAL ETIOLOGY

Accommodative, ocular motility, and binocular vision anomalies are often associated with a characteristic set of signs and symptoms. Typical signs and symptoms are as follows:

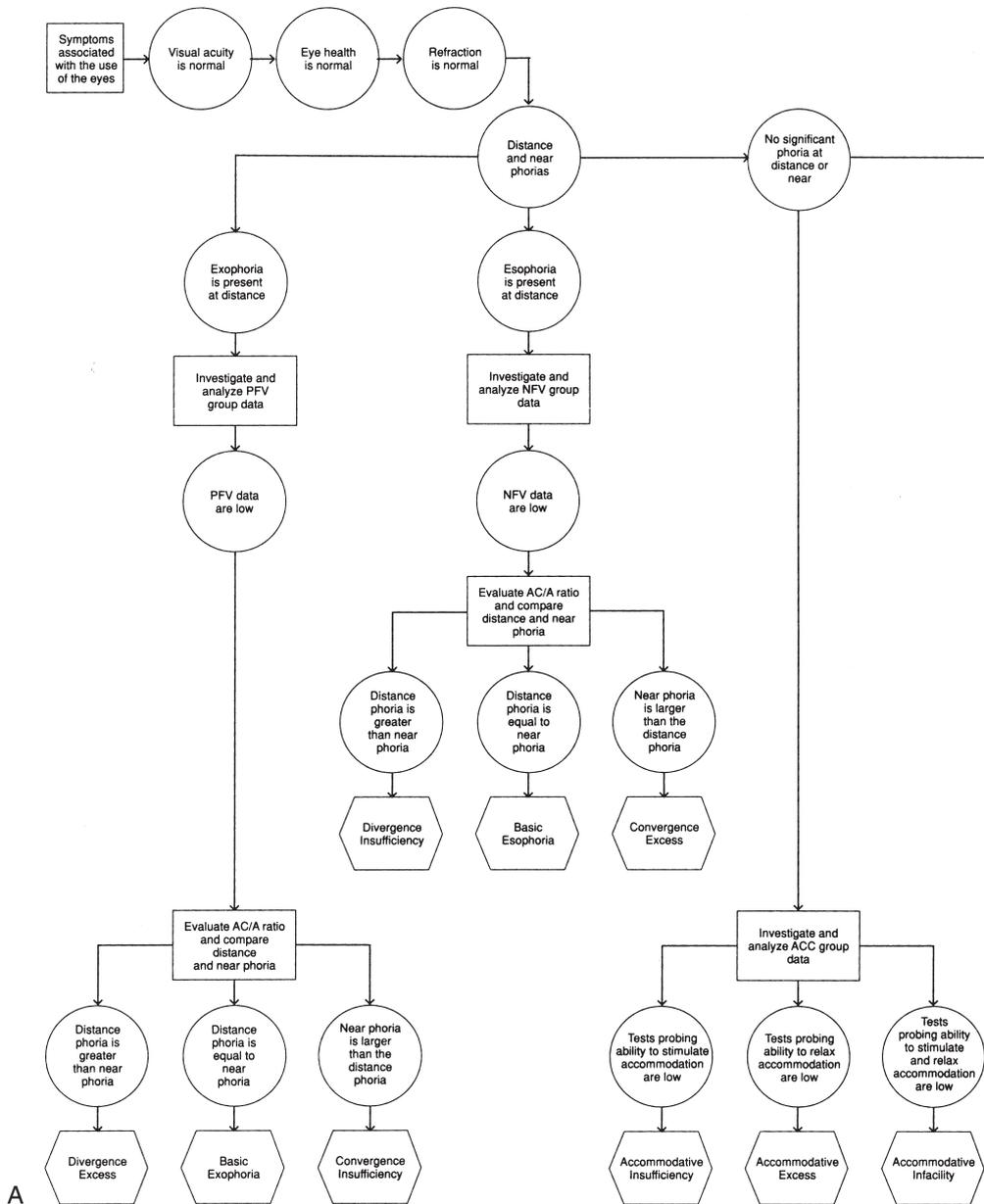
- Excessive blinking
- Eyestrain associated with reading or close work
- Burning and tearing
- Headaches associated with near work
- Inability to sustain near point work
- Poor concentration
- Intermittent diplopia
- Worse when looking to the right or left

TABLE 2.5 COMMON ACCOMMODATIVE AND NONSTRABISMIC BINOCULAR VISION DISORDERS: SUMMARY OF DIAGNOSTIC FINDINGS

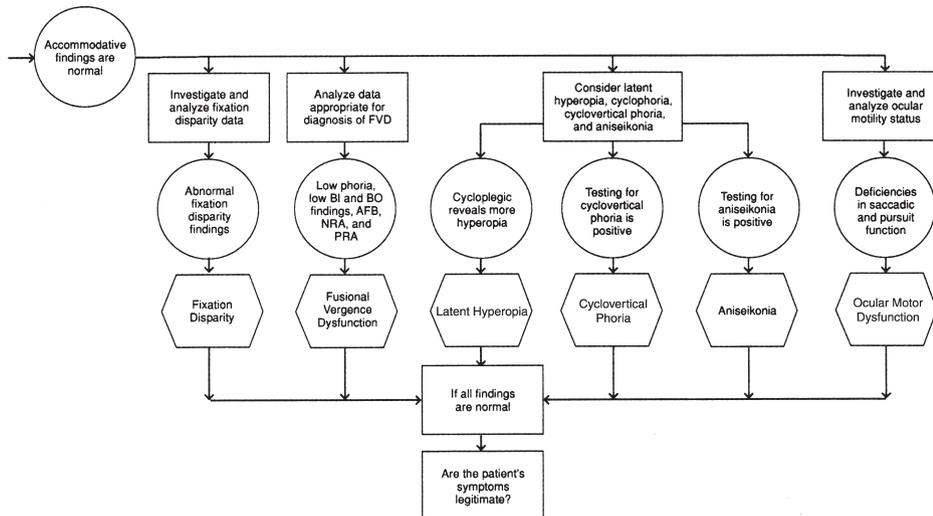
Condition	Cover Test	AC/A Ratio	NPC	Vergence Amplitude	Vergence Facility	Stereopsis	Accommodative Amplitude	Binocular Accommodative Facility	Monocular Accommodative Facility	NRA and PRA	Monocular Estimation Method
Accommodative insufficiency	No predictable pattern	Normal	Normal	BO blur at near may be low	Normal	Normal	Low	FAILS -	FAILS -	Low PRA	High
Ill-sustained accommodation	No predictable pattern	Normal	Normal	BO blur at near may be low	Normal	Normal	Normal	FAILS -	FAILS -	Low PRA	High
Accommodative excess	No predictable pattern	Normal	Normal	BI blur at near may be low	Normal	Normal	Normal	FAILS +	FAILS +	Low NRA	Low
Accommodative infacility	No predictable pattern	Normal	Normal	BO and BI blur at near may be low	Normal	Normal	Normal	FAILS +/-	FAILS +/-	Low NRA and PRA	Normal
Convergence insufficiency	Exo > N	Low	Receded	Low BO	Low BO	Normal	Normal	FAILS +	Normal	Low NRA	Low
Convergence excess	Eso > N	High	Normal	Low BI	Low BI	Normal	Normal	FAILS -	Normal	Low PRA	High
Fusional vergence dysfunction	Low eso or low exo	Normal	Normal	Low BO and BI	Low BO and BI	Normal	Normal	FAILS +/-	Normal	Low NRA and PRA	Normal
Divergence insufficiency	Eso > D	Low	Normal	Low BI at D	Low BI at D	Normal	Normal	Normal	Normal	Normal	Normal
Divergence excess	Exo > D	High	Normal	Low BO at D Low BI at N	Low BO at D Low BI at N	Normal	Normal	Normal	Normal	Normal	Normal
Basic exophoria	Equal exo at D and N	Normal	Normal	Low BO at D and N	Low BO at D and N	Normal	Normal	FAILS +	Normal	Low NRA	Low
Basic esophoria	Equal eso at D and N	Normal	Normal	Low BI at D and N	Low BI at D and N	Normal	Normal	FAILS -	Normal	Low PRA	High

NPC, near point convergence; NRA, negative relative accommodation; PRA, positive relative accommodation; BO, base-out; BI, base-in; N, near; D, distance.

- Worse when looking up or down
- Words appear to move
- Sensitivity to light
- Blurred vision at near or distance
- Blur when looking from near to far or far to near
- Close working distance
- Closing or covering an eye
- Loss of place
- Skipping lines
- Slow reading
- Poor reading comprehension
- Head tilt or face turn.



■ **Figure 2.2** Flowchart illustrating case analysis decision-making process.



B

■ **Figure 2.2** (Continued)

A key determination is whether a pattern or relationship exists between the symptoms and the use of the eyes. The clinician should try to establish whether there is an increase in severity of symptoms toward the end of the day, when the patient is tired, or with prolonged use of the eyes. When such a pattern cannot be established, other etiologies should be considered, including nonfunctional causes and malingering.

There are many nonfunctional causes of accommodative, ocular motility, and binocular vision disorders. Many of these etiologies can be investigated and ruled out with an appropriate case history. Even if the most likely hypothesis is an accommodative or binocular problem, these other conditions should be considered through a careful case history and a minimum database. Chapters 9 to 13 discuss these nonfunctional disorders in detail. Box 2.1 lists recommended case history questions. The minimal database designed to rule out nonfunctional etiologies of accommodative, ocular motility, and binocular vision disorders is as follows:

- External evaluation
- Pupil evaluation
- Swinging flashlight test

BOX 2.1 SAMPLE CASE HISTORY QUESTIONS TO RULE OUT NONFUNCTIONAL CAUSES

When did these symptoms begin?
 Have you been ill lately?
 Have you been taking any medication?
 Has there been any change in your appetite?
 Has there been any change in your sleep habits?
 Have you gained or lost significant weight recently?
 Do you have problems with chewing or swallowing?
 Are your problems worse in the morning or evening?
 Are you dizzy?
 Do you have any headaches?
 When do the headaches occur?
 How bad are the headaches?
 Do the headaches wake you up at night?
 Has there been any recent trauma?
 Have you had any difficulty with balance?
 Have you had any fainting spells?
 Have you experienced any muscle weakness?
 Have you experienced any numbness or tingling sensations?

- Color vision
- Ophthalmoscopy
- Versions
- Cover test at distance and near
- Cover test in cardinal positions of gaze
- Confrontation fields.

The flowchart reflects this concern and suggests that the process of precisely determining the specific diagnosis should wait until more serious causes of such symptoms are eliminated. Visual acuity (VA), pupillary evaluation, comitancy testing, internal and external ocular health tests, and refraction are all critical aspects of the differential diagnosis. A number of excellent resources discuss these aspects of the diagnostic process in more detail (31–33).

SIGNIFICANT PHORIA IS PRESENT AT DISTANCE OR AT NEAR

Once the clinician determines that the history suggests an accommodative, ocular motility, or binocular disorder and rules out nonfunctional causes or refractive error, full attention can be turned toward case analysis and identification of the accommodative or binocular vision anomaly.

Figure 2.3 illustrates the next step in this process. The primary entry points into case analysis are the distance and near phorias and the AC/A ratio. Step 1 is to determine the distance and near phorias. Based on this information, the starting point for analysis of data can be established.

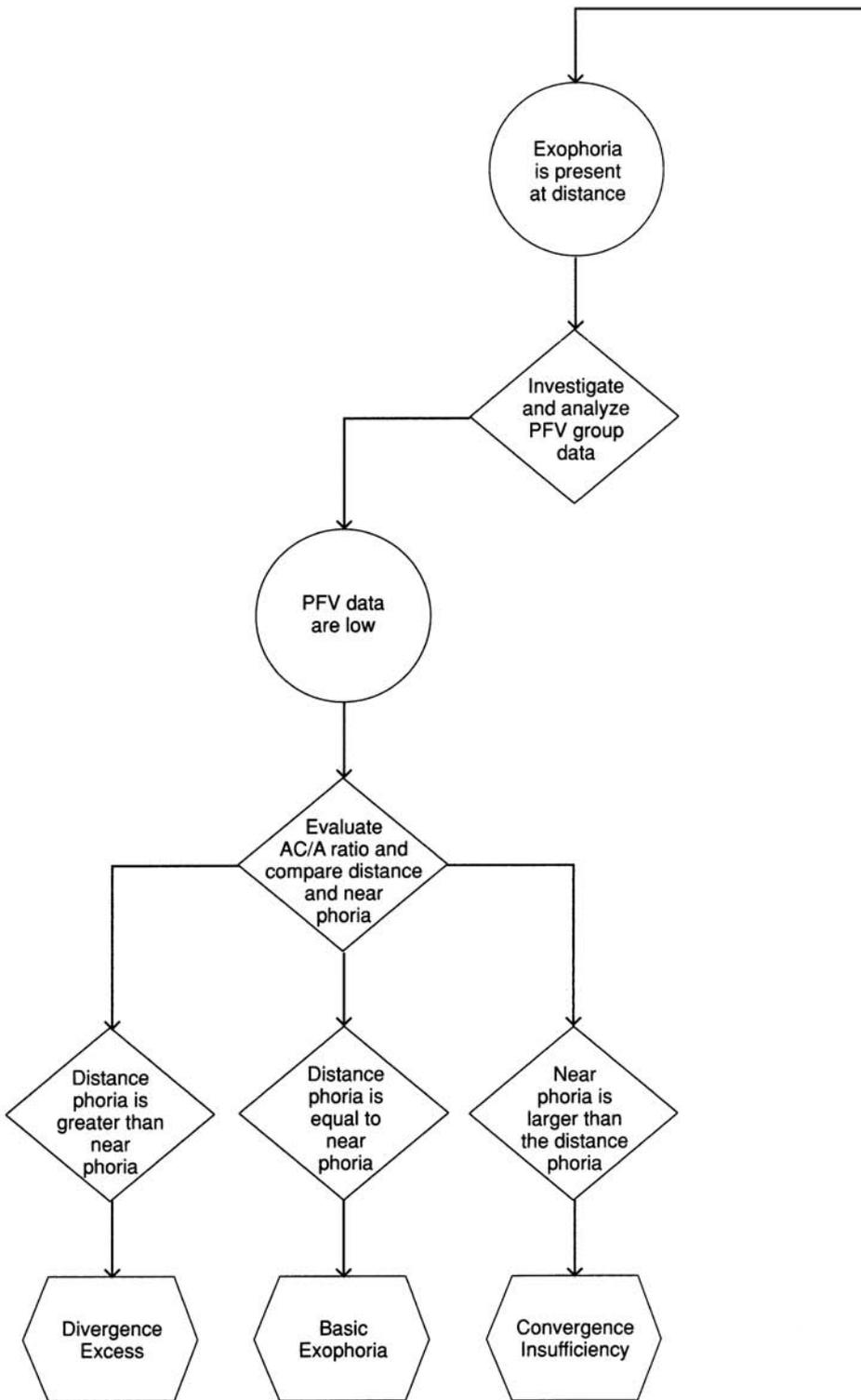
The next step in the analytical process is to determine the degree of the phoria and compare it to normative data. The result directs the optometrist to investigate and analyze groups of tests to look for trends in the data supporting a specific diagnosis. It is important to emphasize that a phoria or any finding in isolation has little significance. Rather, if a patient is esophoric, the optometrist should direct his or her attention to the NFV group data. The clinical hypothesis at this point would be that the patient's symptoms are secondary to an esophoria low NFV problem. The three primary possibilities would be convergence excess, divergence insufficiency, or basic esophoria. To determine which of the three to consider, the AC/A ratio, along with the relationship between the distance and near phoria, must be analyzed. Based on this step, the direct and indirect measures of NFV—at the particular distance of concern—can be studied. For example, if the patient presents with 12 Δ esophoria at near and 2 Δ esophoria at distance, the optometrist would be considering convergence excess as the most likely hypothesis and would look at the NFV group data at near for confirmation of this hypothesis (Fig. 2.4).

A possible scenario is that the NFV findings as a group will indeed be low compared to expected findings, and this will confirm the hypothesis and allow one to reach a diagnosis of convergence excess. However, it is important to understand that other possibilities exist. This is reflected in the flowchart. The presence of near point esophoria by itself does not necessarily suggest that the patient has an esophoria and low NFV-type problem. There are many situations in which esophoria is present and the etiology is actually an accommodative problem (Fig. 2-5).

Thus, if esophoria is present, the first approach would be to investigate the NFV group data. However, if the NFV data are within the expected values, attention should be directed to the ACC group data. Cases 2.1, 2.2, and 2.3 illustrate this point.

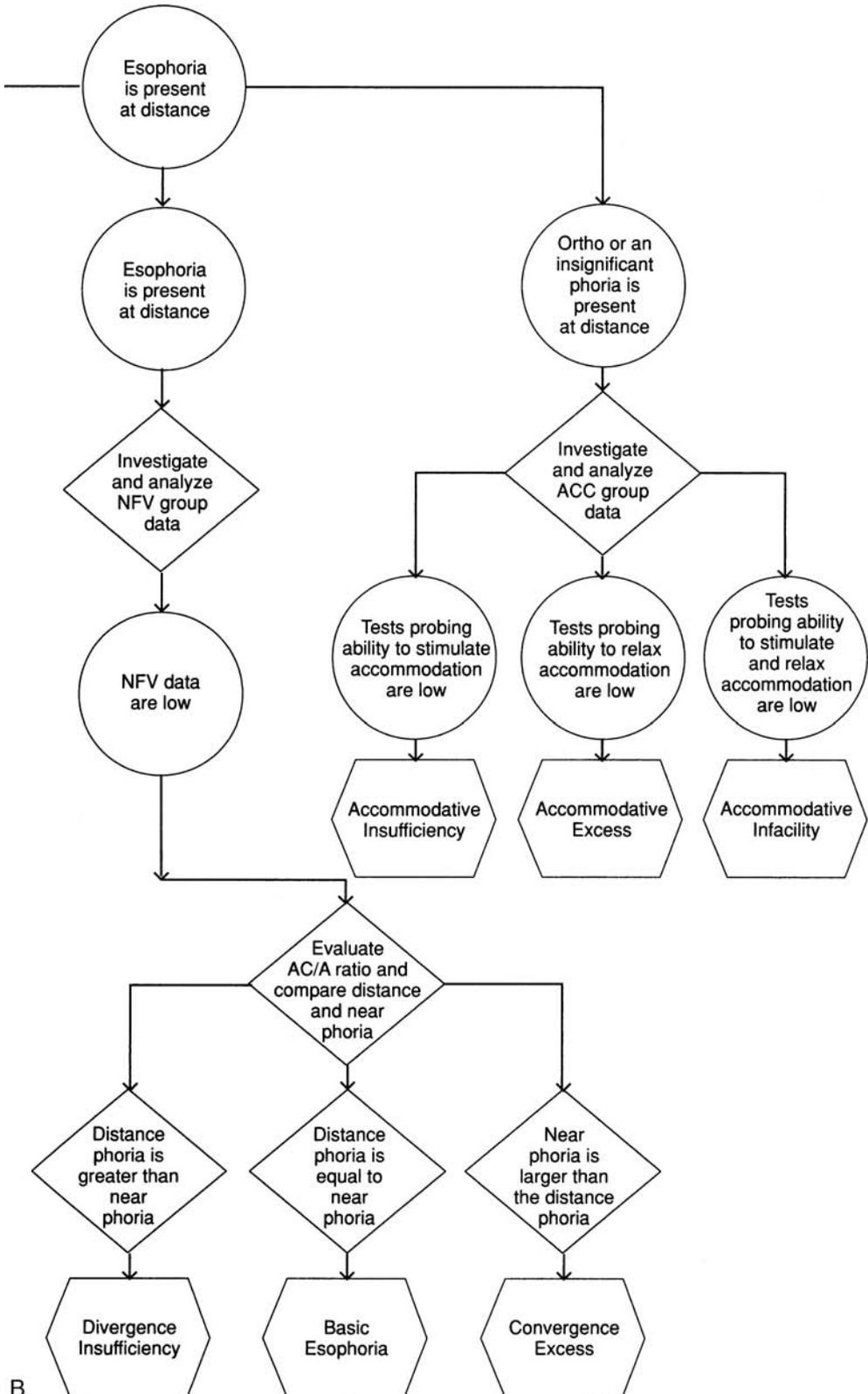
Cases 2.1–2.3 illustrate the importance of looking for trends and evaluating groups of data rather than establishing a diagnosis on any one or two pieces of information. In all three cases the patient presented with a history of near point symptoms associated with reading. Nonfunctional etiologies were eliminated in all three cases. Initially a clinical hypothesis of convergence excess appeared most likely in all cases because of the greater esophoria at near than at distance. However, in Cases 2.1 and 2.2 the actual diagnosis was an accommodative disorder, and in Case 2.3, it was a convergence excess. These cases also demonstrate that esophoria is often associated with disorders of the ACC. In accommodative insufficiency, esophoria can be the result of the use of excessive innervation to the ACC to maintain clarity during reading. In accommodative excess, the etiology of an associated finding of esophoria can be explained based on the additional convergence associated with overaccommodation.

If a significant degree of exophoria is present compared to expected values, the flowchart directs the optometrist's attention to the PFV group data (Fig. 2.6). If the exophoria is greater at distance than near, the initial hypothesis is divergence excess. If the near deviation is larger, the hypothesis is convergence insufficiency. If the deviation is equal at distance and near, it is basic exophoria.



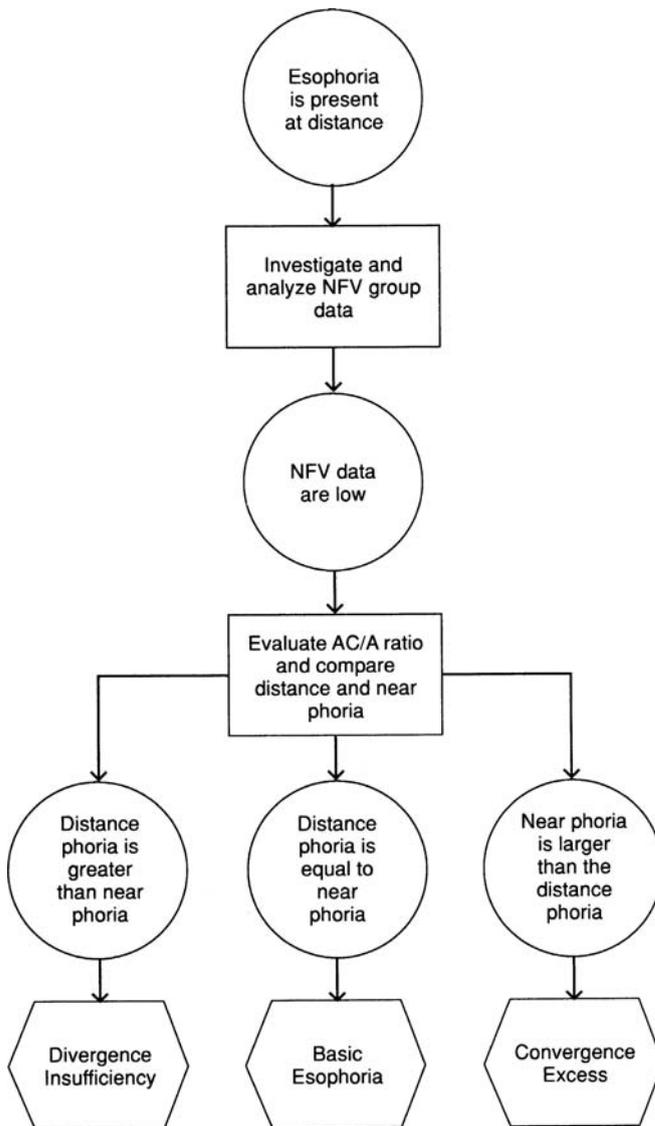
A

■ **Figure 2.3** Flowchart illustrating that the primary entry points into case analysis are the distance and near phorias and the AC/A ratio.



B

■ Figure 2.3 (Continued)



■ **Figure 2.4** Flowchart: negative fusional vergence group data.

Case 2.1

History

A 12-year-old boy presented with a history of blurred vision after 5 to 10 minutes of reading, along with a report of eyestrain. Initial history and testing to consider nonfunctional causes were negative.

Examination Results

VA (distance, uncorrected):	OD: 20/20
	OS: 20/20
VA (near, uncorrected):	OD: 20/20
	OS: 20/20

Near point of convergence	
Accommodative target:	2.5 to 5 cm (1 to 2 in.)
Penlight:	2.5 to 5 cm
Cover test (distance):	Orthophoria
Cover test (near):	4 esophoria
Subjective:	OD: plano
	OS: plano
Distance lateral phoria:	Orthophoria
Base-in vergence (distance):	X/7/4
Base-out vergence (distance):	9/18/12
Near lateral phoria:	4 base-out
-1.00 gradient:	8 base-out
Base-in vergence (near):	10/19/11
Base-out vergence (near):	12/22/10
Vergence facility (near):	12 cpm
NRA:	+1.50
PRA:	-2.50
Accommodative amplitude (push-up):	OD: 13 D
	OS: 13 D
Monocular accommodative facility:	OD: 0 cpm fails +2.00
	OS: 0 cpm fails +2.00
Binocular accommodative facility:	0 cpm fails +2.00
MEM retinoscopy:	Plano OU

Pupils were normal, all external and internal health tests were negative, the deviation was comitant, and color vision testing revealed normal function.

Case Analysis

The binocular findings in this case indicate orthophoria at distance and 4 esophoria at near. The flowchart in Figure 2.4 suggests that, in the presence of esophoria at near, the best initial approach is to first look toward the NFV group data for confirmation of a convergence excess. In this case, however, the base-in at near was 10/19/11, vergence facility was 12 cpm, the PRA = -2.50, the NRA = +1.50, and binocular accommodative facility revealed no difficulty with minus lenses, but the patient was unable to clear even one attempt with +2.00 lenses. Monocular accommodative facility also revealed no difficulty with minus lenses, but inability to clear +2.00 even once.

The NFV group data clearly demonstrate that the NFV is well within expected values. Therefore, the initial hypothesis of convergence excess must be rejected and the most likely hypothesis becomes some type of accommodative disorder. This is reflected in the flowchart that directs the investigation toward the ACC group data (Fig. 2.5). All the findings that probe the patient's ability to relax accommodation (MEM retinoscopy, monocular accommodative facility, and binocular accommodative facility with +2.00, NRA) are low in this case. A diagnosis of accommodative excess can, therefore, be established.

Case 2.2

History

A 20-year-old college student presented with complaints of blurry vision and discomfort around his eyes after 15 minutes of reading.

Examination Results

VA (distance, uncorrected):	OD: 20/20 OS: 20/20
VA (near, uncorrected):	OD: 20/20 OS: 20/20
Near point of convergence	
Accommodative target:	5 to 7.5 cm (2 to 3 in.)
Penlight:	5 to 7.5 cm
Cover test (distance):	Orthophoria
Cover test (near):	4 esophoria
Subjective:	OD: plano OS: plano
Distance lateral phoria:	Orthophoria
Base-in vergence (distance):	X/8/3
Base-out vergence (distance):	X/20/12
Vergence facility (near):	13 cpm
Near lateral phoria:	4 esophoria
–1.00 gradient:	8 esophoria
Base-in vergence (near):	10/18/10
Base-out vergence (near):	12/23/11
NRA:	+2.50
PRA:	–1.00
Accommodative amplitude (push-up):	OD: 5 D OS: 5 D
Monocular accommodative facility	OD: 0 cpm, cannot clear –2.00 OS: 0 cpm, cannot clear –2.00
Binocular accommodative facility:	0 cpm, cannot clear –2.00
MEM retinoscopy:	+1.25 OU

Pupils were normal, all external and internal health tests were negative, the deviation was comitant, and color vision testing revealed normal function.

Case Analysis

Initial testing reveals orthophoria at distance and 4 esophoria at near, with convergence excess the most likely initial hypothesis. Analysis of the NFV group data demonstrates normal NFV with direct testing. The NRA is +2.50, and the PRA is reduced to –1.00. In addition, binocular accommodative facility suggests that the patient can readily clear +2.00 but is unable to clear –2.00 even once. When accommodative facility is evaluated monocularly, the patient continues to easily clear +2.00 but is unable to clear –2.00. No obvious trend is present in the NFV group data. Rather, some test results (PRA, binocular accommodative facility) suggest low NFV, whereas others (smooth and vergence facility with base-in) show that NFV is within expected values. In this case, the direct measures of NFV indicate normal values, whereas the indirect measures suggest a problem. When no obvious trend exists, the flowchart directs the optometrist to look toward the ACC group data.

If we do so, it becomes apparent that in Case 2.2, all the data that assess the patient's ability to stimulate accommodation (PRA, MEM retinoscopy, monocular and binocular accommodative facility with –2.00) are low and an obvious trend exists in this group. A diagnosis of accommodative insufficiency can be established. The low PRA and binocular accommodative facility, in this case, simply reflect the patient's inability to stimulate accommodation.

Case 2.3

History

An 18-year-old woman presented with complaints of inability to read comfortably for more than 10 minutes. After 10 minutes her eyes burn, the print becomes blurry, and, if she continues, she experiences double vision.

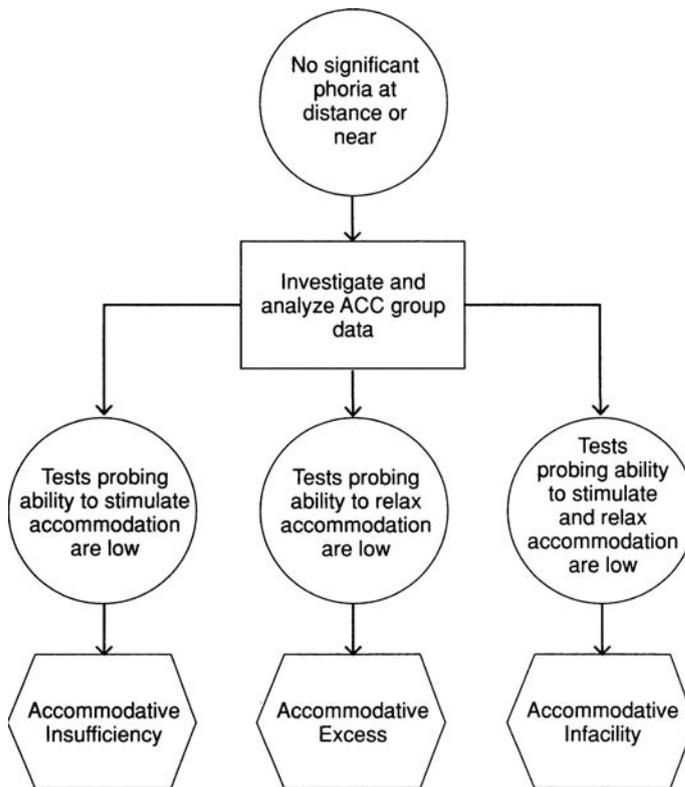
Examination Results

VA (distance, uncorrected):	OD: 20/20 OS: 20/20
VA (near, uncorrected):	OD: 20/20 OS: 20/20
Near point of convergence	
Accommodative target:	2.5 to 5 cm (1 to 2 in.)
Penlight:	2.5 to 5 cm
Cover test (distance):	Orthophoria
Cover test (near):	6 esophoria
Subjective:	OD: plano OS: plano
Distance lateral phoria:	Orthophoria
Base-in vergence (distance):	X/6/4
Base-out vergence (distance):	12/18/10
Near lateral phoria:	6 esophoria
–1.00 gradient:	13 esophoria
Base-in vergence (near):	4/6/–2
Base-out vergence (near):	18/28/16
Vergence facility (near):	0 cpm, diplopia with base-in
NRA:	+2.50
PRA:	–0.50
Accommodative amplitude (push-up):	OD: 13 D OS: 13 D
Monocular accommodative facility:	OD: 12 cpm OS: 12 cpm
Binocular accommodative facility:	0 cpm, diplopia with –2.00
MEM retinoscopy:	+1.50 OU

Pupils were normal, all external and internal health tests were negative, the deviation was comitant, and color vision testing revealed normal function.

Case Analysis

Case 2.3 also presents with orthophoria at distance and 6 esophoria at near; again, the most likely initial hypothesis is convergence excess. Analysis of the NFV group data, in this case, establishes low NFV on both direct measures and indirect measures. In Case 2.3, therefore, a diagnosis of convergence excess can be reached.



■ **Figure 2.5** Flowchart: accommodative system group data.

NO SIGNIFICANT PHORIA IS PRESENT

In the integrative analysis approach, the distance phoria and AC/A ratio are the entry points into the system. The absence of a significant phoria, however, also directs the analysis of data (Case 2.4). This is illustrated in Figure 2.7. The flowchart suggests several possible etiologies: an accommodative disorder, ocular motor dysfunction, fusional vergence dysfunction, fixation disparity, latent hyperopia, cyclovertical phoria, or aniseikonia. The most likely explanation is the presence of an accommodative anomaly. If the ACC appears normal based on an analysis of ACC group data, the hypotheses of ocular motor dysfunction or fusional vergence dysfunction should be pursued. If this investigation is also negative, fixation disparity testing is appropriate. Finally, conditions such as latent hyperopia, cyclovertical phoria, and aniseikonia should be considered.

In other cases, the key to developing the initial hypothesis is the case history. This is particularly true in ocular motor dysfunction. A characteristic history is illustrated in Case 2.5.

There are situations in which all avenues of investigation produce negative results. In such cases, it is important to reevaluate whether the patient's symptoms are legitimately related to the use of the eyes. The patient should be questioned again. The optometrist should consider the following issues:

- Is the patient malingering?
- Were the patient's responses on optometric testing accurate and reliable?
- Could there be a nonfunctional basis to the patient's symptoms?
- Would the findings be different if I examined the patient at another time of the day?

Through additional history questions, repetition of selected tests, and reevaluation at another time, these important issues can generally be answered, leading to a diagnosis.

Case 2.4

History

A 15-year-old tenth grader presented with a history of asthenopia associated with short periods of reading.

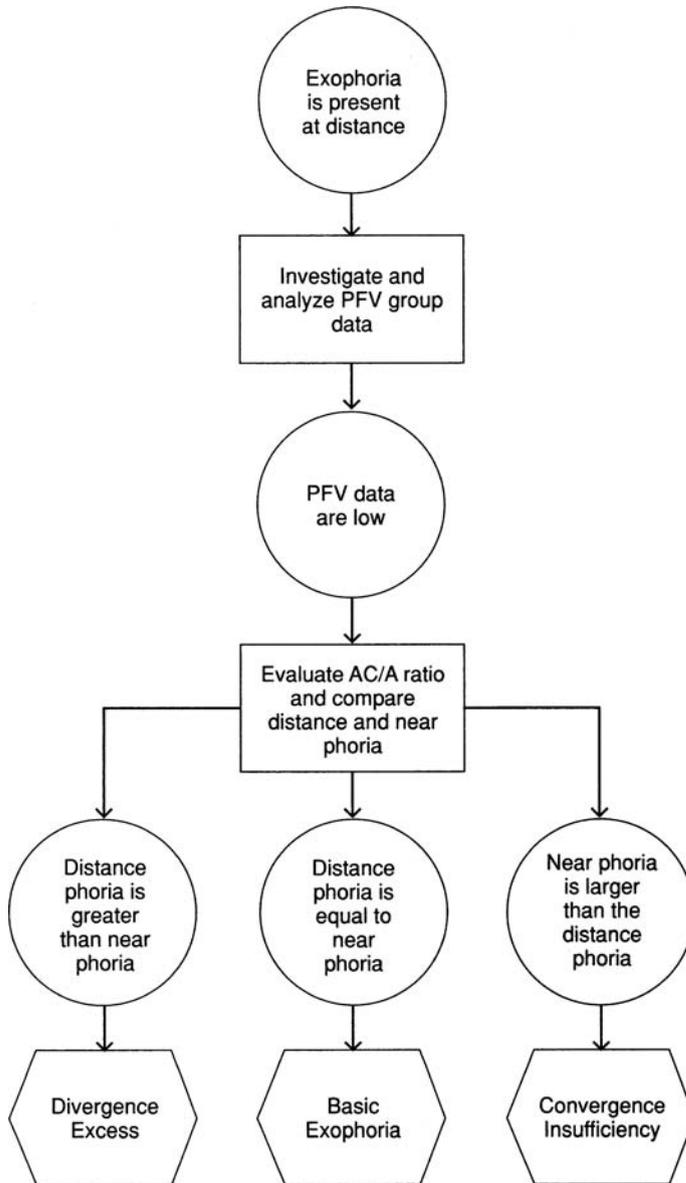
Examination Results

VA (distance, uncorrected):	OD: 20/20 OS: 20/20
VA (near, uncorrected):	OD: 20/20 OS: 20/20
Near point of convergence	
Accommodative target:	2.5 to 5 cm (1 to 2 in.)
Penlight:	5 to 7.5 cm (2 to 3 in.)
Cover test (distance):	Orthophoria
Cover test (near):	2 esophoria
Subjective:	OD: plano OS: plano
Distance lateral phoria:	Orthophoria
Base-in vergence (distance):	X/5/2
Base-out vergence (distance):	6/10/6
Near lateral phoria:	2 base-in
–1.00 gradient:	2 base-out
Base-in vergence (near):	6/10/4
Base-out vergence (near):	4/8/6
Vergence facility (near):	4 cpm, reduced base-in and base-out
NRA:	+1.50
PRA:	–1.25
Accommodative amplitude (push-up):	OD: 13 D OS: 13 D
Monocular accommodative facility	OD: 12 cpm OS: 12 cpm
Binocular accommodative facility:	2 cpm, difficulty with both ± 2.00
MEM retinoscopy:	+0.25 OU

Pupils were normal, all external and internal health tests were negative, the deviation was comitant, and color vision testing revealed normal function.

Case Analysis

In this case, no significant phoria is present. In addition, analysis of ACC group data reveals normal findings in both the ability to stimulate and to relax accommodation. In this situation, the most likely hypothesis is fusional vergence dysfunction as illustrated in Figure 2.7. To determine whether such a condition exists, the optometrist must analyze both the PFV and NFV group data, looking for reduced vergence findings both base-in and base-out. In fusional vergence dysfunction, both direct and indirect measures of PFV and NFV will be below expected. If these findings appear normal, fixation disparity testing and analysis should be performed. In this case, the data support a diagnosis of fusional vergence dysfunction.



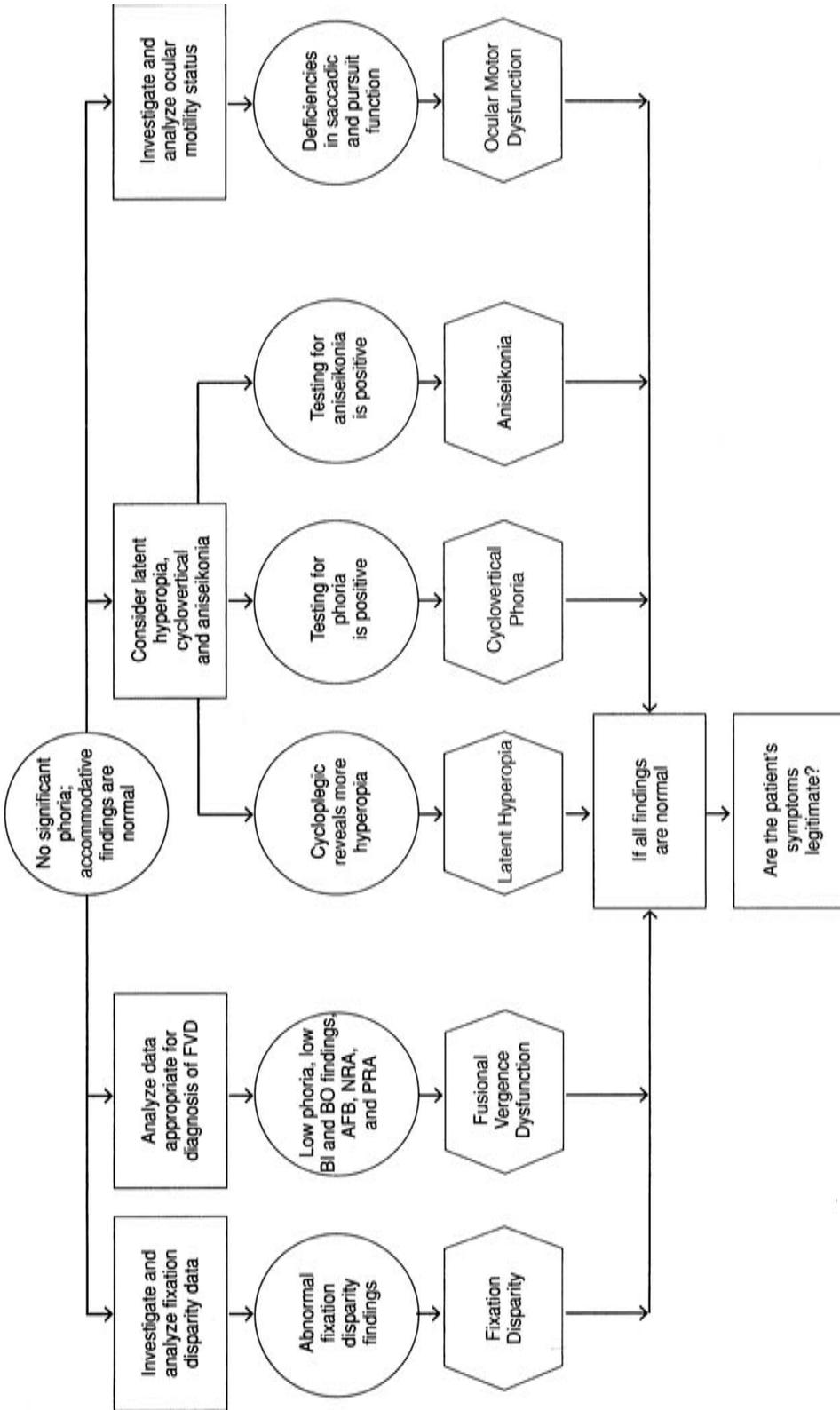
■ **Figure 2.6** Flowchart: positive fusional vergence group data.

Summary

The integrative analysis approach is a system of analysis that attempts to make use of the most positive aspects of other case analysis approaches, while avoiding the problems associated with these other approaches. It requires three distinct steps:

1. Comparison of individual tests to a table of expected findings
2. Grouping the findings that deviate from expected findings
3. Classification of the condition

In later chapters, each of the classifications in Table 2.4 is described in detail, including information about etiology, incidence, characteristics, differential diagnosis, and treatment.



■ **Figure 2.7** The flowchart suggests several possible etiologies if a significant phoria is not present: an accommodative disorder, ocular motor dysfunction, fusional vergence dysfunction, fixation disparity, latent hyperopia, cyclovertical phoria, or aniseikonia.

Case 2.5

History

Jimmy was referred for a vision evaluation by his reading tutor. She was concerned because she had observed frequent loss of place, skipping of lines, inability to sustain at the reading task, and poor comprehension. She wanted to rule out a vision problem as a possible cause of these behaviors. Jimmy had not had a previous full vision examination, although he had passed all of the previous school screenings. He did not report any symptoms of eyestrain, blur, or diplopia. Academically he was experiencing difficulty, primarily in the area of reading. The reading problems had been present to some degree since the first grade, although the problems appeared worse this year. Although his sight vocabulary and phonics skills were average to above average, he consistently scored poorly on comprehension tests. In addition, his reading speed was significantly slower than expected. Because of these difficulties, his parents had initiated work with the reading tutor. After several weeks of working with Jimmy, his tutor suggested the vision evaluation because of the observations described above. A recent medical evaluation revealed normal health, and he is not taking any medication.

In this case, the history of frequent loss of place, skipping of lines, and poor comprehension strongly suggests that there may be a cyclovertical heterophoria or an ocular motor problem. The best approach, in such a case, would be to analyze the data from the VFV and ocular motor group.

Study Questions

1. Name all tests that indirectly assess PFV and NFV.
2. Name all tests that directly or indirectly assess accommodation.
3. Explain why the NRA is an indirect method of assessing PFV.
4. Explain why the binocular accommodative facility (BAF) with minus lenses is an indirect method of assessing NFV.
5. Explain how the MEM can be an indirect method of assessing PFV. What would the MEM finding be if a patient had a problem with PFV?
6. If a patient is symptomatic and has normal VA, refraction, and eye health and no significant phoria, what condition would you investigate?
7. A patient presents with a receded NPC, ortho at distance, and 10 exophoria at near. Predict what you would find with step vergence, vergence facility, NRA, PRA, MEM, BAF, and monocular accommodative facility (MAF).
8. A patient presents with a normal NPC, ortho at distance, and 10 esophoria at near. Predict what you would find with step vergence, vergence facility, NRA, PRA, MEM, BAF, and MAF.
9. A patient presents with ortho at distance and 6 esophoria at near and has an AC/A ratio of 8:1. Which of the following findings is inconsistent with this presentation? An NRA of +2.50, a PRA of -2.50, base-out X/35/25, and base-in X/8/2.
10. A patient completes 15 cpm with BAF, but can only get to -1.50 on the PRA. Are these data inconsistent? Why?

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General Treatment Modalities, Guidelines, and Prognosis

This chapter provides an overview of general management strategies for accommodative, ocular motor, and nonstrabismic binocular anomalies. Chapters 9 through 13 provide specific details on each type of accommodative, ocular motor, and binocular vision disorder.

The treatment model we present is based on the information in Chapters 1 and 2 regarding diagnosis, analysis, and classification. To use the information in this chapter as a general guide in treating a specific binocular vision case, it is first necessary to determine, from the clinical evaluation, whether there is an exophoria, orthophoria, or esophoria at distance (low, normal, or high distance tonic vergence) and whether it is associated with a low, normal, or high AC/A ratio. In addition, it is important to determine whether the grouped data suggest a problem in a particular area. In regard to accommodative anomalies, it is important to ascertain whether the difficulty is in stimulation of accommodation, relaxation of accommodation, or both. Once this information is known, you will be able to apply the general treatment model presented in this chapter.

A primary objective of the model we present is to emphasize the significance of considering all treatment options for every accommodative, ocular motor, and binocular vision anomaly encountered. There are a limited number of management options for any patient with these disorders. When managing such patients, it is best to acquire the habit of always considering each option and then either using or rejecting that management for a particular patient. This approach will ensure that no management option has been ignored and should lead to more frequent and rapid success. For instance, several of the treatment options discussed below (i.e., occlusion, vision therapy for amblyopia and anomalous correspondence, and surgery) are rarely necessary when managing accommodative and nonstrabismic binocular vision problems. In heterophoria cases associated with anisometropia, however, occlusion and amblyopia treatment will often be necessary. In very rare instances, when dealing with exceptionally large-magnitude heterophorias, surgery may be necessary. Thus, it is prudent to always consider all treatment options for all cases.

We also stress the order in which different treatment procedures should be considered for efficient and successful management of any specific type of accommodative, ocular motor, or binocular anomaly case. Sequencing decisions are based on the characteristics of the condition being considered. Specific sequencing for each classification described in Chapter 2 is covered in detail in Chapters 9 through 13.

Determination of “Successful Treatment”

For accommodative and nonstrabismic disorders, the chief concern of the patient is overcoming symptoms or some visual performance deficiency, such as limited ability to maintain clear vision while reading. The goal of the practitioner is to improve certain visual functions in some measurable way. The criteria that practitioners use to define functional correction of these cases therefore involve some combination of decrease in symptoms and improvement in measured visual functions. After treatment, the patient should feel that his or her original symptoms have been eliminated or significantly improved. In addition, accommodative and binocular test findings should fall within the parameters consistent with the expected findings discussed in Chapter 1. Investigators have developed symptom and quality of life questionnaires that have been used for research purposes and can now be used in optometric practice, allowing clinicians to reliably measure symptoms before and after treatment.

SYMPTOM AND QUALITY OF LIFE QUESTIONNAIRES

Convergence Insufficiency Symptom Survey

The convergence insufficiency treatment trial (CITT) investigator group conducted a series of studies to develop a symptom questionnaire for use as the primary outcome measure in a series of CITT studies. This questionnaire, the Convergence Insufficiency (CI) Symptom Survey (CISS), is the first standardized instrument that has been shown to be valid and reliable for measuring the type and frequency of symptoms before and after treatment for patients with CI (1–5). It can be used in clinical practice to compare symptoms before and after optometric intervention for patients with CI and other binocular vision and accommodative disorders.

The CISS allows a two-factor analysis of symptoms: first, whether the symptom is present, and second, how frequently the symptom occurs. The questionnaire consists of 15 items (Fig. 3.1). The patient chooses one of five possible answers (never, infrequently, sometimes, fairly often, always). Each answer is scored from 0 to 4, with 4 representing the highest frequency of symptom occurrence (i.e., always). The 15 items are summed to obtain the CISS score, with the lowest possible score being 0 (totally asymptomatic) and the highest possible score being 60 (most symptomatic). For children aged 9 to 17 years, a symptom score of 16 or higher on the CISS has been found to differentiate children with symptomatic CI from those with normal binocular vision. For adults (18 and older), a symptom score of 21 or higher has been found to be significant. Research using this survey has demonstrated that a score below 16 for children and below 21 for adults or a change of 10 or more points is clinically significant.

Name _____

DATE (mm-dd-yy)

		Never	Infrequently (Not very often)	Sometimes	Fairly often	Always
1.	Do your eyes feel tired when reading or doing close work?					
2.	Do your eyes feel uncomfortable when reading or doing close work?					
3.	Do you have headaches when reading or doing close work?					
4.	Do you feel sleepy when reading or doing close work?					
5.	Do you lose concentration when reading or doing close work?					
6.	Do you have trouble remembering what you have read?					
7.	Do you have double vision when reading or doing close work?					
8.	Do you see the words move, jump, swim or appear to float on the page when reading or doing close work?					
9.	Do you feel like you read slowly?					
10.	Do your eyes ever hurt when reading or doing close work?					
11.	Do your eyes ever feel sore when reading or doing close work?					
12.	Do you feel a "pulling" feeling around your eyes when reading or doing close work?					
13.	Do you notice the words blurring or coming in and out of focus when reading or doing close work?					
14.	Do you lose your place while reading or doing close work?					
15.	Do you have to reread the same line of words when reading?					

■ **Figure 3.1** Convergence Insufficiency Symptom Survey (CISS).

College of Optometrists in Vision Development Quality of Life Outcomes Assessment

The College of Optometrists in Vision Development Quality of Life Outcomes Assessment (COVD-QOL) is a clinical survey instrument that also can be used to evaluate changes in symptoms before and after treatment (Fig. 3.2). It was originally developed with 30 items (6,7), but a 19-item version has been developed to make the survey more efficient to use (8,9). Both the original and short forms of the COVD-QOL have been shown to be reasonably reliable assessment tools for children and adults (7–9). The short form of the assessment consists of 19 items. For each item, the patient selects from the following five possible response options: never, once in a long while, sometimes, a lot, or always. The options are scored from 0 for never to 4 for always. Thus, the highest score (most symptomatic) is 76, and the lowest score is 0. Previous research indicates that a score of 20 or greater suggests that the patient

College of Optometrists Quality of Life Outcomes Assessment COVD-QOL

PATIENT'S NAME: _____ DATE: _____

Check the column that best represents the occurrence of each symptom.

	NEVER	ONCE IN A LONG WHILE	SOMETIMES	A LOT	ALWAYS
1. Headaches with near work					
2. Words run together reading					
3. Burn, itch, watery eyes					
4. Skips/repeats lines reading					
5. Head tilt/close one eye when reading					
6. Difficulty copying from chalkboard					
7. Avoids near work/reading					
8. Omits small words when reading					
9. Writes up/down hill					
10. Misaligns digits/columns of numbers					
11. Reading comprehension down					
12. Holds reading too close					
13. Trouble keeping attention on reading					
14. Difficulty completing assignments on time					
15. Always says "can" before trying					
16. Clumsy, knocks things over					
17. Does not use his/her time well					
18. Loses belongings/things					
19. Forgetful/poor memory					

■ **Figure 3.2** College of Optometrists Quality of Life Outcomes Assessment (COVD-QOL).

has significant symptoms. Several authors have reported on the use of the COVD-QOL short form to evaluate symptoms before and after vision therapy (10–12) and found the assessment to be a valuable clinical tool.

We recommend that clinicians choose one of these two assessment tools to evaluate patient symptoms before and after treatment for accommodative, binocular vision, and eye movement problems.

General Treatment Sequences for Accommodative and Nonstrabismic Binocular Vision Anomalies

In this system for treating phorias, the size of the AC/A ratio (low, normal, or high) determines the specific treatment sequence. The direction of the distance phoria and the analysis of the grouped data determine certain particulars of treatment, such as whether base-out or base-in prism should be prescribed and the nature of the vision therapy recommended.

SEQUENTIAL MANAGEMENT APPROACH

1. Optical correction of ametropia
2. Added lens power
3. Prism
4. Occlusion
5. Vision therapy
 - (a) Amblyopia
 - (b) Suppression
 - (c) Anomalous correspondence
 - (d) Sensory motor function
6. Surgery.

Optical Correction of Ametropia

The first consideration for all patients with accommodative, ocular motor, and nonstrabismic binocular anomalies is optical correction of ametropia. Prescription of lenses to correct the refractive error is generally not thought of as management for accommodative and binocular problems because we so routinely prescribe lens corrections. However, such prescriptions are often so essential in the management of these conditions that it is wise to routinely think of correction of ametropia as the first consideration.

SIGNIFICANT DEGREES OF REFRACTIVE ERROR

As a general rule, it is advisable to first prescribe for any significant refractive error. Table 3.1, based on the Orinda study (13), lists criteria for significant refractive error. It is important to view these criteria only as guidelines. With any given patient, a variety of factors must be considered. Several underlying assumptions form the basis for the approach of first considering management of refractive error.

TABLE 3.1 GUIDELINES FOR SIGNIFICANT REFRACTIVE ERROR

Type of Refractive Condition	Significant Amount
Hyperopia	+1.50 D or greater
Myopia	–1.00 D or greater
Astigmatism	–1.00 D or greater
Anisometropia	1.00 D difference in either the sphere or cylinder

The presence of an uncorrected refractive error may:

- Result in either underaccommodation or overaccommodation, leading to disorders of accommodative function
- Result in a high phoria and an unusual demand of either negative or positive fusional vergence (PFV)
- Create an imbalance between the two eyes, leading to sensory fusion disturbances
- Create decreased fusional ability as a result of blurred retinal images.

The strategy of first prescribing for significant refractive error is, therefore, based on the assumption that there may be a cause-and-effect relationship between refractive error and accommodative and binocular vision anomalies. Dwyer and Wick (14) reported improvement of binocular function that occurred 1 or more months after prescription of an initial spectacle correction for 143 nonstrabismic patients who had a refractive error and either a vergence anomaly, an accommodative anomaly, or both. Most corrections were low to moderate in power, essentially following the guidelines in Table 3.1. Recovery of normal vergence and accommodative function varied according to refractive error type, direction of astigmatic axes, age, and vergence anomaly. These results support the strategy of first prescribing for significant refractive error.

There are some differences in refractive errors between patients with esodeviations and exodeviations. Esodeviations tend to be associated with greater amounts of hyperopia, whereas exodeviations tend to be associated with myopia. By prescribing for the refractive condition, we are attempting to minimize a possible underlying etiologic factor.

When deciding on a prescription for ametropia, it is also important to consider and understand that the correction influences the vergence posture of the eyes through the AC/A ratio. As a result, we generally recommend prescribing maximum plus for esodeviations and minimum plus for exodeviations. Optical correction may also have a negative effect on binocular vision. An example is an exophoric patient with uncorrected hyperopia of 2.00 diopters (D). With correction of the ametropia, he or she may experience asthenopia and diplopia. Another common example is that of an esophoric patient with 4.00 D of uncorrected hyperopia. With correction, this patient may become exotropic. Management of these patients is more complex and requires the use of additional steps described next.

If a significant refractive error is present, the patient is generally asked to wear the prescription for 4 to 6 weeks, at which point another evaluation is performed to reassess the status of accommodative and binocular function. In some instances, the previously detected disorders will have resolved and no additional treatment will be necessary. If accommodative, ocular motor, or binocular disorders still persist after wearing the prescription, additional treatment alternatives must be considered.

A typical example would be a patient who presents with a history of eyestrain associated with visually demanding tasks. The evaluation reveals +2.00 D of uncorrected hyperopia in both eyes, along with an accommodative insufficiency. Appropriate management would be a prescription for the hyperopia and a reevaluation in 4 to 6 weeks to reassess the status of accommodation. If the patient continues to feel uncomfortable and the accommodative problem is still present, additional treatment would be prescribed. Occasionally, however, management of a significant refractive error will lead to resolution of the secondary accommodative or binocular anomaly.

CYCLOPLEGIC REFRACTION

Static retinoscopy and a dry subjective refraction are sufficient to determine the refractive error in most cases. When esophoria is present or latent hyperopia is suspected, a cycloplegic refraction may be helpful. For children younger than 3 years, 1 gtt of 0.5% cyclopentolate hydrochloride repeated in 5 minutes is the recommended concentration and dosage. For children aged 3 years and older, the dosage is the same as for younger children, while the recommended concentration is 1.0%. After waiting approximately 40 minutes, retinoscopy is performed. To determine the final refractive correction, the following issues must be considered:

- **Tonus of the ciliary muscle:** If full cycloplegia is achieved, then the normal tonus of the ciliary muscle will also be relaxed. Thus, more plus will be found than can be prescribed. If we know that complete cycloplegia has been achieved, about 0.75 D should be subtracted from the net finding.
- **Type of refractive error:** In myopes, it is usually not necessary to subtract the 0.75 D of plus, whereas in hyperopia it is necessary.
- **Binocular status:** If esophoria or intermittent esotropia is present, maximum plus should be considered.

SMALL DEGREES OF REFRACTIVE ERROR

Far less agreement exists about the management of small amounts of refractive error. This would be defined as a refractive error less than the values listed in Table 3.1. An example would be a patient presenting with a history of eyestrain associated with reading, with the refraction as follows:

OD: +0.25 – 0.50 × 90

OS: +0.25 – 0.50 × 90

The question the clinician must answer is whether such a refractive error could be the cause of the patient's discomfort. This decision should be based on additional testing and analysis of accommodative and binocular data.

Two scenarios generally occur. First, the patient may also present with significant accommodative and binocular problems. Assume this patient also had a near point of convergence of 6 in./12 in., orthophoria at distance, and 12 exophoria at near, and that the PFV group of data strongly suggested decreased PFV. In the presence of this additional data, the low refractive error becomes significant only if the clear retinal images achieved through refractive correction will improve fusion and assist in management.

Another possible situation would be a patient with the low refractive error listed above and all accommodative and binocular testing within the expected values. In this case, the clinician may be left with no other possible visual basis for the patient's discomfort and must make a decision about prescribing for the low refractive error. It is wise, in such a situation, to ask additional questions about the nature of the symptoms to clarify whether there truly appears to be a relationship between the use of the eyes and the discomfort. If based on this additional questioning there seems to be a relationship, prescription for the low refractive error may sometimes be helpful—especially if small astigmatism corrections against the rule or oblique axis are present. In our experience, however, there is often an accommodative, ocular motor, or binocular vision disorder present in addition to the low refractive error. It is very unusual to find a low refractive error in isolation that accounts for the significant symptoms.

Other authors have addressed the issue of prescribing for low refractive errors (15–18). Blume (18) reported that symptoms induced by low refractive error include slightly blurred vision, headaches, and ocular discomfort associated with activities such as reading and other near work. There have been case reports (15–18) demonstrating the positive effect of prescribing for low refractive errors. A critical analysis of these case reports, however, indicates that an assessment of accommodation and binocular vision either was not performed or was not reported in the majority of cases. This lack of data about accommodative and binocular function makes it difficult to interpret these reports.

MANAGING ANISOMETROPIA AND ANISEIKONIA IN NONSTRABISMIC BINOCULAR VISION DISORDERS

Anisometropia is defined as a condition in which the refractive status of one eye differs from that of the other. A difference of 1 D or more in the sphere or cylinder is considered clinically significant. The critical underlying concept that should be considered when deciding about correction of anisometropia is that clear retinal images facilitate fusion. The general rule, therefore, is to fully correct the anisometropia. If the patient is amblyopic, the underlying cause of the amblyopia is the uncorrected refractive error. Unless the refractive error is corrected, there is little reason to expect maximal improvement in acuity, accommodative response, and binocular skills. A possible exception is a patient who might become more symptomatic if corrected. An example is an elderly patient who requires a large increase in cylindrical correction in one eye. For such patients, consider reducing the prescription. In all other cases, fully correct the anisometropia.

There are two additional concerns that one must take into consideration when prescribing for anisometropia. The first issue is the possibility of inducing aniseikonia. *Aniseikonia* is defined as a condition in which the ocular images are unequal in size or shape or both. The different image sizes induced by the prescription can cause symptoms and affect sensory fusion. This topic is covered in depth in Chapter 19. Although aniseikonia may occur occasionally in clinical practice, it affects only a small percentage of patients with anisometropia. The decision that must be made is whether to prescribe spectacle lenses or contact lenses. Knapp law provides guidelines and suggests prescribing eyeglasses for aniseikonia secondary to axial length differences and contact lenses for anisometropia due to refractive differences. Since most anisometropia is due to axial length differences, eyeglasses would be the method of choice according to Knapp law.

Clinically, however, we find that this is not the case. The reason for this is the second problem associated with the correction of anisometropia. An anisometric prescription will always cause prismatic differences for the patient as he or she looks from one position of gaze to another. The greater the degree of anisometropia, the larger the prismatic differences. This creates a motor fusion problem, placing a demand on horizontal and vertical fusional vergence (VFV). Whereas aniseikonia only occurs in a small percentage of patients, this motor problem affects all anisometropes after correction with eyeglasses. As a result, contact lenses should be considered the treatment method of choice in cases of anisometropia.

Added Lens Power (Minus and Plus)

The other primary use of lenses in the treatment of accommodative and binocular disorders is to alter the demand on either the accommodative or binocular systems. The important clinical data used to determine whether such an approach will be effective are listed in Tables 3.2 and 3.3. The idea that optometric case analysis should be based on groups of data (Chapter 2) applies to decision making about the possible effectiveness of additional lenses as well. Table 3.2 lists the eight findings that should be considered when trying to determine whether added plus lenses should be prescribed, and Table 3.3 lists the findings that should be considered when trying to determine whether added minus lenses should be prescribed.

The primary test finding that helps determine the effectiveness of added lenses is the magnitude of the AC/A ratio. If the AC/A ratio is greater than expected, the use of added lenses will generally be an effective approach. A high AC/A ratio suggests that a very large change in binocular alignment can be achieved with a small addition of lenses. A low AC/A ratio indicates that the use of lenses will have little desirable effect. When the AC/A ratio is in the normal range of 3:1 to 7:1, the other data in Tables 3.2 and 3.3 must be taken into consideration before determining the potential value of prescribing added lenses. It is important to understand the effect that plus or minus lenses will have on all examination findings. Tables 3.4 and 3.5 provide

TABLE 3.2 CONSIDERATIONS FOR PRESCRIBING ADDED PLUS LENSES

Test	Consider the Use of Added Plus	Added Plus Not Indicated
AC/A ratio	High	Low
Refractive error	Hyperopia	Myopia
Near phoria	Esophoria	Exophoria
NRA/PRA	Low PRA	Low NRA
Base-out at near	Normal to high	Low
Monocular estimation method retinoscopy	High	Low
Amplitude of accommodation	Low	Normal
Accommodative facility testing	Fails minus	Fails plus

NRA, negative relative accommodation; PRA, positive relative accommodation.

TABLE 3.3 CONSIDERATIONS FOR PRESCRIBING ADDED MINUS LENSES

Test	Consider the Use of Added Minus	Added Minus Not Indicated
AC/A ratio	High	Low
CA/C ratio	High	Low
Phoria	Exophoria	Esophoria
Base-in at near	Normal to high	Low
Amplitude of accommodation	Normal	Low
Accommodative facility	Fails plus	Fails minus
Testing		
Age	Younger than 6 years	9 years or older

TABLE 3.4 EXAMPLE OF THE EFFECT OF PLUS LENSES ON TEST RESULTS

Given AC/A ratio = 8:1, if a +1.00 add is prescribed, it would be expected to lead to the following changes:	
Test	Expected Change with +1.00
Near phoria	About 8 Δ less esophoria
Negative relative accommodation	Decrease of about 1.00 D
Positive relative accommodation	Increase of about 1.00 D
Base-out (near)	Decrease of about 8 Δ
Base-in (near)	Increase of about 8 Δ
Monocular estimation method retinoscopy	Decrease in +
Amplitude of accommodation	Increase of about 1.00 D
Accommodative facility testing	Better performance with -2.00

TABLE 3.5 EXAMPLE OF THE EFFECT OF MINUS LENSES ON TEST RESULTS

Given AC/A ratio = 8/1, if a -1.00 add is prescribed, it would be expected to lead to the following changes:	
Test	Expected Change with -1.00
Near phoria	About 8 Δ less exophoria
Negative relative accommodation	Increase of about 1.00 D
Positive relative accommodation	Decrease of about 1.00 D
Base-out (near)	Increase of about 8 Δ
Base-in (near)	Decrease of about 8 Δ
Monocular estimation method retinoscopy	Increase in +
Amplitude of accommodation	Decrease of about 1.00 D
Accommodative facility testing	Better performance with +2.00

examples of these effects. If one keeps in mind the effect that a prescription of additional plus or minus will have on all of the different diagnostic tests, it becomes easier to make decisions about appropriate treatment for any particular patient.

The most common example of the effectiveness of the use of lenses in the absence of refractive error is convergence excess. In such a case, the patient will generally have no significant phoria at distance and a moderate to high degree of esophoria at near. The findings in the negative fusional vergence (NFV) group will be low, suggesting decreased NFV, and the AC/A ratio is typically high. These findings suggest that a significant change could be achieved in the amount of esophoria at near simply by prescribing plus lenses for near. If the patient has 12 Δ of esophoria at near, for example, with base-in at near of 4/6/2 and an AC/A ratio of 10:1, an add of +1.00 would be expected to have a considerable beneficial effect. In this case, the add would result in a near point phoria of about 2 esophoria, and the base-in range measured through this add would be expected to increase as well. If, however, the clinical data are somewhat different and the patient has moderate esophoria at near with a low AC/A ratio, then the use of added lenses may not be sufficient to lead to a resolution of the patient's complaints.

The classic example of the ineffectiveness of the use of lenses in the absence of refractive error is CI. In such a case, the distance phoria is insignificant, while a moderate to large exophoria may be present at near along with a low AC/A ratio, a receded near point of convergence, and low PFV group data. The use of lenses—in this case, to achieve a desirable change in the near phoria—would not be expected to be helpful. For instance, one might consider the use of additional minus at near. If the patient has 12 exophoria at near with an AC/A ratio of 2:1 and base-out at near of 2/4/-2, the use of -1.00 or even -2.00 at near would have little effect on the exophoria or base-out relationship. Thus, because of the low AC/A, the use of lenses in this situation would not be an effective strategy.

TABLE 3.6 CONDITIONS RESPONDING FAVORABLY TO ADDED LENSES

Added Plus Lenses	Added Minus Lenses
Convergence excess	High exophoria
Basic esophoria	Divergence excess
Accommodative insufficiency	
Ill-sustained accommodation	

The use of added plus or minus lenses is particularly helpful for the conditions listed in Table 3.6. Prescription guidelines for prescribing added plus lenses are based on the information in Table 3.2. This table lists all of the findings from the optometric evaluation that contribute to the final decision about prescribing added plus. The concept, stressed in Chapter 2, that groups of data should be analyzed rather than a single isolated finding applies to the issue of added plus lenses. Although all of the data points do not have to agree, there will generally be a trend suggesting the amount of plus that should be prescribed. Cases 10.1, 10.2, and 10.3 in Chapter 10 provide specific examples about determining the amount of added plus to prescribe.

When prescribing added plus lenses, a bifocal prescription is almost always preferable. With children younger than about 10 years, we recommend setting the segment height at about the lower pupil margin to ensure that the child reads through the segment. A flat-top 28-mm segment works well with young children. In older children and adults, the segment height can be set at the lower lid margin.

Added minus lenses should also be considered in certain cases. Added minus lenses are used for high exophores or exotropes. In such cases, the lenses are used to reduce the angle of deviation using accommodative convergence to supplement fusional vergence. These lenses can be prescribed as training lenses to be used only during active vision therapy or for general wear. When used as a training device, large amounts of minus can be prescribed. For a constant exotrope, it would not be unusual to prescribe 6 or 7 D of additional minus. To determine the prescription, the clinician would find the least amount of minus that allows the patient to fuse. The power of the lenses would gradually be reduced as therapy progresses and the patient's ability to fuse improves.

Added minus lenses can also be prescribed for full-time wear. This would be done to reduce the percentage of time that an intermittent exotropia occurs or to provide more comfortable fusion in high exophoria. When prescribed for this purpose, smaller amounts of minus (i.e., 1.00 to 2.00 D) are used. In such cases, the AC/A ratio is not the critical factor in determining the amount of minus to prescribe. The objective of the added minus is to create a stimulus to convergence. Once this is accomplished, the patient is able to maintain fusion using fusional vergence.

Prism

The use of prism to treat binocular anomalies should be a consideration in all cases. Generally, there are five situations in which the use of prism may be helpful:

- Horizontal relieving prism
- Vertical relieving prism
- Prism as an aid to begin vision therapy
- Prism used when vision therapy is inappropriate or impractical
- Prism used at the end of vision therapy.

HORIZONTAL RELIEVING PRISM

If a large lateral heterophoria or an intermittent strabismus is present, it may be helpful to prescribe prism to decrease the demand on fusional vergence. Prism is most often effective in cases of high tonic vergence or esophoria at distance along with a normal to low AC/A ratio. Prism can be prescribed as a temporary measure until a vision therapy program has been completed or as an attempt to eliminate the patient's symptoms without vision therapy.

Although the use of prism to treat heterophoria has been recommended by numerous authors (19–28), there is surprisingly limited research support for its effectiveness. A study by Worrell et al. (26) investigated the effectiveness of prism prescribed based on Sheard's criterion. They found that prism was only preferred by patients in cases of distance esophoria. For exophoria and esophoria at near, the authors did not find any preference for prism glasses. Payne et al. (27) did a similar study prescribing prism based on fixation disparity testing. They prescribed two pairs of glasses that were identical in every way except that one had prism and one had none. After wearing each pair of glasses for 2 weeks, the subjects were asked to choose the ones they preferred. All 10 subjects chose the glasses with the prism. In a study that investigated the effectiveness of base-in prism glasses for the treatment of CI, Stavis et al. (28) found that patients reported subjective improvement in asthenopic symptoms and headaches after 2 weeks of wear. However, the authors did not have a placebo control group. Thus, there is no way to know whether the reported improvement in symptoms was due to a placebo effect.

Until recently all of the published research on the effectiveness of base-in prism for the treatment of CI has had fundamental design flaws, such as small sample size, lack of a control group, no randomization, and nonmasked outcome examinations. Scheiman et al. (29) completed a randomized, double-masked, placebo-controlled clinical trial of base-in prism reading glasses (based on Sheard's criterion) for the treatment of symptomatic CI in children. They found that the base-in prism glasses were no more effective than placebo reading glasses. Neither treatment group demonstrated clinically significant changes in the near point of convergence or positive fusional convergence at near, although nearly half of the children assigned to each of the two treatment groups reported a statistically significant decrease in symptoms (albeit neither group achieved a decrease in symptoms to a level considered clinically asymptomatic). The authors attribute these improvements in symptoms to the placebo effect.

Teitelbaum, Pang, and Krall (30) studied 29 symptomatic CI subjects aged 45 to 68 years. All subjects took the CISS V-15 and scored ≥ 16 points. Each subject was assigned two pairs of progressive addition glasses made by the same manufacturer in a randomized sequence, one with base-in prism and one with the same lens prescription but no prism (placebo). Subjects wore each pair of glasses for 3 weeks and completed the CISS at the end of the third week. Symptom level measured with CISS was the major outcome measure.

The authors found that the mean (standard deviation) CISS score was 30.21 (9.30) at baseline and decreased to 13.38 (9.44) with the base-in prism glasses, versus 23.62 (10.76) with the placebo glasses. There were significant differences between the baseline survey score and the score with the base-in prism glasses ($p < 0.0001$) and between the score with placebo glasses and the score with base-in prism glasses ($p = 0.001$). They concluded that progressive addition glasses with base-in prism were effective in alleviating symptoms of presbyopes with symptomatic CI.

In another randomized clinical trial with a placebo control, O'Leary and Evans (31) studied the effectiveness of prism (based on the associated phoria) for improving reading rate and symptoms in patients with heterophoria. In 58 exophores, there was no significant improvement if the prism prescribed was between 0.5Δ and 2.0Δ . In the group of exophores who required 2.5Δ to 3.0Δ , there was a statistically significant increase in reading rate (3.2% faster) for those wearing prism glasses. However, it is doubtful whether this change is clinically relevant. For example, the mean reading rate with prism was 150.4 words per minute, and in the placebo glasses group it was 145.7 words per minute. There were no significant changes in symptoms in any of the groups. For patients with esophoria, there was no improvement in reading rate or symptoms with prism compared to the placebo lenses.

Thus, although prism is part of the sequential treatment sequence, it is important to understand that the evidence supporting its use is not strong at this time. Additional research is required to understand the most appropriate applications of prism for binocular vision disorders.

The approaches used most often to prescribe prism are fixation disparity analysis, Sheard's criterion, and Percival's criterion.

Fixation Disparity Analysis

Fixation disparity is generally the most desirable method of prescribing horizontal relieving prism. The amount of prism can be based on one of three criteria: the associated phoria, the center of symmetry, or the flat portion of the curve. The criterion used depends on the nature of the forced vergence fixation disparity curve. If the fixation disparity curve is steep, the associated phoria works well. The center of symmetry is most useful when there is a moderate flat portion on the curve. When the curve has a large flat portion, enough prism is prescribed to move the flat portion of the curve to the y-axis. These topics are discussed in detail in Chapter 15.

Sheard's Criterion

Sheard (32) suggested that for a patient to be comfortable, the compensating fusional vergence should be twice the phoria. For exophoria, the compensating vergence is base-out or PFV, and for esophoria, the compensating vergence is base-in or NFV. Sheard suggests that prism can be prescribed if this criterion is not met. Although this criterion can be applied to any type of heterophoria, research suggests that Sheard's criterion works best with exophores (33). Clinically, the following formula can be used to determine the amount of prism to prescribe to meet Sheard's criterion:

$$\text{Prism needed (P)} = \frac{2}{3} \text{ phoria} - \frac{1}{3} \text{ compensating fusional vergence.}$$

For example, if a patient has 10 Δ of exophoria and the base-out to blur finding is 10 Δ , the amount of prism needed would be

$$\begin{aligned} P &= \frac{2}{3}(10) - \frac{1}{3}(10) \\ P &= 6.67 - 3.33 \\ P &= 3.34 \Delta \end{aligned}$$

In this case, to meet Sheard's criterion, one would have to prescribe about 3 Δ base-in. Base-in is used in this example because the deviation is exophoria.

Percival's Criterion

Like Sheard, Percival developed a guideline for the prescription of prism (34). There has also been little clinical research to support this criterion, although studies suggest that Percival's criterion is most effective with esophoria (31).

According to Percival, the patient should be operating in the middle third of the vergence range. This is independent of the phoria and can be described by the following formula:

$$P = \frac{1}{3}G - \frac{2}{3}L$$

where

P = prism to be prescribed

G = greater of the two lateral limits (base-in or base-out)

L = lesser of the two lateral limits (base-in or base-out)

If P is a positive number, it represents the amount of prism to be prescribed. If it is zero or a negative number, prism is not required.

Example 3.1

Phoria: 12 exophoria

Base-out vergence: 6/9/6

Base-in vergence: 18/24/21

$$\begin{aligned} P &= \frac{1}{3}G - \frac{2}{3}L \\ P &= \frac{1}{3}(18) - \frac{2}{3}(6) \\ P &= 6 - 4 \\ P &= 2 \end{aligned}$$

2 Δ base-in would be required in this case because the deviation is exophoria.

Example 3.2

Phoria: 4 exophoria

Base-out vergence: 21/24/18

Base-in vergence: 18/24/21

$$P = \frac{1}{3}G - \frac{2}{3}L$$

$$P = \frac{1}{3}(21) - \frac{2}{3}(18)$$

$$P = 7 - 12$$

$$P = -5$$

Prism is not necessary in this case because the result is a negative number.

Of the 10 nonstrabismic binocular vision anomalies discussed in Chapter 2, prism tends to be most effective for divergence insufficiency, basic esophoria, and vertical heterophoria and, to a substantially lesser extent, CI and basic exophoria. An important characteristic shared by the four horizontal binocular vision conditions is a low to normal AC/A ratio. Prism tends to be less effective than lenses in conditions with high AC/A ratios, such as divergence excess and convergence excess.

Given the high success rates of vision therapy for most nonstrabismic binocular vision problems (35–38) and the limited research on the efficacy of prism therapy, relieving prisms should be used primarily when there is high tonic vergence (esophoria) at distance or in other situations in which vision therapy is unlikely to achieve good results. Table 3.7 lists the cases in which prism would be most likely to be effective. We generally reserve the use of relieving prism for those cases that do not respond successfully to vision therapy or for those people who do not accept the recommendation of vision therapy because of financial or other concerns.

VERTICAL RELIEVING PRISM

London and Wick (39) have reported that correction of a vertical fixation disparity may have a beneficial effect on the horizontal deviation. Based on this finding, they suggest that when vertical and horizontal deviations are both present, the clinician should first consider prism correction of the vertical component. Wick (20) does not feel that vertical prism needs to be prescribed in all cases, however. He suggests that vertical prism should be prescribed when it results in improved visual performance, such as decreased suppression and increased fusion ranges. When management of a horizontal heterophoria is not proceeding well, it is worthwhile to recheck for a small vertical component that may have not been detected initially. As little as 0.5 Δ of vertical prism may be beneficial for fusion.

The most accepted criterion for determining the amount of vertical prism to prescribe is the associated phoria measurement (20,21). This is determined using a fixation disparity device, as described in Chapter 15.

TABLE 3.7 RECOMMENDED TREATMENT APPROACH BY DIAGNOSIS

Diagnosis	Primary Recommended Treatment Approach	Secondary Treatment Recommendations
Ocular motor dysfunction	Vision therapy	Added +
Accommodative insufficiency	Added +	Vision therapy
Ill-sustained accommodation	Added +	Vision therapy
Accommodative excess	Vision therapy	
Accommodative infacility	Vision therapy	
Low AC/A conditions		
Convergence insufficiency	Vision therapy	Prism
Divergence insufficiency	Prism	Vision therapy
High AC/A conditions		
Convergence excess	Added lenses	Vision therapy
Divergence excess	Vision therapy	Added lenses
Normal AC/A conditions		
Basic esophoria	Vision therapy and added lenses	Prism
Basic exophoria	Vision therapy	Added lenses
		Prism
Fusional vergence dysfunction	Vision therapy	
Vertical disorders		
Vertical phoria	Prism	Vision therapy

In vertical heterophoria, prescribe the prism that reduces the fixation disparity to zero. Another method that has been described is Sheard's criterion. Enough vertical prism is prescribed to establish a situation in which the vertical vergence is twice the vertical phoria. There is sufficient evidence in the literature, however, demonstrating that the use of the associated phoria is preferable to Sheard's criterion (32).

PRISM USED AS AN AID TO BEGIN VISION THERAPY

With very high degrees of heterophoria or when an intermittent strabismus is present, prism is sometimes helpful in the initial phase of vision therapy. Prism is used in such a case to decrease the overall demand on the binocular system. For example, base-out prism would be used to reduce the demand on NFV. This enables the clinician to more easily find a starting point for vision therapy. When prescribed for this purpose, prism glasses are generally used primarily during office or home therapy.

PRISM USED WHEN VISION THERAPY IS INAPPROPRIATE OR IMPRACTICAL

Although vision therapy may be indicated for a particular patient, there are factors that may limit the prognosis for vision therapy. Such factors include cooperation, motivation, the age of the patient, scheduling issues, and finances. If a child is too young to be able to communicate or cooperate, if an elderly patient is unable or unwilling to perform vision therapy, or if there is simply a lack of time or money for vision therapy, then prism becomes an option that should be considered.

PRISM USED AT THE CONCLUSION OF VISION THERAPY

If the patient's symptoms persist after the conclusion of a vision therapy program, prism should be considered. In such cases, prism is prescribed as a relieving prism to reduce the demand of the fusional vergence system. Criteria for prescribing are identical to those described for horizontal and vertical relieving prism.

Occlusion

Occlusion is a commonly used treatment option in the management of strabismus and its associated conditions: amblyopia, eccentric fixation, suppression, and anomalous correspondence. There are also instances in which occlusion is necessary in the treatment of patients with heterophoria, and it must be included as part of the sequential considerations in the management of nonstrabismic binocular anomalies.

Occlusion is used when heterophoria is associated with anisometropic amblyopia. The length of occlusion is important in anisometropic amblyopia. Our current recommendations are based on randomized studies that demonstrated the effectiveness of 2 hours of patching per day along with 1 hour per day of near visual activities for moderate amblyopia (20/30 to 20/80), and 6 hours per day with 1 hour per day of near visual activities for severe amblyopia (20/100 or worse) (40–44). These should be the initial recommendations. If there is no improvement at follow-up, the amount of patching can be increased. This topic is discussed in depth in Chapter 17.

Another type of occlusion that should be considered in heterophoria is the use of regional occlusion of a lens. This is particularly useful when a strabismus is present at one distance or one direction of gaze, while a heterophoria exists at other distances or positions of gaze. An example is a patient with a 25 Δ constant right exotropia at distance and a 5 Δ exophoria at near. An appropriate treatment option would be occlusion of the upper portion of the lens of the right eye, with the lower portion of the lens clear. This setup permits reinforcement of binocularity at near, while preventing suppression and other adaptations at distance.

Vision Therapy

A significant percentage of patients with binocular vision and accommodative problems cannot be successfully treated solely with lenses or prism or both. Of the 15 different accommodative, ocular motor, and binocular disorders discussed in Chapter 2, for instance, only accommodative insufficiency, divergence

insufficiency, convergence excess, basic esophoria, and vertical heterophoria are readily treated with lenses or prism alone. Prism is generally most effective for divergence insufficiency (Table 3.7). Analysis of the data for the other conditions indicates that the use of optics and prism would not be expected to be totally effective. The goal of a lens or prism prescription for many of these cases, however, is to maximally increase binocularity optically. This can then be reinforced with vision therapy management.

Vision therapy is the treatment of choice for CI, divergence excess, fusional vergence dysfunction, basic exophoria, accommodative excess, accommodative infacility, and ocular motor dysfunction. It can also be used successfully, either alone or in conjunction with lenses or prism, to treat accommodative insufficiency, convergence excess, basic esophoria, and vertical heterophoria.

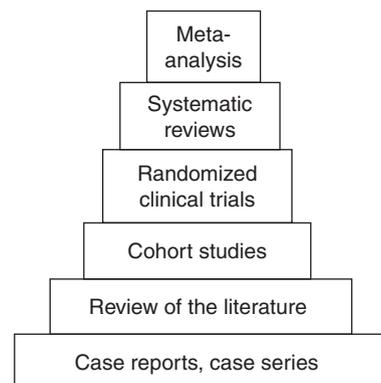
RESEARCH EVIDENCE FOR THE EFFECTIVENESS OF VISION THERAPY FOR BINOCULAR VISION, ACCOMMODATIVE, AND EYE MOVEMENT DISORDERS

Evidence-based practice has become an important concept in all health care professions, including optometry (45,46). Evidence-based practice has been defined as the “integration of best research evidence with clinical expertise and patient values” (47). The best evidence is usually found in clinically relevant research that has been conducted using sound methodology.

Clinical research studies can be categorized based on the methodology used and are sometimes referred to as “levels of evidence” and portrayed as an evidence pyramid (Fig. 3.3). A clinician may not always find the best level of evidence to answer a clinical question. The base of the pyramid is the weakest level of evidence and usually the most common type of study available. As you move up the pyramid, the amount of available literature decreases, but its relevance to the clinical setting increases. In the absence of the best evidence, the clinician needs to consider moving down the pyramid to other types of studies.

- A *meta-analysis* examines a number of valid studies on a topic and combines the results using accepted statistical methodology as if they were from one large study.
- *Systematic reviews* focus on a clinical topic and answer a specific question. An extensive literature search is conducted to identify all studies with sound methodology. The studies are reviewed, assessed, and the results summarized according to the predetermined criteria of the review question.
- *Randomized clinical trials* are carefully planned projects that study the effect of a therapy on real patients. They include methodologies that reduce the potential for bias (randomization and masking) and that allow for comparison between intervention groups and control groups (no intervention).
- *Cohort studies* take a large population and follow patients who have a specific condition or receive a particular treatment over time and compare them with another group that has not been affected by the condition or treatment being studied. Cohort studies are observational and not as reliable as randomized controlled studies, since the two groups may differ in ways other than the variable under study.
- *Case reports* and *case series* consist of collections of reports on the treatment of individual patients or a report on a single patient. Because they are reports of cases and use no control groups with which to compare outcomes, they have no statistical validity.

■ **Figure 3.3** Evidence pyramid.



Studies have been performed to evaluate the methodologic quality of journal articles in different medical specialties. Based on standardized criteria for the assessment of methodologic rigor and clinical relevance of research articles, McKibbin et al. (48) demonstrated that only about 7% of articles published in the top 20 clinical journals in general internal medicine passed the prespecified criteria as having high methodologic quality and clinical relevance. A similar study in physical therapy found only 11% meeting the predefined standard (49). Lai et al. (50) completed a similarly designed study for the ophthalmology literature and found that only 14.7% of the articles involving treatment passed the methodologic assessment.

Although a similar study has not been performed for the optometric literature on vision therapy, the results are likely to be comparable to other professions. Much of the literature on vision therapy effectiveness is based on case reports, case series, cohort studies, and literature reviews (51–84). There have been some small placebo-controlled studies in the past (85–88), a number of randomized clinical trials have been published (89–92), and one systematic review is available (93). The weight of the evidence supports the use of vision therapy for most nonstrabismic, accommodative, and eye movement problems. Like all health care professions, optometry must strive to plan and implement more studies with rigorous design to investigate the effectiveness of commonly used treatments. In the meantime it is incumbent upon clinicians to practice evidence-based optometry.

Vision therapy has been shown to be effective for accomplishing the following in accommodative, ocular motor, and nonstrabismic binocular vision disorders (51–92,94,95):

- Reducing symptoms
- Increasing amplitude of accommodation
- Increasing accommodative facility
- Eliminating accommodative spasm
- Improving the near point of convergence
- Increasing fusional vergence amplitudes
- Increasing fusional vergence facility
- Eliminating suppression
- Improving stereopsis
- Improving the accuracy of saccades and pursuits
- Improving stability of fixation

DETERMINING THE NECESSITY OF VISION THERAPY

The decision to recommend vision therapy should be based on a careful analysis of the following factors:

- Age and intelligence of the patient
- Analysis of data
- Determination of prognosis for the particular patient and the specific problem
- Financial issues
- Motivation
- Relationship between the chief visual complaint and optometric findings
- Time course of therapy.

Age and Intelligence of the Patient

Vision therapy involves a learning process and therefore requires a certain level of maturity and intelligence. Although vision therapy is a viable option with infants and very young children (96), this treatment tends to be used only in the treatment of strabismic and amblyopic patients at this age. It is, of necessity, rather passive and involves very short therapy sessions with as little communication as possible. Vision therapy for heterophoria patients, as described in this text, involves the need for good attention and the ability to concentrate for significant periods of time. Communication of feelings and an ability to follow instructions and work independently are all important characteristics of the successful vision therapy patient.

Age is one factor affecting the success of a vision therapy program. As a general rule, vision therapy programs are seldom initiated before the age of 6 years for heterophoria patients. Children who are immature or have limited intelligence may not be good candidates even at older ages. On the other hand, children as young as 3 or 4 years are often ready for vision therapy when the problem is strabismus or amblyopia. In such cases, the therapy tends to be more passive than that necessary for heterophoria. Thus, the decision

to recommend vision therapy requires some experience and clinical judgment about the child's age, level of maturity, intelligence, and clinical diagnosis.

Although a lower age or maturity limit exists, there is no real upper limit. As long as a patient is motivated and can communicate and interact with the therapist, vision therapy can be successful. Studies have demonstrated that the success rates of vision therapy to treat binocular vision disorders in presbyopes are excellent (57,71,72). Many clinicians who are involved with vision therapy actually prefer the adult patient because of the ease with which therapy generally progresses due to the motivation and understanding of the adult patient. Of course, some elderly patients may not be able or willing to participate in a vision therapy program. Lack of desire, inability to attend and concentrate, and financial and transportation problems may also interfere with vision therapy.

Analysis of Data

Depending on analysis of the data in the various groups described in Chapter 2, one or more treatment alternatives may be present. Table 3.7 lists the treatment options available by diagnosis. It is important to understand that whereas vision therapy is a viable option in all 15 common accommodative and binocular vision disorders, added lenses and prism are only options for some diagnoses. Prism is very useful for divergence insufficiency and vertical deviations, helpful with basic esophoria, and of occasional value in cases of CI and basic exophoria. The use of added lenses is a viable option for 4 of the 12 diagnoses: accommodative insufficiency, convergence excess, basic esophoria, and divergence excess. To make these decisions, it is helpful to refer to Tables 3.2 and 3.3, which describe the criteria for determining whether added lenses would be useful. Table 3.6 lists the binocular and accommodative conditions that respond well to added plus and minus lenses.

Determination of Prognosis for the Particular Patient and the Specific Problem

For each patient, a determination must be made about the prognosis for successful treatment using vision therapy. The prognosis for all accommodative and nonstrabismic binocular vision problems is good to excellent, with the exception of divergence insufficiency (51–81,85–92,94,95).

Studies investigating the clinical effectiveness of vision therapy for accommodative dysfunction have shown success in approximately 9 of 10 cases (52–54,59,60,63,66,69,70,86,92). Daum (70), in a retrospective study of 96 patients, found partial or total relief of both objective and subjective difficulties in 96% of the subjects studied. Hoffman et al. (52) reported a vision therapy success rate of 87.5% in a sample of 80 patients with accommodative problems.

Other studies, using objective assessment techniques, have investigated the actual physiologic changes that occur as a result of vision therapy. Both Liu et al. (59) and Bobier and Sivak (63) found that the dynamics of the accommodative response were significantly changed after therapy. Liu et al. found that the latency of the accommodative response was decreased and the velocity of the response was increased. Bobier and Sivak were able to show a decrease in symptoms along with objective changes in accommodative dynamics.

In the only results from a randomized clinical trial of accommodative therapy, Scheiman et al. compared the effectiveness of office-based vergence/accommodative therapy (OBVAT), home-based computer vergence/accommodative therapy (HBCVAT), and home-based pencil push-ups (HBPP) to office-based placebo therapy for improving accommodative amplitude and facility in children with both symptomatic CI and accommodative dysfunction who were enrolled in the CITT (92). Although the primary objective of the study was the comparison of the effectiveness of active treatments for symptomatic CI, accommodative function was measured at baseline and at all subsequent study visits, and each active therapy program included accommodative therapy. This allowed the authors to evaluate the kinetics of change in accommodative function and the effectiveness of the three therapy modalities in improving accommodative amplitude and facility. All three of the vision therapy/orthoptic treatments were significantly more effective than placebo therapy for improving accommodative amplitude in patients with decreased accommodative amplitude while only OBVAT was significantly more effective than placebo therapy in improving accommodative facility. In addition, at the end of the 12-week treatment period, significantly fewer patients had a decreased amplitude of accommodation or subnormal accommodative facility in the active therapy groups compared with those receiving the placebo. Finally, the gains demonstrated at 12 weeks were still present in the majority (87%) of patients after 1 year.

Numerous investigators have shown that vision therapy for nonstrabismic binocular vision disorders leads to improved fusional vergence ranges. Most studies have investigated the use of vision therapy to treat CI and other nonstrabismic problems associated with exophoria.

In three placebo-controlled, randomized clinical trials completed by the CITT investigator group, office-based vision therapy was found to be an effective treatment for symptomatic CI, improving both symptoms and signs (89–91). These studies also found that HBPP were not effective for the treatment of CI. Other studies (85,87,88) have used both experimental and control groups to demonstrate the efficacy of binocular vision therapy. Daum (88) investigated the effectiveness of vision therapy for improving PFV using a double-blind placebo-controlled experimental design. He found statistically significant changes in vergence in the experimental group, with no changes in the control group. Vaegan (85) also found large and stable improvement in vergence ranges in his experimental group, with no changes in the control group. Cooper et al. (87) studied patients with CI using a matched subjects control group crossover design to reduce placebo effects. They found a significant reduction in asthenopia and a significant increase in fusional vergence after the treatment. During the control phase, significant changes in symptoms and vergence were not found.

Several studies have also investigated the use of vision therapy as a treatment option for convergence excess (76–78). Gallaway and Scheiman (78) reviewed the records of 83 patients with convergence excess who had completed vision therapy and found that 84% reported total elimination of symptoms. They found significant increases in NFV. Other investigators have also reported reduction in symptoms (77) and increases in NFV (76).

Clinical studies have also been performed to investigate the efficacy of treating ocular motor dysfunction (58,97–102). Wold et al. (58) reported on a sample of 100 patients who had completed a vision therapy program for a variety of problems, including accommodation, binocular vision, pursuits, and saccades. Saccadic and pursuit function was determined using subjective clinical performance scales like those described in Chapter 1. Vision therapy consisted of three 1-hour visits per week. The number of visits ranged from 22 to 53. It is important to understand that these patients did not only have eye movement disorders—almost all patients had accommodative and binocular vision problems as well. Pretesting and posttesting revealed statistically significant changes in both saccadic and pursuit function.

In a clinical study, Rounds et al. (97) used a Visagraph Eye-Movement Recording System to assess reading eye movements before and after vision therapy. This investigation is one of the few to specifically study eye movement therapy alone. The investigators used 19 adults with reading problems and assigned 12 to the experimental group and 9 to a control group. The experimental group received 4 weeks (12 hours) of exclusively ocular motor skill enhancement vision therapy. The therapy consisted of three 20-minute office sessions and six 20-minute home sessions per week for 4 weeks. The control group received no intervention of any kind. Although no statistically significant changes were found, the experimental group trended toward improving reading eye movement efficiency (less regressions and number of fixations and increased span of recognition) compared to the control group.

Young et al. (98) also used an objective eye movement recording instrument (Eye Trac) to assess reading eye movements before and after therapy. They studied 13 schoolchildren who had failed a vision screening. The children each had three 5-minute vision therapy sessions per day for 6 weeks. They received a total of 6 hours of eye movement vision therapy. Posttesting revealed a significant decrease in number of fixations, an increase in reading speed, and a decrease in fixation duration.

Fujimoto et al. (99) investigated the potential for using vision therapy procedures prerecorded on videocassettes for eye movement vision therapy. They had three groups of subjects. The first group of nine subjects received standard eye movement vision therapy. The second group received videocassette-based eye movement therapy, and the third group received no treatment. The results showed that both standard eye movement vision therapy and videocassette-based therapy were equally effective in improving saccadic ability.

Punnett and Steinhauer (103) studied two different approaches for eye movement therapy. They compared the effectiveness of vision therapy for eye movements using feedback versus no feedback. They used the Eye Trac to monitor eye movements and studied nine subjects. They found that the use of verbal feedback and reinforcement during vision therapy led to better treatment results.

Fayos and Ciuffreda (100) used oculomotor-based auditory biofeedback to improve saccadic ability and reading efficiency in 15 subjects ranging in age from 18 to 38 years; 11 of the 12 subjects exhibited varying degrees of improvement in overall reading efficiency. There was a decrease in the number of saccades and regressions when reading, a decreased number of saccades per return sweep, and an increased reading rate. The authors concluded that oculomotor-based auditory biofeedback can be an effective training tool, especially in low-normal readers.

Although the success rates are excellent for all cases of binocular, ocular motility, and accommodative disorders, not all patients with these problems may be good candidates for vision therapy. Issues such as motivation, age, ability to communicate, and financial factors must all be taken into consideration before a recommendation is made for vision therapy.

Financial Issues

Finances must be a consideration as well. An intelligent, cooperative, and highly motivated patient may not be enough to guarantee a successful vision therapy program. If the cost of vision therapy creates a burden for a family, compliance and consistency will be problems leading to less than adequate results. Financial issues must be discussed with the patient when various options are being considered. It is therefore important for the optometrist to have an understanding of insurance reimbursement for vision therapy. These issues are addressed in detail in Chapter 25.

Motivation

The importance of motivation should not be underestimated. Any optometrist who practices vision therapy has experienced dramatic and surprising success in cases with apparently poor prognoses. Conversely, simple cases of CI with excellent prognoses based on findings alone can be failures in the absence of motivation. It is not always easy to judge the patient's level of motivation. When dealing with an adult, it is generally easier to decide whether sufficient motivation exists. A discussion of the patient's symptoms and the effects of the vision problem on performance can usually lead to a good understanding of the patient's desires. With a child, this decision is not always as simple. Children may be reluctant, unable, or unwilling to discuss their feelings and symptoms. In such cases, the clinician must then look to the parents for their understanding and motivation and hope that the parents can motivate the child.

We recommend that the issue of motivation be considered a key factor in determining the advisability of vision therapy. With a highly motivated patient, vision therapy should at least be attempted, even if the prognosis is poor.

Relationship between the Chief Visual Complaint and Optometric Findings

Although vision therapy has been shown to be an extremely effective treatment approach for nonstrabismic binocular disorders, accommodative dysfunction, and ocular motor dysfunction, there are situations in which it may not be appropriate. Most clinicians look very carefully at the relationship between the patient's symptoms and clinical findings. When an apparent relationship can be established, treatment is generally recommended. An example of a match between symptoms and findings is a patient presenting with complaints of intermittent diplopia and eyestrain related to reading, and findings that include a receded near point of convergence, high exophoria at near, and reduced PFV. A patient could, however, be asymptomatic with the identical findings just described. It becomes a matter of clinical judgment to determine whether vision therapy should be prescribed in such a case. An astute clinician will inquire about whether the patient simply avoids reading or other near work. Often, once the clinician begins probing, it becomes apparent that the patient is not reading or has avoided certain situations because the activity may lead to discomfort. A classic example is the child with learning difficulties. Children with such problems do not read for long periods of time, and therefore do not complain of the symptoms typically associated with accommodative and binocular vision problems. Thus, the absence of symptoms does not mean that the child is not being adversely affected by the vision anomaly. Treatment of the underlying vision disorder should still be considered in such cases.

In addition to avoidance, another explanation for a lack of symptoms—in the presence of a significant binocular disorder—is suppression. For example, a patient with a severe CI, in which an intermittent exotropia is present at near, may suppress. Suppression eliminates the need to overcome the deviation and thereby decreases or eliminates asthenopia. In either a case of avoidance or suppression, a recommendation of vision therapy may still be appropriate.

In most situations, if an accommodative, ocular motor, or binocular problem is present and the patient is asymptomatic, an explanation such as those just described will be found. It is therefore important to recognize that it is necessary to try to establish a relationship between findings and symptoms, as well as to investigate issues such as avoidance and suppression.

Time Course of Therapy

Once a diagnosis of an accommodative, ocular motor, or binocular problem is reached, the next objective is to select appropriate treatment alternatives. The treatment alternatives are those that have been described in this chapter: optical correction of ametropia, added lenses, prism, occlusion, vision therapy, and surgery. When there is more than one viable treatment option, one factor that should be considered is the time frame for eliminating symptoms. Intuitively it makes some sense to select a treatment approach that will eliminate a patient's problem as quickly and as easily as possible. Thus, if analysis of the data suggests that lenses or prism may be effective, these treatment options should be considered initially. If lenses and prism appear to be reasonable treatment approaches, the beneficial effects of these options occur almost immediately. Weeks of vision therapy may be required before a patient begins to experience beneficial changes.

There are clinical situations in which the time course of the various treatment options is very important to a patient. Examples include busy professionals and college- and graduate-level students who may need positive results as quickly as possible.

In most instances, however, the time course, although important, is not the most significant issue. The long-term effect of the treatment option may be the most critical factor. Although the use of lenses and prism may be desirable because of the short time course, it is important to remember that the long-term effect of lenses and prism is to permit the patient to perform comfortably in spite of the presence of an underlying dysfunction. The patient must continue to wear the prescription to maintain this comfort. The long-term effect of vision therapy, however, is to develop normal motor and sensory fusion and accommodative skills to overcome the binocular, ocular motor, or accommodative dysfunction. This is an important distinction that should be considered and discussed when various treatment options are considered.

Surgery

Although the need to recommend surgery for the treatment of nonstrabismic binocular vision anomalies is highly unusual, surgery must at least be considered as a management option. The one situation in which a clinician may need to consider surgery is in the presence of a very large phoria. If the magnitude of the horizontal deviation exceeds 30Δ , the prognosis for success with vision therapy alone decreases (104). Occasionally, after all of the nonsurgical options listed above have been attempted, a patient may complain of discomfort or blurred vision late in the day. In such instances, the original phoria may have been very large and, in spite of improvement in accommodative and convergence findings, the patient remains uncomfortable. Gallaway et al. (105) and Frantz (106) reported cases of an intermittent exotropia treated with vision therapy. The patient in the former study required surgical intervention because blur and asthenopia continued after vision therapy, whereas the patient in the latter required surgery because of poor compliance with lenses, prism, and vision therapy.

It is important to emphasize the unlikelihood of a recommendation of surgery for a nonstrabismic binocular vision anomaly. Hermann (107) reported on a large sample of CI patients in his ophthalmologic practice. He reviewed records from 10 years of practice and found that of approximately 1,200 patients treated with orthoptics over that time span, 14 (or 1%) still complained of discomfort and required surgery.

The efficacy of surgical intervention for nonstrabismic binocular anomalies is equivocal. Very few cases have been reported in the literature. The few reports available have studied the effectiveness of surgery for CI. Reports by von Noorden (108), Hermann (107), and Yang and Hwang (109) indicate that surgery is an effective approach for relieving the symptoms of these patients. Yang and Hwang (109) found that unilateral medial rectus resection based on near measurements with a lateral rectus recession based on distance measurements was more effective than a bilateral lateral rectus recession based on near measurements. This study, however, was retrospective, unmasked, and there was no randomization. In addition, the authors based "success" criterion on the size of the angle of deviation after surgery and they did not assess symptoms. Thus, the study results have limited value. Haldi (110) found that five of the six patients in her sample demonstrated a recurrence of the exodeviation and no relief of symptoms.

In summary, a recommendation of surgery for a nonstrabismic binocular vision anomaly is highly unlikely. In addition, there is no definitive study suggesting that surgery in such cases is an effective treatment strategy. However, the optometrist may find, in some cases of very high magnitude phorias or intermittent strabismus, that vision therapy alone may leave the patient with residual symptoms. In such cases, a recommendation of surgery should be considered.

Summary

Treatment of accommodative, ocular motor, and nonstrabismic binocular vision disorders is one of the more rewarding aspects of optometric care. The success rates using the treatment approach we have presented are outstanding. Patients often come to our offices after previous unsuccessful attempts to find help for their discomfort. If we are able to eliminate their symptoms and resolve the underlying vision disorders, patient satisfaction is extremely high.

A primary objective of the model we presented in this chapter is to emphasize the significance of considering all treatment options for every accommodative, ocular motor, and binocular vision disorder encountered. This approach will ensure that no management option will be ignored and should lead to more frequent and rapid success.

Study Questions

1. Explain why correction of refractive error is an important first step when treating binocular and accommodative problems.
2. Describe a situation in which correction of refractive error may have a negative effect on a coexisting binocular vision problem.
3. Name the tests that you would use to determine whether an add is appropriate for a given patient and present the expected findings for these tests that would suggest an add is appropriate.
4. Name the one key finding that generally helps determine whether plus will be an effective treatment approach.
5. Describe clinical situations in which prescription of prism may be appropriate.
6. Name those binocular vision conditions that respond best to prism. What is the common factor for these conditions that makes prism effective?
7. Describe three clinical procedures for determining the amount of prism to prescribe for binocular vision problems.
8. A patient has a near phoria of 12 exophoria. His PFV is 4/8/2 and his NFV is 12/20/14. How much prism would you prescribe based on Sheard's criterion?
9. A patient has a near phoria of 12 exophoria. His PFV is 4/8/2 and his NFV is 12/20/14. How much prism would you prescribe based on Percival's criterion?
10. What factors should be considered when deciding whether vision therapy is an appropriate treatment approach for any given patient?

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Primary Care of Binocular Vision, Accommodative, and Eye Movement Disorders

A primary care optometrist has been defined as “a practitioner with ongoing responsibility for the total visual, ocular, and related care of a population of patients. Primary care optometry emphasizes the development and maintenance of a high level of knowledge and clinical ability over the entire area of eye/vision care and associated areas of eye-related health care” (1). What is expected in true primary vision care is an understanding of the entire breadth of eye care, whereby the provider recognizes what needs to be done for the patient and either provides or refers for the appropriate care (2). Thus, the primary care optometrist should be able to examine, diagnose, and treat most patients most of the time, and every patient who visits the primary care optometrist should expect a satisfactory outcome, even if it involves an appropriate referral (2).

Applying this model to binocular vision, accommodative, and eye movement problems suggests that the primary care optometrist must be able to routinely examine and diagnose these problems, treating some of them, and making appropriate referrals when necessary for more detailed diagnosis and treatment. In our opinion, primary care optometry includes diagnosis of routine binocular vision, accommodative, and eye movement disorders. Treatment of these problems using lenses, prism, occlusion, and home-based vision therapy also falls within the realm of primary care. Complex binocular vision, accommodative, and eye movement disorders and office-based vision therapy, however, are typically advanced-care treatment procedures requiring additional clinical training, office space, ability to train therapists, and equipment.

With the first and second editions of this book, our goal was to develop a text that would be valuable to both the optometrist wishing to practice advanced care of binocular vision, accommodative, and eye movement disorders (including office-based vision therapy) and the primary optometrist practicing with a more limited emphasis on these conditions (no office-based vision therapy available). We understand that many optometrists may find the diagnostic routine suggested in Chapter 1 to be too extensive for routine use in primary care practices. Further, most optometrists in primary care practice do not offer office-based vision therapy as a treatment approach. These doctors generally rely on the use of lenses, prism, home-based vision therapy, and in some cases referral to an optometric colleague with advanced experience in the area of vision therapy. This chapter is designed to stand alone as a reference for the primary care management of binocular vision, accommodation, and eye movement disorders. Table 4.1 summarizes the diagnosis and treatment techniques that we recommend for primary care practice.

Diagnosis

Chapter 1 includes a comprehensive presentation of the case history and diagnostic testing required to manage binocular vision, accommodative, and eye movement disorders. Primary care optometrists may use Chapter 1 as a reference; however, this chapter presents a more streamlined evaluation. Using this approach will allow the primary care optometrist to expeditiously diagnose most of the problems most of the time, and to refer to a colleague for a more extensive evaluation and treatment when appropriate.

HISTORY AND SYMPTOMS

Use of a written symptom questionnaire, such as the Convergence Insufficiency Symptom Survey (CISS) or the Vision Quality Scale (VQS) can help establish the need for binocular vision and accommodative testing.

TABLE 4.1 PRIMARY CARE HETEROPHORIA EXAMINATION AND TREATMENT

	Low AC/A Ratio (<3Δ/D)			Normal AC/A Ratio (3 to 7Δ/D)			High AC/A Ratio (>7Δ/D)		
	Eso	Normal	Exo	Eso	Normal	Exo	Eso	Normal	Exo
Case history	High symptom scores on the CISS or VFS symptom questionnaires or complaints of eye strain, blurred vision, discomfort, double vision, loss of place, trouble sustaining, avoidance, and so forth, when symptoms are associated with visual tasks								
Tonic vergence	Determine phoria magnitude and direction at distance with cover test or prism dissociation								
AC/A ratio (calculated)	Determine whether AC/A ratio is high (more eso at near), normal (same distance and near), or low (more exo at near) Calculated AC/A = IPD(cm) + NFD(m) (H _n - H _d)								
Distance phoria	Eso	Ortho	Exo	Eso	Normal	Exo	Eso	Normal	Exo
Near phoria			More Exo			Exo			Ortho
Vergence assessment									
Base-out (distance)	y	y	X	y	y	X	y	y	X
Base-in (distance)	X	y	y	X	y	y	X	y	y
Supra and infra	Assess whether vertical phoria is seen on cover test OR whether symptoms exist (e.g., losing place when reading, getting on wrong line)								
Base-out (near)	z	X	X	y	y	X	y	y	z
Base-in (near)	z	y	y	X	y	y	X	X	z
NPC (amplitude)	y	X	X	X	X	X	X	X	y
Facility									
Near (12 BO/3 BI)	z	X	X	X	X	X	X	X	z
Associated phoria (lag)									
Horizontal	z	y	y	z	y	y	z	y	y
Vertical	X	X	X	X	X	X	X	X	X
Comitance	y	y	y	y	y	y	y	y	y
Accommodation									
Amplitude (push-up)	X	X	X	X	X	X	X	X	X
Facility (scaled)	X	X	X	X	X	X	X	X	X
Lag (MEM)	y	y	y	y	y	y	y	y	y
Sensory status									
Stereopsis	y	y	y	y	y	y	y	y	y
Suppression	y	y	y	y	y	y	y	y	y

(Continued)

TABLE 4.1 CONTINUED

Treatment	A	A	A	A	A	A	A	A	A	A
Best correction	A	A	A	A	A	A	A	A	A	A
Added plus at near							+1.25	+1.25	+1.25	+1.25
Prism										
Horizontal	BO									
Vertical										
Home-based vision therapy	b	A	A	b	A	A	b	b	b	Refer for office-based VT

+1.25 near addition if abnormal findings on accommodative testing

Prescribe BO prism equal to one-third the distance phoria in esophoric patients

Prescribe vertical prism equal to associated phoria if symptoms exist

CISS, Convergence Insufficiency Symptom Survey; VFS, Vision Function Scale; IPD, inter pupillary distance (in cm); NFD, near fixation distance (in meters); H_{ip}, near phoria; H_{sp}, distance phoria; (eso, +; exo, -); NPC, near point convergence; BO, base-out; BI, base-in; MEM, monocular estimation method; VT, vision therapy.
 Diagnosis: **X**, necessary diagnostic information; **y**, important at times; **z**, information that you may wish to gather.
 Treatment: **A** or **bold**, necessary treatment; **b**, may be useful treatment.

These questionnaires, illustrated in Figures 4.1 and 4.2, are standardized instruments that have been shown to be valid and reliable for measuring the type and frequency of symptoms for patients with convergence insufficiency and intermittent exotropia, respectively (3–7). Either can be used in clinical practice to efficiently determine whether a patient has symptoms related to binocular vision, accommodative, or eye movement disorders.

The CISS consists of 15 items. The patient chooses one of five possible answers (never, infrequently, sometimes, fairly often, always). Each answer is scored from 0 to 4, with 4 representing the highest frequency of symptom occurrence (i.e., always). The 15 items are summed to obtain the CISS score, with the lowest possible score being 0 (totally asymptomatic) and the highest possible score being 60 (most symptomatic). For children aged 9 to 17 years, a symptom score greater than 16 on the CISS has been found to suggest significant symptoms (5); for adults (18 and older), a symptom score greater than 21 on the CISS has been found to be significant (4).

A generic tool for quality of vision assessment known as the Vision Function Scale (VFS) was developed by McKeon et al. (7) to measure the underlying construct of vision function of patients with intermittent exotropia; its domains were symptoms, physical functioning, and role functioning. The VFS has been modified (three questions dropped pertaining to the subject’s sex, age, and feeling of correctness of his or her answers) and relabeled as the VQS. Numerous applications of the VQS support its content validity. For example, the VQS discriminates between patients with and without asthenopia who have

Name _____ DATE __/__/__

		Never	Infrequently (not very often)	Sometimes	Fairly often	Always
1.	Do your eyes feel tired when reading or doing close work?					
2.	Do your eyes feel uncomfortable when reading or doing close work?					
3.	Do you have headaches when reading or doing close work?					
4.	Do you feel sleepy when reading or doing close work?					
5.	Do you lose concentration when reading or doing close work?					
6.	Do you have trouble remembering what you have read?					
7.	Do you have double vision when reading or doing close work?					
8.	Do you see the words move, jump, swim or appear to float on the page when reading or doing close work?					
9.	Do you feel like you read slowly?					
10.	Do your eyes ever hurt when reading or doing close work?					
11.	Do your eyes ever feel sore when reading or doing close work?					
12.	Do you feel a “pulling” feeling around your eyes when reading or doing close work?					
13.	Do you notice the words blurring or coming in and out of focus when reading or doing close work?					
14.	Do you lose your place while reading or doing close work?					
15.	Do you have to reread the same line of words when reading?					
		___ 0	___ 1	___ 2	___ 3	___ 4

Total Score: _____

■ **Figure 4.1** Convergence Insufficiency Symptom Survey (CISS).

Name: _____ Date: _____

Directions: please circle the number for the response which best represents your answer. Please provide an answer for each of the 9 questions listed.

1. In general, would you say that you have problems with your eyes:
 - 1 ALL OF THE TIME
 - 2 MOST OF THE TIME
 - 3 A GOOD BIT OF THE TIME
 - 4 SOME OF THE TIME
 - 5 A LITTLE OF THE TIME
 - 6 NONE OF THE TIME

2. How would you rate the clearness of your vision (with glasses or contact lenses) when doing certain tasks (for example, watching television, movies, driving, reading, writing or sewing)?
 - 1 EXCELLENT
 - 2 VERY GOOD
 - 3 GOOD
 - 4 FAIR
 - 5 POOR

3. How often have you had episodes of blurred vision and/or double vision during the past 4 weeks?
 - 1 ALL OF THE TIME
 - 2 MOST OF THE TIME
 - 3 A GOOD BIT OF THE TIME
 - 4 SOME OF THE TIME
 - 5 A LITTLE OF THE TIME
 - 6 NONE OF THE TIME

4. To what extent do problems with your eyes limit your ability to do certain tasks or the amount of time that you need to do them (for example, because you become tired, lose concentration, or are not able to see well enough to complete the tasks)?
 - 1 EXTREMELY
 - 2 QUITE A BIT
 - 3 MODERATELY
 - 4 SLIGHTLY
 - 5 NOT AT ALL

5. How often do you lose your place, reread the same line, or skip lines when you are reading or copying (for example, when going back to the beginning of the next line, you find yourself on the line just read)?
 - 1 ALL OF THE TIME
 - 2 MOST OF THE TIME
 - 3 A GOOD BIT OF THE TIME
 - 4 SOME OF THE TIME
 - 5 A LITTLE OF THE TIME
 - 6 NONE OF THE TIME

6. To what extent does bright light and/or dim light affect your ability to do certain tasks?
 - 1 EXTREMELY
 - 2 QUITE A BIT
 - 3 MODERATELY
 - 4 SLIGHTLY
 - 5 NOT AT ALL

■ **FIGURE 4.2** Vision Quality Scale (VQS).

7. How often have your eyes hurt, watered, burned, itched, or become red or swollen in the past 4 weeks?
 - 1 ALL OF THE TIME
 - 2 MOST OF THE TIME
 - 3 A GOOD BIT OF THE TIME
 - 4 SOME OF THE TIME
 - 5 A LITTLE OF THE TIME
 - 6 NONE OF THE TIME

8. How often have you had headaches during the past 4 weeks?
 - 1 ALL OF THE TIME
 - 2 MOST OF THE TIME
 - 3 A GOOD BIT OF THE TIME
 - 4 SOME OF THE TIME
 - 5 A LITTLE OF THE TIME
 - 6 NONE OF THE TIME

9. To what extent are you embarrassed when others notice your eye turn in, out, move independently, or that you are unable to do certain tasks because of your eyes? (If this does not apply to you, circle 6.)
 - 1 EXTREMELY
 - 2 QUITE A BIT
 - 3 MODERATELY
 - 4 SLIGHTLY
 - 5 NOT AT ALL
 - 6 DOES NOT APPLY

■ **FIGURE 4.2** (Continued)

normal heterophoria, visual acuity, and ocular health. The patient chooses one of six possible answers (all of the time, most of the time, a good bit of the time, some of the time, a little of the time, none of the time). Each answer is scored from 0 to 6, with 6 representing the highest frequency of symptom occurrence (i.e., all of the time). The nine items are then converted to a percentage. A symptom score (percentage) of less than 71 on the VQS has been found to reliably suggest significant symptoms for patients older than 8 years (6).

After symptoms and signs typically associated with binocular vision, accommodative, and eye movement disorders are identified in the case history (or through a standardized questionnaire), evaluation of binocular vision involves several distinct steps. The testing protocol we suggest requires minimal equipment and setup time, with most of the equipment readily available in most primary care practices. Our suggested minimum database (Table 4.1) for a primary care examination (after determination of the refractive error) includes the cover test at distance and near, determination of the calculated accommodative convergence to accommodation (AC/A) ratio, the near point of convergence, vergence facility, and testing of accommodation (amplitude and binocular facility testing). The setup and administration of these procedures is described in detail in this chapter.

Diagnostic Evaluation

DETERMINATION OF REFRACTIVE ERROR

Accurate measures of alignment and accommodation are facilitated by performance of a full-plus refraction with a binocular balance. Such an examination is often aided by an initial objective determination of the refractive error, which can be accomplished with static retinoscopy, autorefractometry, or even starting with the

patient's previous refractive correction. To perform a modified full-plus binocular refraction, we recommend the following procedure:

1. Use a 20/30 line (or an acuity line two lines above threshold).
2. With the left eye occluded, add plus (0.25 diopters [D] at a time) to the objective findings until the right eye is barely able to read the 20/30 threshold line. If too much plus is used, the next step will be difficult, so you may want to back off slightly (add -0.25 D, at most).
3. Perform Jackson cross-cylinder (JCC) testing (adding plus in the step above allows the patient to make more accurate JCC responses).
4. Repeat for the left eye, with the right occluded.
5. Add prism (3Δ up before the right eye; 3Δ down before the left) and $+0.75$ D to each eye.
6. Perform a dissociated balance by adding plus to the clearer target until both are reported to be equally blurred.
7. Remove the dissociating prism and slowly add minus until the patient can just read 20/20. *Do not* arbitrarily add some amount of minus.
8. Place the vectographic slide in the projector with analyzers in the phoropter. Place "I" target with letters on each side in the patient's view and ask if both sides are equally clear. If not, add $+0.25$ D to the clearer side. This is a binocular balance but not a true binocular refraction (in which the JCC would be performed under these conditions as well).
9. Perform stereopsis testing.
10. Return to the standard slide and check visual acuity. If the patient cannot see 20/15, check whether -0.25 more OU improves the acuity. It is virtually never necessary to add more than -0.50 OU total. *Do not* arbitrarily add some amount of minus.

The maximum-plus refraction technique breaks down when acuity is very unequal (e.g., amblyopia). In these instances, where often no refractive technique works well, use retinoscopy to determine balance after attempting to achieve maximum plus on the "good" eye (make the retinoscopic reflexes appear equal for the two eyes).

Assessment of Nonstrabismic Binocular Vision Disorders

GENERAL CONSIDERATIONS

Primary care evaluation of binocular vision involves several distinct steps. The first phase of testing is measurement of the magnitude and direction of the phoria at distance and near, along with determining the calculated AC/A ratio. In a primary care practice, the most convenient procedure to accomplish phoria measurement is cover testing.

ASSESSMENT OF SIZE AND DIRECTION OF THE PHORIA

Cover Test (in the Absence of Strabismus)

1. **Purpose** The cover test is an objective method of evaluating the presence, direction, and the magnitude of the phoria.
2. **Important issues**
 - (a) **Controlling accommodation** The most important aspect of the cover test procedure or any other test of binocular alignment is control of accommodation; underaccommodation will result in an overestimation of the degree of exophoria or an underestimation of the esophoria. Overaccommodation will yield the opposite results. There are two techniques that can be used to maximize control of accommodation during the cover test procedure. The examiner can use multiple fixation targets to maintain attention and accommodation on the task. This can easily be accomplished using Gulden fixation sticks that have 20/30 targets on both sides of the stick (see Fig. 1.3). Periodically, the fixation stick is turned around to change targets. The patient is asked to identify the target during the cover test. These refinements to the basic procedure tend to increase attention on the task.

Another useful procedure is to move the target left to right very slightly (1 to 3 cm), between movements of the cover paddle. The examiner looks for a small pursuit movement in the uncovered eye. If a pursuit movement occurs when the target is moved left to right, it suggests that the patient is attending to the target. Attention on the target tends to encourage accommodation.

- (b) **Objectivity** Because the cover test is an objective technique, it is one of the most valuable methods for assessing the motor characteristics of binocularity. It becomes particularly valuable when working with children.
3. **Expected values** Although the expected finding for the cover test has not been specifically studied, the expected distance phoria (tonic vergence) is 1 exophoria, with a standard deviation of $\pm 1 \Delta$. The mean expected near phoria is 3 exophoria, with a standard deviation of $\pm 3 \Delta$.

Calculated AC/A Ratio

1. **Purpose** To determine the change in convergence that occurs when the patient looks from distance to near.
2. **Important issues**
 - (a) **Significance in diagnosis and treatment** The AC/A finding is a key characteristic in the final determination of the diagnosis and is also one of the most important findings used to determine the appropriate management sequence for any given condition. For example, esophoria at near associated with a high AC/A ratio generally responds well to plus lenses. If the same degree of esophoria is associated with a normal or low AC/A ratio, the recommended treatment approach would include prism correction or vision therapy or both.
 - (b) **Calculated AC/A ratio** The calculated AC/A ratio is determined using the following formula:

$$AC/A = IPD(\text{cm}) + NFD(\text{m}) (H_n - H_f)$$

where

- IPD = interpupillary distance in centimeters
- NFD = near fixation distance in meters
- H_n = near phoria (eso is plus and exo is minus)
- H_f = far phoria (eso is plus and exo is minus)

Example: IPD = 60 mm, the patient is 2 exophoric at distance and 10 exophoric at near (40 cm).

$$\begin{aligned} AC/A &= 6 + 0.4(-10 + 2) \\ &= 6 + 0.4(-8) = 6 + (-3.2) \\ &= 2.8 \end{aligned}$$

When using this formula, remember to use the correct signs for esophoria and exophoria. A rule of thumb is that a high AC/A ratio will result in findings of more eso or less exo at near, and a low AC/A ratio will lead to findings of less eso or more exo at near.

- (c) **Controlling accommodation** A source of measurement error in the AC/A evaluation is failure to control accommodation. Emphasize, in the instructional set, that clarity of the target is essential because variation in accommodative response from one measurement to another can adversely affect results.
3. **Expected values** The expected calculated AC/A ratio is 6:1, with a standard deviation of ± 2 .

Vergence Assessment

Gall et al. (8) found that the use of 3 Δ base-in/12 Δ base-out for vergence facility testing can differentiate symptomatic from nonsymptomatic patients. We recommend vergence facility testing on all primary care patients. In this view, vergence range measures only need to be performed on selected patients and in selected directions—for example, it is useful to assess convergence amplitudes on patients with distance exophoria but not as useful to determine the divergence ability of these same patients (Table 4.1).

Vergence Range Testing

Detailed vergence range measurement can often be deferred in a busy primary care practice.

Vergence Facility Testing

Notwithstanding the possibility of deferring testing of fusional vergence ranges, some vergence assessment is important. Use of 3 Δ base-in/12 Δ base-out for vergence facility testing can differentiate symptomatic from nonsymptomatic patients.

1. **Purpose** Vergence facility testing is designed to assess the dynamics of the fusional vergence system and the ability to respond over a period of time.

2. Important issues

(a) **Strength of prism to use and target to use** Gall et al. (8) performed a systematic study of vergence facility and found that the magnitude of choice is 3 Δ base-in/12 Δ base-out. This combination of prism yielded the highest significance for separating symptomatic from nonsymptomatic subjects as well as producing repeatable results ($R = 0.85$) when used for near vergence facility testing. In another study, Gall et al. (9) compared the use of three different vertically oriented targets for vergence facility testing and found that vergence facility is nearly independent of the target and that a simple vertical column of 20/30 letters is an appropriate target.

Near Point of Convergence

The third vergence area that should be evaluated is convergence amplitude. Generally referred to as the *near point of convergence*, this test is particularly important in the diagnosis of one of the most common binocular vision disorders—convergence insufficiency. Important issues include the type of target or targets to be used and performance over time (10,11).

1. **Purpose** The purpose of the near point of convergence is to assess convergence amplitude. A remote near point of convergence was found to be the most frequently used criterion by optometrists for diagnosing convergence insufficiency (12).

2. Important issues

(a) **Target to be used and number of times to perform the test** We recommend repeating the near point of convergence twice—first using an accommodative target and then using a transilluminator or penlight with red/green glasses.

ANCILLARY VERGENCE TESTING

Fixation Disparity

Fixation disparity testing represents a more recent method of assessing binocular vision and provides additional information that should be included in primary care assessment when deciding on a prism prescription for vertical heterophoria. The primary advantage of fixation disparity testing is that it is performed under binocular or associated conditions, in contrast to other tests that are performed under dissociated conditions.

Fixation Disparity Assessment

1. **Purpose** In contrast to cover testing, which is done under conditions in which one eye is covered and fusion is prevented, fixation disparity testing is designed to evaluate binocular vision under associated conditions.

2. Important issues

(a) **Fixation disparity testing is performed under binocular conditions** The main deficiency of the typical phoria measurement is that the evaluation occurs under dissociated conditions. Although some clinicians suggest the routine use of fixation disparity testing, we have found that in the majority of cases, phoria/vergence testing is sufficient to reach a tentative diagnosis and management plan. In situations in which the diagnosis is unclear or a vertical or base-out prism prescription is being considered, fixation disparity testing is an important addition to the examination procedure.

(c) **Determination of prism correction** Fixation disparity is currently considered the method of choice for determining the amount of prism to prescribe for vertical heterophoria.

Assessment of Accommodative Disorders

GENERAL CONSIDERATIONS

The traditional evaluation of accommodative function (Table 4.2) involves measurement of the amplitude of accommodation using Donder's push-up method. It is also important to test accommodative response and facility as well as amplitude (13–19). An important concept is that an individual may experience asthenopic symptoms and have an accommodative disorder even when the accommodative amplitude is normal (16,18). Wick and Hall (20) studied the relationship among the three areas of accommodation (amplitude, facility, and response) that are usually tested. They screened 200 children and, after eliminating those who had strabismus or significant uncorrected refractive error, found that only 4% had deficits in all three of the accommodative functions. Their results suggest that it is impossible to predict the results of one test based on the results of another.

The suggested minimum database would include the amplitude of accommodation and assessment of accommodative facility. If a near addition is being considered as a treatment option, monocular estimation method (MEM) retinoscopy should also be included in the examination. Table 4.3 lists the expected findings for all the accommodative testing described below.

ASSESSMENT OF ACCOMMODATIVE AMPLITUDE

Push-up Amplitude

1. **Purpose** To subjectively measure the amplitude of accommodation under monocular conditions.
2. **Important issues**
 - (a) **Careful measurement of distance** It is critical to accurately measure the distance at which the patient reports a blur. Even small errors in measurement can lead to large differences in results. To reduce this problem, the push-up amplitude can be measured through -4.00 D lenses. This modification moves the endpoint further away from the patient and allows more exact measurement of the endpoint.
 - (b) **Monitor patient response** It is important periodically to ask the patient to read the letters to be sure that the print is not blurred.

TABLE 4.2 IMPORTANT ASPECTS OF ACCOMMODATIVE TESTING

Accommodative amplitude	Push-up test
Accommodative facility	Children 8–12 years: $+2.00$ flippers at 40 cm Age 13 to adult: Amplitude scaled testing
Accommodative response	Monocular estimation method (MEM) retinoscopy

TABLE 4.3 TABLE OF EXPECTED FINDINGS: ACCOMMODATIVE TESTING

Test	Expected Finding	Standard Deviation
Amplitude of accommodation		
Push-up test (minimum expected)	$15 - 1/4$ age	± 2 D
Binocular accommodative facility		
<i>Children</i> (± 2.00 flippers, calling out numbers or letters on accommodative rock cards)		
8–12 yr old	5.0 cpm	± 2.5 cpm
<i>Age 13 to adult</i> (Use lens power based on amplitude scaled testing) Test distance = 45% of amplitude; lens power range = 30% of amplitude	10.0 cpm	± 5.0 cpm
Monocular estimation method (MEM) retinoscopy	$+0.50$ D	± 0.25 D

- (c) **Relative distance magnification** A problem associated with the push-up method is that the letters no longer subtend the angle expected for a 20/30 letter because of relative distance magnification. A 20/30 letter at 40 cm becomes equivalent to a 20/120 letter at 10 cm. The push-up test, therefore, overestimates the accommodative amplitude. A possible solution to this problem is to decrease the size of the letters at 20 cm and again at 10 cm.
3. **Expected values** A commonly used system is Hofstetter's formula, which is based on Duane's figures (21). The minimum amplitude expected for a given age can be calculated using this formula: $15 - (\text{age}/4)$. For a 20-year-old patient, the minimum expected amplitude is $15 - (20/4) = 10$ D.

ASSESSMENT OF ACCOMMODATIVE FACILITY

Accommodative Facility Testing

1. **Purpose** To evaluate the stamina and dynamics of the accommodative response. The objectives of this test are similar to those discussed relative to vergence facility testing.
2. **Important issues**
 - (a) **Age** The norms for these tests were initially developed using young adult subjects. Questions have been raised about the validity of applying these norms to other populations, such as schoolchildren and older adults between the ages of 30 and 40. Yothers et al. (22) suggest altering binocular accommodative facility (BAF) testing in response to measurement of the push-up accommodative amplitude—that is, amplitude scaled facility (Table 4.4)—because they found that amplitude scaled testing differentiates symptomatic from nonsymptomatic patients better than using ± 2.00 lenses at 40 cm.
 - (b) **Instructional set** When testing adults and older children, the clinician can simply ask the patient to report when the target is clear.
 - (c) **Monocular versus binocular testing** We recommend routine use of BAF testing. If a patient experiences difficulty with binocular testing, monocular testing can then be administered. When the patient cannot clear minus lenses binocularly or monocularly, an accommodative problem is present. If, however, the patient fails binocularly and passes monocularly, a binocular vision problem is more likely.
 - (d) **Target for binocular testing** The importance of using a suppression control when performing BAF testing has been stressed in the literature (14,17–19). The target that is generally used is the Bernell No. 9 vectogram. This is a Polaroid target (see Fig. 1.6) that has one line seen by the right eye, one by the left eye, and one by both.
3. **Expected values** Table 4.4 lists expected amplitude scaled values.

ANCILLARY ACCOMMODATIVE TESTING

Monocular Estimation Method Retinoscopy

Although some clinicians advocate the routine use of testing that assesses accommodative response (MEM retinoscopy), we suggest that in the majority of cases seen in a primary care practice, careful history and testing of the amplitude and facility of accommodation is sufficient to reach a tentative diagnosis and management plan. In situations in which the diagnosis is unclear or a near addition is being considered, MEM retinoscopy can be an important addition to the examination procedure.

1. Important issues

- (a) **Testing must be done with the subjective** MEM retinoscopy is a form of near point retinoscopy. MEM cards (see Fig. 1.7) are available for the Welch-Allyn retinoscope and magnetically attach to the retinoscope head. For primary care evaluation, the working distance should be at 40 cm. Select an MEM card that is appropriate for the age and grade level of the patient. While the patient reads the words on the card, perform retinoscopy along the horizontal axis and estimate the amount of plus or minus necessary to neutralize the motion of the retinoscopic reflex observed. A lens can be quickly placed before the eye being evaluated to confirm the estimate.
- (b) **The results of MEM testing reflect both accommodative and binocular function** Any testing performed under binocular conditions is affected by both accommodative and binocular function. Thus, although MEM is considered a test of accommodative function, binocular vision is also being

TABLE 4.4 AMPLITUDE SCALED FACILITY

Test distance = 45% of amplitude ^a			
Lens power range = 30% of amplitude ^b			
Amplitude	Distance from Nose (cm)	Test Distance (cm)	Flip Lens Power ^c
22.25	4.5	10.0	±3.25
20.00	5.0	11.0	±3.00
18.25	5.5	12.0	±2.75
16.75	6.0	13.5	±2.50
15.50	6.5	14.5	±2.25
14.25	7.0	15.5	±2.25
13.25	7.5	16.5	±2.00
12.50	8.0	18.0	±2.00
11.75	8.5	19.0	±1.75
11.00	9.0	20.0	±1.75
10.50	9.5	21.0	±1.50
10.00	10.0	22.0	±1.50
9.50	10.5	23.5	±1.50
9.00	11.0	24.5	±1.50
8.75	11.5	25.5	±1.25
8.25	12.0	26.5	±1.25
8.00	12.5	28.0	±1.25
7.75	13.0	29.0	±1.25
7.50	13.5	30.0	±1.00
7.25	14.0	31.0	±1.00
7.00	14.5	32.0	±1.00
6.75	15.0	33.5	±1.00
6.50	15.5	34.0	±1.00
6.25	16.0	35.5	±1.00
6.00	16.5	37.0	±1.00
5.75	17.5	38.5	±1.00
5.50	18.0	40.5	±0.75
5.25	19.0	42.5	±0.75
5.00	20.0	44.5	±0.75
4.75	21.0	47.0	±0.75
4.50	22.0	49.5	±0.75

Scoring criteria: Patients scoring less than 10 cpm are likely to be symptomatic.

^aRounded to nearest 0.5 cm.

^bRounded to nearest 0.25 D.

^cRange divided by 2.

assessed. For example, a finding of less plus than expected may reflect overaccommodation secondary to accommodative excess or high exophoria and decreased positive fusional vergence. The same reasoning applies to a finding of more plus than expected on MEM retinoscopy, which could suggest either underaccommodation secondary to accommodative insufficiency or high esophoria and reduced negative fusional vergence.

- (c) **Lighting** When performing MEM retinoscopy, it is important to use normal room illumination. Accommodation is affected by illumination (e.g., dark focus), and dim illumination may alter the accommodative response. Accommodation should therefore be tested under illumination that the patient habitually uses.
- (d) **Determination of near addition** MEM retinoscopy is the method of choice for refining the amount of near addition to prescribe for binocular disorders. Other methods tend to yield less accurate amounts of near addition than MEM analysis.
3. **Expected values** The expected value for MEM retinoscopy is +0.25 D to +0.50 D, with a standard deviation of +0.25 D. A finding of plano or minus or greater than +0.75 D should therefore raise suspicion.

Primary Care Analysis of Common Accommodative and Nonstrabismic Binocular Vision Problems

As optometrists, we are confronted by a finite number of accommodative, ocular motor, and nonstrabismic binocular vision anomalies in clinical care, and a number of classification systems are available to help categorize these disorders. Once the distance and near phoria and AC/A ratio are known, the specific syndrome can be selected from the list of the 15 common accommodative, ocular motility, and binocular vision problems provided below. This classification is a modification of the well-known Duane-White classification (23) suggested by Wick (13).

BINOCULAR ANOMALIES

Heterophoria with Low AC/A Ratio

- Orthophoria at distance and exophoria at near—convergence insufficiency
- Exophoria at distance, greater exophoria at near—convergence insufficiency
- Esophoria at distance, orthophoria at near—divergence insufficiency

Heterophoria with Normal AC/A Ratio

- Orthophoria at distance, orthophoria at near—fusional vergence dysfunction
- Esophoria at distance, same degree of esophoria at near—basic esophoria
- Exophoria at distance, same degree of exophoria at near—basic exophoria

Heterophoria with High AC/A Ratio

- Orthophoria at distance and esophoria at near—convergence excess
- Esophoria at distance, greater esophoria at near—convergence excess
- Exophoria at distance, less exophoria at near—divergence excess

Vertical Heterophoria

- Right or left hyperphoria

Accommodative Anomalies

- Accommodative insufficiency
- Ill-sustained accommodation
- Accommodative excess
- Accommodative infacility

Ocular Motor Problems

- Ocular motor dysfunction

General Treatment Modalities, Guidelines, and Prognosis

The primary care treatment model we present here is based on the information in Chapters 1 and 2 regarding diagnosis, analysis, and classification. To use the information as a general guide in treating a specific binocular vision case, it is first necessary to determine, from the clinical evaluation, whether there is an exophoria, orthophoria, or esophoria at distance (low, normal, or high tonic vergence) and whether it is associated with a low, normal, or high AC/A ratio. In addition, it is important to determine whether these findings are associated with symptoms that suggest a binocular vision problem. In regard to accommodative anomalies, it is important to ascertain whether the difficulty is in stimulation of accommodation, relaxation of accommodation, or both.

A primary objective of the model is to emphasize the significance of considering all treatment options for every accommodative, ocular motor, and binocular vision anomaly encountered. There are a limited number of management options for any patient with these disorders. When managing such patients, it is best to acquire the habit of always considering each option and then either using or rejecting that management for a particular patient. This approach will ensure that no management option has been ignored and should lead to more frequent and rapid success. For instance, several of the possible treatment options (i.e., occlusion, vision therapy for amblyopia and anomalous correspondence, and surgery) are rarely necessary during primary care management of accommodative and nonstrabismic binocular vision problems. In heterophoria cases associated with anisometropia, however, occlusion and amblyopia treatment will often be necessary. In very rare instances, when dealing with exceptionally large magnitude heterophorias, surgery may be necessary. Thus, it is sometimes necessary to consider referral for these treatment options for some patients.

BEST REFRACTIVE CORRECTION

Significant Degrees of Refractive Error

As a general rule, it is advisable to first prescribe for any significant refractive error. Table 4.5, based on the Orinda study (24), lists criteria for significant refractive error. The strategy of first prescribing for significant refractive error is based on the assumption that there may be a cause-and-effect relationship between refractive error and accommodative and binocular vision anomalies. When deciding on a prescription for ametropia, it is also important to consider and understand that the correction influences the vergence posture of the eyes through the AC/A ratio. As a result, we generally recommend prescribing maximum plus for patients with esodeviations and minimum plus for patients with exodeviations.

If a significant refractive error is present, the patient is generally asked to wear the prescription for 4 to 6 weeks, at which point another evaluation is performed to reassess the status of accommodative and binocular function (Case 4.1). In some instances, the previously detected disorders will have resolved and no additional treatment will be necessary. For example, Dwyer and Wick (25) reported improvement of binocular function that resulted one or more months after prescription of an initial spectacle correction for 143 nonstrabismic patients who had a refractive error and either a vergence anomaly, an accommodative anomaly, or both. If accommodative, ocular motor, or binocular disorders persist after wearing the prescription, additional treatment alternatives must be considered.

TABLE 4.5 GUIDELINES FOR SIGNIFICANT REFRACTIVE ERROR

Type of Refractive Condition	Significant Amount
Hyperopia	+1.50 D or greater
Myopia	−1.00 D or greater
Astigmatism	−1.00 D or greater
Anisometropia	1.00 D difference in either the sphere or cylinder

Case 4.1 Correction of Refractive Error

Robert, a 41-year-old accountant, presents with complaints of eyestrain, blurred vision, burning, and frontal headaches. These problems begin every afternoon during the workweek and have been occurring for the last 6 months. He has never worn glasses before. Testing reveals +2.50 OD and OS, orthophoria at distance, and 8 exophoria at near without correction. With correction, he is 6 exophoric at distance and about 15 exophoric at near.

Base-out ranges at near (without the correction): 8/16/8

Base-out ranges at near (with the correction): 4/10/4

Near point of convergence (without correction): 3 to 6 in.

Near point of convergence (with correction): 6 to 10 in.

In this case, the patient is uncomfortable when reading and needs a correction for the hyperopia. In a primary care practice, the patient could be prescribed the full prescription and instructed to wear the glasses full time and return for a reevaluation after 4 to 6 weeks. If symptoms persist, vision therapy could then be recommended.

ADDED LENS POWER (MINUS AND PLUS)

The other important use of lenses in the primary care treatment of accommodative and binocular disorders is to alter the demand on either the binocular or accommodative systems. The vital test finding that helps determine the effectiveness of added lenses is the magnitude of the AC/A ratio. A high AC/A ratio suggests that a very large change in binocular alignment can be achieved with a small addition of lenses and that use of added lens power will generally be an effective approach. A low AC/A ratio indicates that the use of added lens power will have little desirable effect.

The most common example of the effectiveness of the use of lenses in the absence of refractive error is convergence excess. In such a case, the patient will often have no significant phoria at distance and a moderate to high esophoria at near. In the presence of the high AC/A ratio, a significant change can be achieved in the amount of esophoria at near simply by prescribing plus lenses for near. If, however, the clinical data are somewhat different and the patient has the moderate esophoria at distance and near (and, by definition, a normal AC/A ratio), then a small amount of base-out prism would provide a more effective resolution of the patient's complaints.

The Near Addition Type: Bifocal versus Progressive versus Single Vision

When prescribing added plus lenses, a bifocal prescription is almost always preferable. A flat-top 28-mm segment works well with young children. For children younger than about 10 years, we recommend setting a flat-top segment height at or slightly above the lower pupil margin to ensure that the child reads through the segment. For older children and adults, a flat-top segment height can be set at the traditional lower lid margin height, or a relatively high-set progressive lens can be used.

The Near Addition Power

Determination of the near addition requires knowledge of the amount of accommodation (or accommodative effort) used (26). To maximally relax accommodation at distance, refraction is generally done to achieve best visual acuity with the maximum plus (or least minus) lenses possible. The maximum-plus refraction places distant objects at the farthest focus point from the retina. Once the maximum-plus refraction has been performed, a near addition can be determined using either the AC/A ratio (in the case of convergence excess patients who are more esophoric at near than at distance) or the relation between the accommodative response at distance and near (in the case of patients with accommodative problems who have no significant phoria at distance or near). Fortunately, as will be seen below, the near addition that works well has about the same power (+1.25 D) in either case.

Plus at Near and Calculated AC/A Ratio

In a primary care practice, determination of the near addition based on the calculated AC/A ratio requires consideration of the amount by which the near esophoria is changed with a near addition (Case 4.2). Table 4.6 shows that a +1.25 near addition will have a positive impact on the near esophoria for most convergence excess patients. The calculations underlying Table 4.6 assume that the tentative +1.25 near addition will have maximum effect on accommodation (or accommodative effort) and a corresponding maximum effect on the near esophoria. Although this is not always the case, prescription of a +1.25 near addition will always have a significant effect on the near esophoria, and in a busy primary care practice +1.25 can be easily used as a

Case 4.2 The Use of Added Lenses

A 10-year-old boy presented with a complaint of eyestrain, blurred vision, and inability to concentrate when reading after 10 minutes. These problems had been bothering him since the beginning of the school year. The refraction was +1.00 D OD and OS, the distance phoria was 4 esophoria, and the near phoria was 20 esophoria (IPD = 58 mm). The calculated AC/A ratio in this case is 8:1. Near point testing through the subjective revealed the following:

Negative relative accommodation (NRA):	+2.50
Positive relative accommodation (PRA):	−1.00
Near lateral phoria (NLP):	3 esophoria
Base-in (near):	4/10/4
Base-out (near):	16/26/16
Vergence facility:	0 cpm, diplopia with base-in
Monocular estimation method (MEM):	+1.25 OD and OS
Binocular accommodative facility (BAF):	Diplopia with −2.00, 0 cpm
Monocular accommodative facility (MAF):	12 cpm

Because the AC/A ratio is high, it is important to prescribe for the ametropia in this case. Prescribing +1.00 will reduce the near phoria to about 2 esophoria. Analysis of the near point data indicates that all of the direct and indirect measures of negative fusional vergence (NFV) are low. The use of added plus lenses in this case is indicated and will eliminate the remaining esophoria, balance the NRA/PRA relationship, and normalize the MEM and base-in findings. The near point analysis in this case suggests that a +1.00 to +1.25D add is appropriate. The final glasses prescription in a primary care practice would be as follows:

OD: +1.00
OS: +1.00
+1.25 add

TABLE 4.6 EFFECT OF A +1.25 NEAR ADDITION IN PATIENTS WITH VARIOUS CALCULATED AC/A RATIOS

Distance Phoria	Near Phoria	Calculated AC/A Ratio (60 cm pupillary distance; 40 cm working distance)	Predicted Near Phoria with 11.25 Add
Ortho	5 eso	8/1	5 exo
Ortho	10 eso	10/1	2.5 exo
Ortho	15 eso	12/1	Ortho

“default” near addition for patients with binocular vision problems. The default +1.25 D near addition can be modified as needed based on cover test measures (remaining near esophoria suggests that a stronger near addition should be considered) or MEM retinoscopy (a lead of accommodation—minus finding—suggests the need for a weaker near addition).

Depth of Focus and Lag of Accommodation

Clinicians typically think in terms of the stimulus rather than the response to accommodation. However, the accommodative response is significantly smaller than the stimulus. Because of the refractive technique and the depth of focus of the eye, as an object is moved closer the blur circle moves through the limits of the depth of focus, and for approximately the first 0.75 D of accommodative stimulus there is no accommodative change due to the refraction and the depth of focus of the eye (27). The distance depth of focus, combined with the normal lag of accommodation of 0.50 D or more when accommodating on near objects (28), causes only approximately 1.25 D to 1.50 D of accommodative change when fixation is changed from distance to 40 cm (29) (see Fig. 16.3), an amount that is significantly less than the 2.5 D accommodative stimulus. This suggests that for patients with accommodative problems but without significant phoria at distance or near, a near addition of +1.25 D can also be used in primary care with confidence that it will relieve accommodative symptoms. Typically, the default +1.25 D near addition can be used most of the time without added testing; however, when refining the default +1.25 D near addition, MEM retinoscopy is the test of choice. On MEM retinoscopy a lead of accommodation (minus MEM finding) suggests that a weaker near addition should be considered, whereas a continuing lag (plus finding) suggests that the near addition could be increased.

Added Minus Lenses

Added minus lenses should also be considered in certain cases. Added minus lenses are used to reduce the percentage of time that an intermittent exotropia occurs or to provide more comfortable fusion in high exophoria. When prescribed for this purpose, small amounts of minus (i.e., -1.00 to -2.00 D) are used; in most cases a -1.25 D minus overcorrection can be used as the default for patients in a primary care practice. In such cases, the AC/A ratio is not the critical factor in determining the amount of minus to prescribe. The objective of added minus in these patients is to reduce the negative effect that convergence has on accommodation and clarity of distance vision as a result of the convergence accommodation to convergence (CA/C) ratio or to create a stimulus to convergence, or both. Once this is accomplished, the patient is able to maintain fusion using fusional vergence.

Patients for Whom a Near Addition Would Be Ineffective

The classic example of the ineffectiveness of the use of lenses in the absence of refractive error is convergence insufficiency. In such a case, the distance phoria is typically insignificant, while a moderate to large exophoria is present at near because of the low AC/A ratio. Use of lenses—in this case, to achieve a desirable change in the near phoria—would not be expected to be helpful.

PRISM

Prism to treat binocular anomalies is useful and should be a consideration in all cases. Generally there are two situations in which the use of prism may be helpful in primary care management:

- Horizontal relieving prism
- Vertical relieving prism

Of the nonstrabismic binocular vision anomalies listed above, prism tends to be most effective for divergence insufficiency, basic esophoria, and vertical heterophoria and, to a substantially lesser extent, convergence insufficiency and basic exophoria (30). Table 4.7 lists cases in which prism would be most likely to be effective.

Horizontal Relieving Prism

If a large lateral heterophoria or an intermittent strabismus is present, it may be helpful to prescribe prism to decrease the demand on fusional vergence and attempt to reduce the patient's symptoms. Prism is most

TABLE 4.7 RECOMMENDED PRIMARY CARE TREATMENT APPROACH BY DIAGNOSIS

Diagnosis	Primary Treatment	Secondary Treatment
Ocular motor dysfunction	Vision therapy	Added plus
Accommodative dysfunction		
Accommodative insufficiency	Added plus	Vision therapy
Ill-sustained accommodation	Added plus	Vision therapy
Accommodative excess	Vision therapy	Added plus
Accommodative infacility	Vision therapy	
Low AC/A conditions		
Convergence insufficiency	Vision therapy	Base-in prism
Divergence insufficiency	Base-out prism	Vision therapy
High AC/A conditions		
Convergence excess	Added lenses	Vision therapy
Divergence excess	Vision therapy	Added lenses (– distance; + near)
Normal AC/A conditions		
Basic esophoria	Base-out prism	Vision therapy, added plus
Basic exophoria	Vision therapy	Added minus, base-in prism
Fusional vergence dysfunction	Vision therapy	
Vertical disorders		
Vertical phoria	Vertical prism	Vision therapy

effective in cases of esophoria at distance (high tonic vergence) along with a normal to low AC/A ratio (Case 4.3). Worrell et al. (31) investigated the effectiveness of prism prescribed based on Sheard's criterion and found that prism was preferred by patients in cases of distance esophoria. For exophoria and esophoria at near, they did not find any preference for prism glasses. Payne et al. (32) prescribed two pairs of glasses that were identical in every way except that one had prism determined by fixation disparity testing and the other had none. After wearing each pair of glasses for 2 weeks, all of the 10 subjects chose the glasses with the prism. Based on unpublished data (33), Wick suggests that the amount of prism found by Sheard's

Case 4.3 Use of Horizontal Prism

A 21-year-old man presents with a complaint of intermittent diplopia that is more bothersome when he looks at a distance. The problem has been present for several years. The refraction is +0.50 D OD and OS, the distance phoria is 10 esophoria, and the near phoria is ortho. The calculated AC/A ratio in this case is 2:1.

Prescribing for the ametropia in this case would have virtually no effect on the distance esophoria, reducing it from 10 esophoria to 9 esophoria. Of course, added plus lenses at distance for divergence insufficiency cannot even be considered because it would cause distance vision blur. In a primary care practice, the full-plus distance correction with 3 base-out prism (one-third the distance phoria) can be prescribed; if the patient remains symptomatic, he should be referred for vision therapy.

In a randomized clinical trial, Scheiman et al. (34) found that base-in prism reading glasses were no more effective than the refractive correction alone in treating children 9 to 17 years old with symptomatic convergence insufficiency. Although there is no similar study with adults, the effectiveness of vision therapy for patients with exodeviations is typically excellent. Thus, for patients with distance exophoria, we suggest that no prism be prescribed; these patients are more easily and successfully treated with vision therapy and should be referred by primary care practitioners for such treatment.

criterion for patients in cases of distance esophoria is similar to that found by fixation disparity analysis and that both are typically about equal to one third of the distance phoria. Based on this finding, we suggest that patients in a primary care practice with distance esophoria be prescribed base-out prism equal to one-third of the distance phoria.

Prism Prescription Considerations

When prescribing prism in a primary care practice, it is almost always preferable to prescribe all of the prism in one lens when the prism power is 1.25 prism diopter or less and to split the prism between the lenses when the prism power is 1.5 prism diopter or more. Polycarbonate lenses have come to be the lens of choice because of their increased safety. However, the Abbe value of polycarbonate lenses occasionally causes patients to notice “color fringes”—this effect is exaggerated with prism prescriptions, because prism also causes color fringes at times. As the prism power is increased, the primary care practitioner should consider either CR-39 or high index material, rather than polycarbonate, to reduce these effects. Additionally, a 2 D steeper than stock base curve helps reduce unwanted prismatic aberrations. Antireflective coatings are valuable for the same reason and should be used on all prism prescriptions.

Fixation Disparity Analysis: Vertical Relieving Prism

London and Wick (35) reported that correction of a vertical fixation disparity may also have a beneficial effect on the horizontal deviation. Based on this finding, they suggest that when there is both vertical and horizontal deviation, the clinician should first consider prism correction of the vertical component. Wick (36) suggests that vertical prism should be prescribed when it results in improved visual performance, such as decreased suppression and increased fusion ranges. As little as 0.5 Δ of vertical prism may be beneficial for fusion.

Vertical Associated Phoria

In general, the amount of prism to reduce the fixation disparity to zero can be prescribed with confidence that it will dramatically relieve the patient’s symptoms (Case 4.4). Because this measure is so easy to implement,

Case 4.4 Prescribing Vertical Prism Based on Associated Phoria

A 17-year-old boy complained of slow reading, loss of place while reading, reading the same line when going back to the beginning of a line, and headaches after approximately 30 minutes of reading (eyelid/brow area). He stated that blinking cleared the near blur. The current spectacle prescription was essentially the same as the refractive findings:

OD: – 1.50 diopter sphere (DS)	20/15
OS: – 1.75 DS	20/15

All further testing was performed through the habitual spectacle lenses. Cover test and Maddox rod testing revealed 2 Δ of left hyperphoria in all fields of gaze at distance and near. The associated phoria findings were 1.75 Δ left hyper-associated phoria at distance and near. There were no changes in associated phoria response as the patient shifted vision into lateral gaze. Accommodative findings were normal (lag = 0.75 D, amplitude = 14 D, binocular facility = 6 cpm with ± 2.00 D flippers at near).

Based on the examination findings, the habitual spectacle correction was judged to be adequate, as were accommodative and fusional abilities. The myopic correction alone and then with the addition of 1.75 Δ base-down before the left eye were placed into a trial frame and the patient was allowed to read for 10 to 15 minutes under both conditions. He expressed a feeling of less eyestrain and more accurate eye movements (easier returning to the next line of letters) with the additional prism, which was then prescribed. With the new prescription, the patient reported a decrease in the frequency of losing his place while reading, and he experienced no symptoms while reading.

this form of fixation disparity testing has become the test of choice for vertical heterophoria. Associated phoria measures can be made using the American Optical (AO) vectographic slide, Turville testing, and the Mallett near unit (see Fig. 14.4).

A valuable addition to vertical associated phoria evaluation can be used to be certain that the endpoint has been reached. The principle is to align the eyes vertically so that there is no alteration in ocular alignment required when the patient blinks. This can be achieved by interposing vertical prism until the nonius lines seem to be stable through the prism. Then have the patient close both eyes for 1 to 2 seconds. When the eyes are first opened, the patient's task is to notice whether the nonius lines are exactly aligned or whether one line or the other had to move up or down to become aligned. Repeat the open–close eyes procedure and modify the prism prescription in 0.5 Δ steps until the lines appear stable and aligned at all times. Frequently, small increases in vertical prism from that seen in standard eyes-open associated phoria measurement is required to reach the stable endpoint of alignment of the lines immediately after opening the eyes. When the lines remain aligned immediately after the eyes have been opened again, the amount of prism that is in place can be prescribed.

PASSIVE THERAPY: OCCLUSION AND ATROPINE TREATMENT

Occlusion is a commonly used treatment option in the management of strabismus and its associated conditions: amblyopia, eccentric fixation, suppression, and anomalous correspondence. Passive therapy using occlusion or atropine penalization is often needed when heterophoria is associated with anisometropic amblyopia. Our management recommendation for anisometropic amblyopia is a sequential program that consists of four steps (Table 4.8):

1. Full refractive correction
2. Added lenses or prism when needed to improve alignment of the visual axes
3. Passive therapy utilizing either 2 to 6 hours per day of direct occlusion or atropine penalization (one drop of atropine sulfate in the better-seeing eye at bedtime two times per week)
4. Active vision therapy to develop best acuity and improve binocular function.

Many times in a primary care practice, the patient will improve with only the first step—full refractive correction (Case 4.5). More often, added lenses or prism are needed to improve alignment of the visual axes, and passive therapy utilizing either 2 to 6 hours per day of direct occlusion or atropine penalization (one drop of atropine sulfate in the better-seeing eye at bedtime two times per week) is needed. If active vision therapy is needed to develop best acuity and improve binocular function, the patient can be referred for management.

CASE 4.5 Refractive Correction Alone

A 12-year-old girl presented with the chief complaint of blurred vision when looking from reading books to the chalkboard. She also complained of irregular headaches and felt that the left eye bothered her more than the right. Her parents reported that she had received a visual examination 2 years previously, but did not wear the prescription. External and internal ocular health was within normal limits. Visual acuity (VA) and refraction with cycloplegia were as follows:

OD: +0.50	20/20 – 1
OS: +4.25 – 2.00 \times 005	20/60 – 1
OU 20/20	

There was a comitant 5 Δ esophoria at 6 m, and 8 Δ esophoria at 40 cm. Stereopsis was 100 seconds at 40 cm with Randot circles. There was no suppression. Fixation was central with both eyes.

The cycloplegic refractive finding less 0.50 D was prescribed. The patient was instructed to return for reevaluation in 1 month, but she did not return until 3 months later. She had noticed diplopia for the first 2 days while wearing the new glasses, but now wore them full time without complaint.

Aided VA

OD: 20/15 – 2

OS: 20/20

OU: 20/15

Eye alignment was 2 Δ esophoria at 6 m and 4 Δ esophoria at 40 cm. Stereopsis was 20 seconds at 40 cm with random dot circles.

Passive Therapy

Passive therapy involves either occlusion (patching) or penalization (atropine therapy) of the better-seeing eye. Both treatments force the patient to use the amblyopic eye, stimulating vision improvement in that eye by reactivating the visual pathways. Thus, when the patient does not improve with spectacle correction alone, we recommend use of either part-time direct occlusion for 2 or 6 hours per day (depending on the best corrected visual acuity) or atropine penalization. The initial choice can be made by balancing the desire for more rapid improvement (occlusion) with the objection to the patch while considering the issues of light sensitivity (atropine) along with the side effects of each treatment. Incomplete responders to one treatment should later be considered for the other treatment to be sure that maximum acuity improvement has been achieved. In general, either treatment should be continued for 3 months after improvement stops before considering the other (37).

Using Occlusion

For moderate amblyopia (better than 20/100), begin with 2 hours of patching per day; for severe amblyopia (20/100 and worse), the initial patching should be 6 hours per day. Patients should be followed about every 6 weeks. If visual acuity improves at least one line, the occlusion dosage can remain the same as the starting dosage. If visual acuity has not improved at least one line, we suggest doubling the number of hours of occlusion per day.

Using Atropine

Atropine penalization of the sound eye has been used for over 100 years as a treatment for amblyopia. Although patients with anisometropic amblyopia who are treated with atropine take slightly longer to reach maximum acuity than those treated with occlusion, the ultimate acuity improvement is essentially equal for the two treatments (38). Studies have demonstrated that 1% atropine used twice per week (on weekends) is as effective as daily atropine (39).

TABLE 4.8 SEQUENTIAL MANAGEMENT OF ANISOMETROPIC AMBLYOPIA

1. Full refractive correction
2. Improve alignment of the visual axes when needed
 - a. Added lenses if
 - 1) High AC/A ratio
 - 2) Inaccurate or insufficient accommodation
 - b. Prism if
 - 1) Esophoric at distance (base-out)
 - 2) Hyperphoric (base-down)
3. Direct occlusion (part-time, 2 to 6 h/d)

or

Atropine penalization of the better-seeing eye (1 gtt twice weekly)
4. Vision therapy
 - a. Monocular—maximize monocular acuity
 - b. Binocular—improve binocular function

HOME-BASED VISION THERAPY

Home-based vision therapy has been proposed as a possible treatment for binocular vision, accommodative, and eye movement disorders that do not respond to lenses and prism (13). Although there are data from retrospective and case studies supporting this approach (40–42), data from randomized clinical trials have found that home-based vision therapy is not as effective as office-based vision therapy. The Convergence Insufficiency Treatment Trial compared office-based vision therapy to home-based pencil push-ups and home-based computer therapy plus pencil push-ups (43). The results indicated that the two home-based treatments were no more effective than placebo treatment; only about 40% of patients were asymptomatic, with a normal near point of convergence and positive fusional vergence ranges at near, after home-based treatment. In contrast, about 75% of the patients receiving office-based vision therapy were asymptomatic, with improved clinical findings.

In theory, home-based therapy should be effective because many of the procedures used at home are the same as those used in the office. Although there are many reasons why office-based therapy might be more effective, the most likely cause is the more rigorous oversight that is possible by a trained therapist in the doctor's office. We suggest that the latest evidence be shared with patients, informing them of the reported success rates with various treatment options. Based on the evidence currently available practitioners who do not offer office-based vision therapy should refer patients to an optometrist who provides this service. There is no evidence that indicates that home-based vision therapy should be the primary treatment option.

ACCOMMODATIVE PROBLEMS: PATIENTS IN WHOM NO SIGNIFICANT PHORIA IS PRESENT

In the integrative analysis approach, the distance phoria and AC/A ratio are the entry points into the system. The absence of a significant phoria also directs the analysis of data, as illustrated in Figure 2.7, where the flowchart suggests several possible etiologies: an accommodative disorder, ocular motor dysfunction, fusional vergence dysfunction, fixation disparity, latent hyperopia, cyclovertical phoria, or aniseikonia. The typical explanation is the presence of an accommodative anomaly. If the accommodation appears normal based on an analysis of the amplitude (near point of accommodation), facility (amplitude scaled lens flippers), and lag of accommodation (MEM), and there is no latent hyperopia, the hypotheses of ocular motor dysfunction or fusional vergence dysfunction should be pursued. If this investigation is also negative, fixation disparity testing is appropriate. Finally, conditions such as cyclovertical phoria and aniseikonia should be considered.

Sequential Management of Accommodative Dysfunction

The concepts that we discussed for the sequential management considerations of binocular vision disorders also apply to accommodative problems. Accommodative fatigue can occur secondary to uncorrected refractive error, such as hyperopia and astigmatism (12). A 3 D hyperope must accommodate 2.50 D for a working distance of 40 cm and an additional 3 D to overcome the hyperopia. The muscular fatigue resulting from 5.50 D of accommodation will often lead to the symptoms associated with accommodative problems. Low degrees of astigmatism and anisometropia can also lead to accommodative fatigue, if accommodation oscillates in an attempt to obtain clarity. Myopic patients also occasionally experience discomfort when reading with new eyeglasses. This may be due to accommodative fatigue and must be considered in any management plan. The first management consideration, therefore, is correction of refractive error. We recommend applying the criteria for prescribing discussed previously in this chapter.

Added lenses also play an important role in the treatment of accommodative dysfunction. Of the various accommodative problems, accommodative insufficiency and ill-sustained accommodation respond best to added plus lenses. The important concept is that any accommodative disorder in which the patient is experiencing problems stimulating accommodation will benefit from added plus lenses. Accommodative problems in which the difficulty is with relaxation of accommodation or changing accommodation (facility) often do not respond as well to added lenses. Thus, accommodative excess and accommodative infacility generally require treatment other than added lenses.

Prism, which is so important in cases of esophoria at distance or hyperphoria, is not used for accommodative dysfunction unless there is an associated binocular alignment problem. For purposes of this chapter, we assume that the accommodative dysfunction is present in isolation. Therefore, prism is not considered as part of the sequential management for accommodative dysfunction.

The same issues discussed above relative to home-based vision therapy for binocular vision disorders apply to accommodative disorders. We suggest that practitioners who do not offer office-based vision therapy should refer patients to an optometrist who provides this service. There is no evidence that indicates that home-based vision therapy should be the primary treatment option for accommodative disorders.

Summary

In primary care management of binocular vision problems, it is important to utilize lenses, prism, and passive therapy to treat as many patients as possible. After determination of the refractive error, necessary diagnostic procedures include the cover test at distance and near, determination of the calculated AC/A ratio, near point of convergence, vergence facility, vertical associated phoria measures, and testing of accommodation (amplitude and binocular facility testing). Primary care treatment includes the best distance correction along with judicious use of added plus lenses for patients with accommodative problems and those having near esophoria with a high AC/A ratio. Added minus lenses may be used at times to facilitate fusion in patients with distance exodeviations. Small amounts of base-out prism are used for relieving symptoms of patients with distance esophoria, and passive treatment such as occlusion or atropine, or both, is needed by patients with anisometropic amblyopia. Home vision therapy can be used in selected cases. Patients needing more extensive diagnosis or office-based therapy should be referred by the primary care practitioner to a doctor who specializes in treatment of binocular vision problems.

Study Questions

1. What is the concept behind vision symptom questionnaires, and why might they be useful in primary care practice?
2. How could adding plus lenses monocularly (just prior to monocular blur) help make Jackson cross-cylinder testing more accurate during refraction?
3. Why is it important to control accommodation during the cover test? Describe two ways to do this.
4. Describe a quick way to be sure you have calculated the AC/A ratio correctly. (*Hint: Consider the relation between the distance and near phoria.*)
5. Why would a +1.25 D near addition have a significant effect on the near phoria for virtually all patients with a high AC/A ratio?
6. Why is vergence facility assessment more “diagnostic” than measuring vergence ranges?
7. Why might amplitude scaled accommodative facility testing for patients over age 12 be more appropriate than using ± 2.00 lenses at 40 cm for every patient?
8. Prescribing vertical prism based on associated phoria measures takes advantage of what feature of the forced vergence fixation disparity curve?
9. What is the relation between accommodative amplitude, facility, and accuracy (lag) that suggests the need to utilize more than one test of accommodation for diagnostic purposes?
10. How could MEM retinoscopy be used to help determine the appropriate near addition?

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SECTION

II

Vision Therapy Procedures and Instrumentation

Introduction and General Concepts

This chapter provides detailed information and guidelines for vision therapy, and Chapters 6 to 8 describe a select group of vision therapy procedures for the treatment of vergence, accommodative, and ocular motility disorders. There are hundreds of vision therapy techniques in use by optometrists, and manuals are available describing a wide variety of instrumentation and procedures (1,2). In our opinion, presentation of a vast array of procedures tends to make vision therapy appear overly complicated. We believe that this may discourage optometrists from becoming involved in vision therapy.

In Chapters 6 to 8, we present a select group of procedures and instruments. Our primary emphasis is on presentation of the principles underlying the vision therapy techniques we have selected. An understanding of this small group of vision therapy procedures will enable an optometrist to successfully treat the vast majority of accommodative, ocular motility, and nonstrabismic binocular vision disorders and achieve success rates consistent with those discussed in the literature (3–11). In addition, the principles discussed for these vision therapy techniques are common to all procedures. Therefore, an appreciation of the key issues and principles in this chapter will allow the clinician to understand almost any other procedure and will permit growth as the practitioner gains experience and confidence.

It is not unusual for us to hear students and clinicians unfamiliar with vision therapy ask the question, “What do I do with it?” regarding vision therapy equipment. Therefore, one of the primary objectives of the following four chapters is to provide a detailed description of how to actually use the vision therapy equipment described. We have provided a detailed sequence of therapy procedures to perform with the specific instruments described. We are well aware that there are other ways to use this instrumentation, but our goal is to present a starting point for clinicians, who then can expand their utilization of this equipment as they gain experience in the area of vision therapy.

Categorization of Vision Therapy Instrumentation and Procedures

Binocular vision therapy procedures have traditionally been subdivided into two broad categories. The first category, referred to as *instrument training*, includes all techniques in which the patient is required to look directly into an instrument. With instrument training, movement of the patient is restricted, and it may be difficult to see the patient’s eyes. These conditions are generally described as being less natural or more artificial than other forms of therapy. The most common example of instrument training is the use of a stereoscopic-type device.

The second category, called *free space training*, involves techniques in which the patient is in a less restricted environment, more movement is possible, and it is easier to observe the patient’s eyes. This type of vision therapy more closely approximates normal seeing conditions and is considered less artificial than instrument training.

Upon careful analysis of this division, several problems become apparent. The first difficulty is the lack of precise criteria for placing a particular procedure in either category. For example, although the Aperture Rule, illustrated in Figure 5.1, is generally considered a free space technique, a patient using this device clearly has to position himself or herself directly against the device and look into the instrument. The same is true of the double mirror stereoscope shown in Figure 5.2. Although these two devices do not use lenses or prisms, they clearly resemble “instrument” devices such as the stereoscope shown in Figure 5.3. Another problem is how to categorize anaglyphic and Polaroid filter procedures. Are these techniques truly “free space,” or do the filters constitute an interference and alteration of the normal visual environment?



■ **Figure 5.1** The Aperture Rule.



■ **Figure 5.2** Double mirror stereoscope.



■ **Figure 5.3** Bernell-O-Scope stereoscope.

We believe that the “free space” versus “instrument” dichotomy is an artificial division that leaves too many devices and procedures without a clear fit into either category. We recommend a classification of vision therapy instrumentation and techniques that is based to a greater extent on the type of equipment being used. This classification is as follows:

1. Anaglyphs and Polaroid filters
2. Lenses, prisms, and mirrors
3. Septa and apertures
4. Paper, pencil, and miscellaneous tasks
5. Stereoscopes
6. Afterimages, entoptic phenomena, and electrophysiologic techniques.

This classification system is used throughout Chapters 6 to 8 as common vision therapy techniques are described. Table 5.1 lists many of the various instruments and procedures that fall into these six different categories.

The concept of natural versus artificial training conditions, however, is a useful one that we emphasize throughout this text. There is a general consensus that vision therapy procedures that approximate normal seeing conditions tend to be more effective in achieving the desired objectives of vision therapy.

TABLE 5.1

**CLASSIFICATION OF VISION THERAPY
INSTRUMENTATION AND PROCEDURES**

<p>1. Stereoscopes Brewster stereoscopes Wheatstone stereoscopes Haploscopes Cheiroscopes</p>
<p>2. Anaglyphs and Polaroid filters Tranaglyphs Vectograms Bar readers TV trainer Computer programs using red/blue or red/green glasses</p>
<p>3. Lenses, prisms, and mirrors Flip lenses Loose lenses Flip prisms Loose prisms Prism bars Hand-held mirrors</p>
<p>4. Septa and apertures Aperture Rule Remy separator Tasks based on Turville test</p>
<p>5. Paper, pencil, and miscellaneous tasks Lifesaver cards Free Space cards Eccentric circles Barrel card, three-dot card Brock string Computer techniques Hart chart and other miscellaneous charts Letter tracking Tracing</p>
<p>6. Afterimages, entoptic phenomena, and electrophysiologic techniques Devices for creating afterimages Maxwell spot Haidinger brush Auditory biofeedback</p>

CATEGORY 1: ANAGLYPHS AND POLAROID FILTERS

Anaglyphs and Polaroids are filters that block out light from a portion of the target being viewed so that one part is visible by one eye and one part is visible by the other eye. These techniques are widely used for heterophoria patients.

Advantages

Anaglyphs (red/green targets) and Polaroids allow good control of stimulus parameters. A wide variety of targets, including second-degree, third-degree, central, peripheral, accommodative, and nonaccommodative targets, are available. These techniques work well with shallow to moderate suppression, and they can be used to train both jump (phasic) or smooth (tonic) vergence. Because the patient does not have to look into an instrument, these procedures more closely resemble normal seeing conditions than instrument-type devices.

Disadvantages

Young children may lose interest, and it is important to use a variety of these targets to maintain interest. The primary disadvantage of Polaroid techniques is high expense. They are approximately 10 times as expensive as anaglyphs. Another problem associated with Polaroids is that if the patient tilts his or her head, both targets can be seen by one eye. This would allow the patient to see both targets even if he or she is suppressing. Although anaglyphs are less expensive, these filters (particularly the red) are darker than Polaroids and may precipitate suppression (1). A potential disadvantage associated with both anaglyphs and Polaroids is that if there is rapid alternate suppression it may be difficult to determine whether suppression is present.

CATEGORY 2: LENSES, PRISMS, AND MIRRORS

Lenses change the accommodative and vergence demand, whereas prisms and mirrors change the direction of light. Lenses, prisms, and mirrors are often used in conjunction with anaglyphs and Polaroids and are among the most widely used procedures for heterophoria patients. These procedures are useful for antisuppression training and fusional vergence, as well as accommodative and ocular motility therapy.

Advantages

Lenses are very effective for accommodative therapy. These devices also allow the clinician to increase or decrease the level of demand of all binocular and accommodative techniques. They can be used to train both smooth (tonic) and jump (phasic) vergence.

Disadvantages

Young children may lose interest, and it is important to use a variety of targets to maintain interest.

CATEGORY 3: SEPTA AND APERTURES

A *septum* is a dividing wall that separates the view of each eye in normal space so that one eye sees one portion of a target while the other eye sees another. An example is the Remy separator (Fig. 5.4). An *aperture* is an opening or window that separates the views of each eye so that one eye sees one portion of the target while the other sees another part. The Aperture Rule (Fig. 5.1) is a popular vision therapy technique based on the use of an aperture.

Advantages

A moderate variety of targets is available, and more targets can be made by the clinician. Apertures and septa work well to treat patients with shallow to moderate suppression.

■ **Figure 5.4** Remy separator.



Disadvantages

It is sometimes difficult to keep a young child's interest with these techniques. Head position is also important with apertures and septa, and the child must sit still and maintain the prescribed head position. The demand of the target cannot be set at zero, forcing the patient to make an initial fusional vergence movement. Because of this, apertures and septa are generally used after anaglyphs, Polaroids, and lenses, prisms, and mirrors.

CATEGORY 4: PAPER, PENCIL, AND MISCELLANEOUS TASKS

This category includes training techniques that are printed on paper and designed to train vergence, accommodation, and accurate eye movements. Many of the eye movement tasks are also useful for suppression training when combined with anaglyphs. Another type of technique included in this category is the Brock string (Fig. 5.5), which is a string with beads that is used to take advantage of physiologic diplopia.



■ **Figure 5.5** Brock string.

Advantages

These techniques are generally the least expensive therapy procedures. A sufficient variety of targets are available, and the techniques work well with shallow to moderate suppression. These techniques work especially well for convergence therapy.

Disadvantages

It is difficult to maintain interest in young children.

CATEGORY 5: STEREOSCOPES

Stereoscopes are designed on the principle of dividing physical space into two separate areas of visual space, each of which is visible to only one eye. This is accomplished by dissociating the eyes mechanically with a septum (Brewster stereoscopes, Fig. 5.3) or by using two separate viewing tubes or mirrors (Wheatstone stereoscopes, Fig. 5.2). In addition, stereoscopes use lenses and prisms (Brewster stereoscopes) or mirrors (Wheatstone stereoscopes) to allow one to test and train at different simulated distances. In most cases, vision therapy for heterophoric patients can be successfully completed without the use of stereoscopes. Instrument training is useful, however, under the following circumstances:

- **If a patient is experiencing difficulty fusing with techniques from other categories.** Some patients respond better initially to instrument training techniques that present stimuli under less natural seeing conditions. Although this is unusual and not totally predictable, it is worthwhile to try stereoscopic procedures when a patient is not responding well to free-space techniques.
- **After a patient has successfully completed the nonstereoscopic techniques described in Chapters 6 to 8 that are more natural.** It is often useful to perform some training with stereoscopes at this point, because such training allows considerable flexibility with the type of target used and the distance at which therapy can occur. With conditions such as divergence excess, the most difficult task is a first-degree target at a distance setting. Stereoscopes are well designed to deliver this type of stimulus.
- **To provide variety, which is an important consideration in vision therapy.** The use of stereoscopes is another way to improve fusional ranges and facility. A particularly useful technique, only available with stereoscopes, is called tromboning. Tromboning can be performed with Brewster-type stereoscopes and is a procedure in which a target is moved toward and then away from the patient. The unique aspect of this technique is that as the target is moved toward the patient, he or she must accommodate to maintain clarity and diverge to maintain fusion. As a target is moved away, the patient must relax accommodation and converge. This, of course, is opposite to what occurs in the normal seeing environment and is why this procedure is valuable.

Advantages

The primary strengths of this approach for nonstrabismic binocular anomalies are the ability to present a large variety of targets at distance and intermediate settings and the ability to select first-, second-, and third-degree targets. Stereoscopes can be effective even in cases of deep suppression.

Disadvantages

The artificial nature of the tasks involved in instrument training is a disadvantage of this approach. Questions have been raised about the transfer of improvements in binocular vision from the instrument to situations outside the instrument (1).

Stereoscopes are the most expensive vision therapy techniques, and they can be heavy and bulky. As a result, many varieties are more appropriate for office therapy than home therapy.

CATEGORY 6: AFTERIMAGES, ENTOPTIC PHENOMENA, AND ELECTROPHYSIOLOGIC TECHNIQUES

Techniques in this category are used in the treatment of amblyopia, eccentric fixation, anomalous correspondence, constant strabismus, and nystagmus. Because these topics fall outside the scope of this text, we do not describe the majority of these procedures. Examples of therapy techniques included in

this category are devices for creating afterimages, the Maxwell spot, the Haidinger brush, and auditory biofeedback. Afterimages are used occasionally in the treatment of ocular motor dysfunction, and we describe these procedures.

General Principles and Guidelines for Vision Therapy

Before describing the various categories of vision therapy procedures, it is important to understand that there are general principles and guidelines that apply to all vision therapy techniques, as well as specific principles and guidelines for binocular vision, ocular motility, and accommodative techniques. Vision therapy is similar in many ways to other types of therapy that involve learning and education. If we look at other types of learning, it becomes clear that there are specific guidelines to facilitate learning and success. Because vision therapy can be considered a form of learning and education, similar principles and guidelines must be used to achieve success. The following guidelines have been derived from basic learning theory.

Before beginning vision therapy, follow sequential management considerations (Chapter 3). When developing the vision therapy program, always consider amblyopia and suppression therapy before beginning fusional vergence therapy.

- **Determine a level at which the patient can perform easily.** Working on this level makes it easier for the patient to become aware of the important feedback cues, strategies, and objectives involved in vision therapy, and also builds confidence and motivation.
- **Be aware of frustration level.** Signs of frustration include general nervous and muscular tension, hesitant performance, and possibly a desire to avoid the task.
- **Use positive reinforcement.** The patient should be rewarded for attempting a task, even if it is not successfully completed. Reinforcers can be verbal praise, tokens that can be exchanged for prizes, or participation in a task that the patient enjoys. Feldman (12) has described, in detail, the various principles of behavior modification applied to optometric vision therapy. It is a valuable reference for clinicians involved with vision therapy.
- **Maintain an effective training level.** Start at an initial level at which the task is easy and gradually increase the level of difficulty, being very careful to watch for signs of frustration. Vision training should be success oriented, that is, build on what the patient can do successfully, as opposed to giving tasks that are too difficult.
- **Emphasize to the patient that changes must occur within his or her own visual system.** Birnbaum (13), in defining some of the critical concepts of which the vision therapist must be aware, goes beyond *what* should be done and concentrates on *how* vision therapy should be performed and the role of the vision therapist. This role, according to Birnbaum, is to carefully arrange conditions for learning to occur. His view parallels ours, stressing the use of learning theory principles. More important, and perhaps the key to vision therapy, is teaching the patient to internalize changes in visual function, as opposed to just achieving certain criteria for specific techniques. Often, as patients go through a vision therapy program, they gain the impression that it is the instrumentation, lenses, or prism that effect the change in their visual system. Unless told otherwise, a patient may believe that these external items are the keys to their success in vision therapy.

Birnbaum (13) stresses that “the patient must be made aware that the changes actually occur internally, within the visual system, and not externally in the instruments and paraphernalia utilized in vision therapy.” To accomplish this objective, the language used in communication between the optometrist and patient is critical. Birnbaum provides several excellent examples, including the following scenario. When performing a fusional vergence technique, the clinician might say, “Try to keep the picture single.” The problem with this instructional set is that although the patient is asked to try, the instructions are given in terms of what happens to the targets rather than what changes the patient must make internally to achieve the desired result. Birnbaum suggests the following as being a preferable instructional set:

Explain to the patient that if the picture is double, it is because he or she is looking too far or too close in space. In order to make it single, the patient needs to look nearer or farther; the patient needs to make adjustments in himself or herself, in where he or she is pointing his or her eyes in space, and then the picture will become single.

The underlying important concept is that it is not just the specific technique that leads to success in vision therapy. Rather, the key factor is to get the patient to take responsibility for creating internal change.

- **Make the patient aware of the goals of vision therapy.** The patient must know why he or she is in vision therapy. The patient should be able to explain what his or her problem is, how it affects performance, and the goals of vision therapy. This is true for children as well as adults. Even with a young child, the therapist should try to establish some understanding on the part of the child about what is wrong with his or her eyes and why vision therapy is necessary. For each therapy technique, the child should be able to explain what he or she needs to do to accomplish the desired task.
- **Set realistic therapy objectives and maintain flexibility with these objectives or endpoints.** With all therapy techniques, there are certain general objectives that we expect to achieve before we proceed to the next procedure. In this text, we call these objectives *endpoints*. For instance, in Chapter 6, we recommend ending the tranaglyph procedure when the patient can fuse to about 30 base-out, and ending accommodative facility when the patient can complete 12 cpm of accommodative facility with +2.00/2.00 lenses using a 20/30 target.

It is important to understand that these endpoints are only guidelines and that flexibility and clinical judgment are ultimately just as important in deciding when to move on to another procedure. The objective of vision therapy is to solve the patient's problems as quickly as possible. If a patient can only achieve 25 base-out with the tranaglyph procedure in spite of sufficient effort, it makes sense to move on and try another technique.

- **Use vision therapy techniques that provide feedback to the patient.** All therapy and teaching progresses more effectively when feedback about performance is available to the student or patient. The various feedback mechanisms used in vision therapy include the following:
 - Diplopia
 - Blur
 - Suppression
 - Luster
 - Kinesthetic awareness
 - Small in, large out (SILO) response
 - Float
 - Localization
 - Parallax.

FEEDBACK MECHANISMS USED IN VISION THERAPY

Diplopia

Diplopia is a powerful feedback cue and relatively easy to explain to a patient. If a patient experiences diplopia during a therapy procedure, he or she receives immediate feedback that he or she is not aligning his or her eyes appropriately. It is important to try to provide the patient with methods of overcoming diplopia. These methods are discussed later.

Blur

Explain to the patient that blur represents feedback that the focusing system is either overfocusing or underfocusing. As the patient gains control over the accommodative system, he or she should be able to make the necessary changes in accommodation to overcome blur.

Suppression

Suppression is also an easy feedback mechanism to demonstrate and explain to patients. Virtually all binocular vision therapy procedures contain elements in the targets that can be used to monitor suppression. For example, there is often a letter "R" and a letter "L" printed on vergence therapy techniques. The "R" is seen only by the right eye and the "L" only by the left eye. If one of these letters is not seen by the patient, he or she receives feedback about suppression. Other techniques use different stimuli, such as a dot, cross, or a vertical or horizontal line, to help monitor suppression. In all cases, the clinician should identify what the suppression cues are for a given therapy technique and utilize these cues to make the patient aware of suppression.

Luster

Luster is the perception of the combination of colors seen when the patient is asked to fuse targets of different colors. Sometimes patients also report a shimmering effect when they fuse targets of different colors. Vision therapy procedures using red and green targets lead to the perception of luster. The clinician should make the patient aware that the fused image is a mixture of the two colors. The absence of luster is clinically significant. For example, if the patient sees only red or only green, it is one indication that he or she may be suppressing.

Kinesthetic Awareness

A common theme throughout all vision therapy techniques for accommodation and binocular vision is stressing an awareness of the sensation of accommodating or converging. We want the patient to be able to feel the difference between stimulating and relaxing accommodation and the difference between converging and diverging. When performing any technique, ask the patient to explain what he or she is feeling. “Does it feel like you are straining or relaxing your eyes? Does it feel like you are looking close and crossing your eyes or looking far and relaxing your eyes?” Therapy will often progress considerably faster if the patient is able to develop this awareness.

SILO Response

SILO Response Associated with Vergence

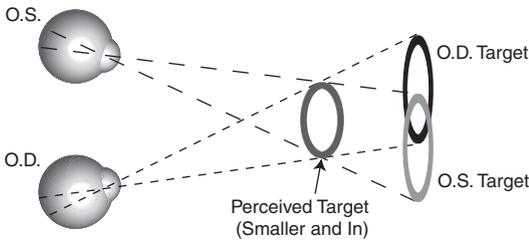
SILO is an acronym for “small in, large out.” It refers to the fact that as a patient is asked to maintain fusion while divergence or convergence demand is varied, he or she will experience perceptual changes. Specifically, as the convergence demand is increased and the patient maintains fusion, the target may appear to become smaller and move closer or in toward the patient. This is the “SI” of the acronym SILO (small and in). Conversely, as the divergence demand is increased and the patient maintains fusion, the target may appear to become larger and move farther away or out. This is the “LO” of the acronym (large and out).

The underlying basis for the SILO phenomenon is size constancy. Leibowitz et al. (14) and Leibowitz and Moore (15) studied the role of accommodation and convergence in the size constancy phenomenon, and their findings offer one explanation for the SILO phenomenon. The authors noted that as one’s gaze shifts from a far to a near object, accommodative and convergence changes must occur for the observer to maintain clear single vision. They found that the initiation of these accommodative and convergence movements is coupled with an expectation that this action will be accompanied by an alteration in retinal image size. Anticipating such a change, the patient corrects for it and thereby maintains size constancy.

According to this theory, when an observer accommodates and converges as an object approaches, the retinal image size increases. The perceptual system therefore must make a correction to maintain size constancy and shrink the size of the image. As an object is moved farther away, the retinal image size decreases and the perceptual system must expand the image. With the vision therapy techniques under consideration here, the important difference is that the retinal image size is never changing while accommodative and convergence changes occur. Therefore, the shrinkage adjustment of the perceptual size constancy system normally associated with convergence and accommodation leads to a perception that the object is becoming smaller. Similarly, the normal expansion adjustment associated with a relaxation of accommodation leads to a perception that the object is becoming larger with divergence techniques. Thus, the perceived size change is directly related to accommodative and vergence changes.

In regard to the apparent distance changes, subjects give variable responses. Some report that the object becomes smaller as it moves closer (SILO). Others report that the image becomes smaller and moves farther away or out (SOLI: small out, large in). These different responses can be explained if we assume that individuals use different cues for distance perception. The first possibility is that an individual uses vergence as a cue for his perception of distance. This person perceives the object to be moving closer because he is converging and he “knows,” from previous experience, that when he does so, it means he is looking at an object moving closer. Conversely, when the person diverges, he “knows,” from prior experience, that the object must be moving away.

Those who do not use vergence as a cue to perceive distance probably use apparent size as a cue. An individual using apparent size as a cue would be expected to report SOLI. For example, as the person converges using a vectogram target, he/she will perceive the target becoming smaller, based on Leibowitz’s study.



■ **Figure 5.6** Geometric explanation for the “small in, large out” phenomenon. The illustration demonstrates that the fused target would appear to be smaller and closer than either of the real targets during a base-out fusion technique.

Because the target is becoming smaller, the person perceives the target as moving out or farther away. The person perceives things this way because, from previous experience, as a target becomes smaller, it generally means it is moving away.

There is also a geometric explanation for the SILO phenomenon. Figures 5.6 and 5.7 illustrate the expected response for a convergence and divergence demand in fusional vergence therapy technique. In Figure 5.6, the right eye is viewing the left target, and the left eye is viewing the right target. The visual axes cross between the patient’s eyes and the targets and represent the location in space at which the patient perceives the fused target. Thus, the target will appear to move closer, or in. The illustration also demonstrates that the fused target would appear to be smaller than either of the real targets. Figure 5.7 is a geometric explanation for a patient’s perception of larger and out during a divergence task. In this illustration, the right eye is viewing the right target, and the left eye the left target. The fused image is perceived where the visual axes cross, which is beyond the plane of the targets. The fused target is therefore perceived as farther away and, as Figure 5.7 illustrates, larger.

SILO Response Associated with Lenses

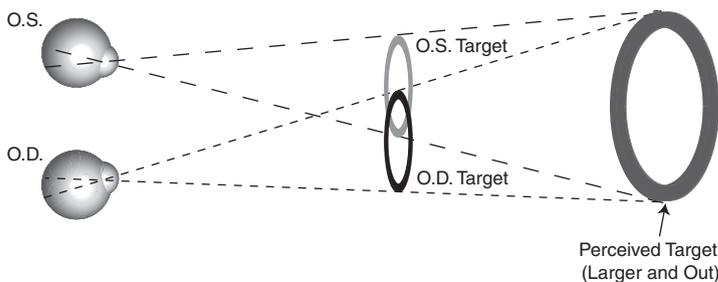
When an individual accommodates through plus or minus lenses, perceptual changes in the apparent size and distance of the object occur similar to those described above. The reasons for these perceived changes, however, must be different, because with lenses the retinal image size *does* change, whereas with vergence the retinal image size remains constant. Minus lenses cause minification of the retinal image, and plus lenses cause magnification.

A possible explanation for perceptual changes that occur with lenses is that minus lenses minify the retinal image and cause the response of “smaller,” whereas plus lenses magnify the retinal image and lead to the response of “larger.” Based on the perceived change in size, the patient reasons “The target is smaller; therefore, it must be farther away” with minus lenses and “The target is larger; therefore, it must be closer.” This would be a SOLI response and is actually the expected finding with lenses.

Clinical Relevance of SILO Response

It is apparent from the literature and clinical experience that SILO is not the only normal or expected response to vergence or accommodative techniques. This is particularly true with lenses.

A response of SOLI is not necessarily an indication of a binocular or accommodative problem. Rather, it is a reflection of the individual’s perceptual style and attention to visual stimuli. Whereas the appreciation of



■ **Figure 5.7** Geometric explanation for the “small in, large out” phenomenon. The illustration demonstrates that the fused target would appear to be larger and farther away during a base-in fusion technique.

the object becoming smaller with convergence demand and minus and becoming larger with divergence and plus seems to be almost universal, the perception of the distance change is by no means predictable. From clinical experience, we have found that adults are more likely to respond with SOLI than SILO. A possible explanation for this is that adults are more likely to respond with what they “know” should occur as a target becomes smaller and to report that the object must be moving away from them. Children tend to be less rigid in their perceptions and will respond with what they see: the object is becoming smaller and moving closer.

It is important to remember that the main value of the SILO phenomenon is to provide feedback to the patient about his or her performance. As long as a consistent pattern can be established, the feedback is useful. Thus, if a patient consistently feels that with increasing convergence demand the target appears to become smaller and move away, this will still represent a useful feedback technique for this patient.

It is desirable, however, to spend some time initially with the patient to try to make him or her more aware of what he or she is seeing and try to elicit a SILO response. A SILO response is desirable because it helps the therapist create an awareness on the part of the patient of what is occurring during the therapy procedure. For example, if we are performing a convergence technique, it is helpful to be able to establish that the patient must cross his or her eyes and look closer as the targets are separated. If the patient perceives that the target is becoming smaller and moving closer, this reinforces the concept of looking closer and crossing the eyes. If a patient experiences SILO, the therapist can say the following: “Do you see how the target appears to become closer and smaller as we separate the targets? This is feedback for you about what your eyes are doing during this task. The target looks like it is moving closer to you because you are looking closer as the task becomes more difficult.” If a SILO response cannot be elicited, the clinician has to use other feedback cues to establish the concept of looking close.

Float

Float refers to the perception that a target is floating closer or farther away as the demand is changed from convergence to divergence during vergence therapy. With convergence, the target should appear to float closer, and with divergence, farther away. This perception is actually part of the SILO phenomenon. As discussed previously, not all patients see the target moving closer with convergence or farther with divergence. If this response can be elicited, it becomes a very helpful feedback cue that can be used by the therapist to establish the concept of looking closer during convergence and farther during divergence therapy.

Localization

Localization is one of the more valuable feedback cues available for vergence therapy. It refers to the ability of the patient to point to where the target appears to be when fusion occurs and is based on the concept of physiologic diplopia. Figure 5.6 illustrates the concept of localization. In Figure 5.8, the patient is working with a Quito vectogram and is fusing with a convergence demand. The visual axes cross before the targets, and the patient should perceive the target as smaller and closer. The patient is now asked to pick up a pointer and point to where he or she sees the target floating. The objective is for the patient to point to the target and perceive one target and one pointer.

■ **Figure 5.8** A patient working with a Quito vectogram is fusing with a convergence demand. The patient points to where she sees the target.



If the patient places the pointer in the general area of where his or her visual axes cross, he or she will perceive one target and one pointer. If the patient points closer or farther away than the intersection of his or her visual axes, he or she will report diplopia of either the target or the pointer. The importance of localization is that it allows the patient to develop an understanding of what changes must occur within his or her visual system to accomplish the therapy task. If the patient can localize the target, he or she will begin to understand that when the targets are separated to create a convergence demand, he or she must look closer and cross his or her eyes to maintain single vision and fusion. We cannot overemphasize the importance of the patient developing this understanding of what changes he or she must make to accomplish a particular task.

Often when a patient is first asked to try to localize during convergence therapy, he or she experiences difficulty. At first, the patient may tend to point to the actual plane of the target, rather than the intersection of the visual axes. It is useful to state, "We both know that the targets are back there, but what I want you to do is to try to get the feeling of where you are looking and where the target is floating."

If the patient continues to have problems localizing, the next step is to make him or her aware of the concept of physiologic diplopia and to use this phenomenon to get the patient started. The explanation we use with patients is as follows: "The way the visual system works is that whatever object we are directly viewing is seen as one, while all other objects are seen as double." It is then useful to demonstrate this by having the patient look at a pointer while you hold another object in the background. Have the patient experiment with this concept for several minutes until he or she is comfortable with this idea and is satisfied that he or she can experience physiologic diplopia. Demonstrate that when the more distant object (seen as two) is moved closer to the fixation object, it will also be seen singly when it is in approximately the same position in space. If the patient now understands the concept that we experience single vision if we point to where the eyes are looking, the idea can be applied to vision therapy techniques.

For example, assume the patient is fusing a Quoit vectogram using positive fusional vergence (PFV). We ask the patient to localize and point to where he or she perceives the quoit. The patient, however, points too far away and experiences diplopia. If the patient understands the concept of physiologic diplopia, we would say the following:

This time I want you to hold the pointer at the slides and look directly at the pointer. Do not try to keep the ropes single. If you look at the pointer, while you do so, you will see two ropes in the background. Now slowly move the pointer toward yourself, always looking directly at the pointer and being aware of the two ropes. As you do this, you will notice that, as you move the pointer toward yourself, the two ropes appear to move closer to one another. Continue moving the pointer toward yourself very slowly and you will notice that, at some distance, you will see one pointer and one set of ropes. This is where you must look to accomplish this task. Do you feel yourself looking closer? Try to get the feel of where you have to look. Can you now understand where you have to look to see one rope? Can you see that the rope is floating closer?

Generally the patient continues to be unable to simply pick up the pointer and immediately localize correctly. However, with repetition, most patients will soon understand what they must do visually during convergence therapy. Once they grasp this concept, the rest of the therapy is simplified.

Localization is a very powerful feedback cue for convergence therapy. With divergence therapy, it is more difficult to use, but it can still be an important aid to therapy. The primary difficulty with divergence is that as the fusional vergence demand increases, the object floats farther away from the patient and the patient can no longer point to it because it is too far away to physically reach with a pointer. Another problem is that depending on the target being used, the patient must visualize an object moving farther away, passing through an opaque background. For example, if we are using a vectogram such as Quoits with the Polachrome illuminated trainer (Fig. 5.9), the patient would be asked to visualize the rope floating behind the white stand. The ability of people to visualize varies greatly, and an inability to do so interferes with the use of localization for divergence therapy.

This second problem is rather simple to overcome and merely involves selecting targets that are printed on clear plastic, such as vectograms, tranaglyphs, Free Space Circles, and Eccentric Circles (Fig. 5.10). In addition, if the targets are to be placed in a holder, the holder should also be transparent, like the one illustrated in Figure 5.10.

The first problem—not being able to point to the target as the divergence demand increases—can also be overcome. The following divergence therapy procedure is a very powerful training technique

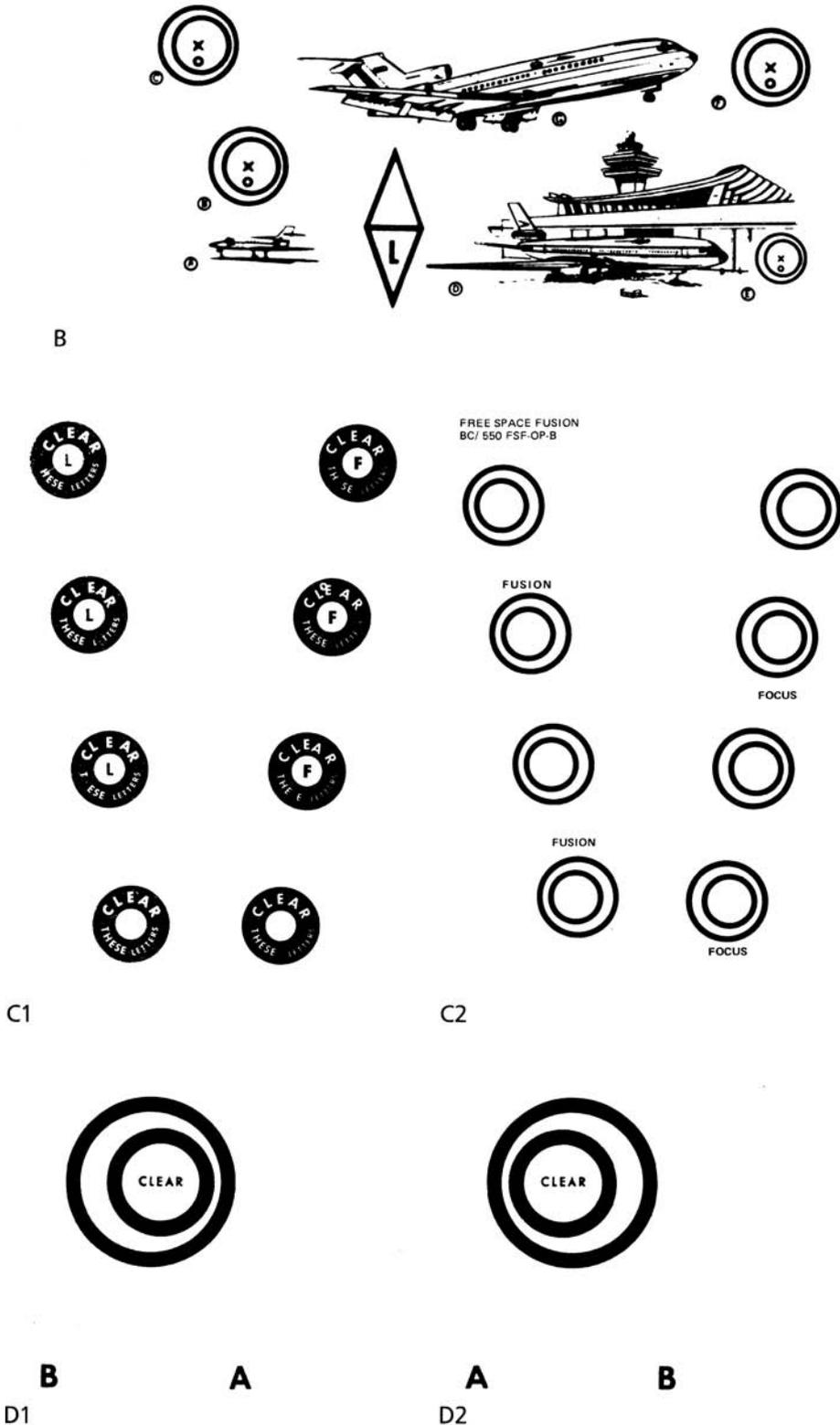


■ **Figure 5.9** Quoit vectogram setup in the Polachrome illuminated trainer.

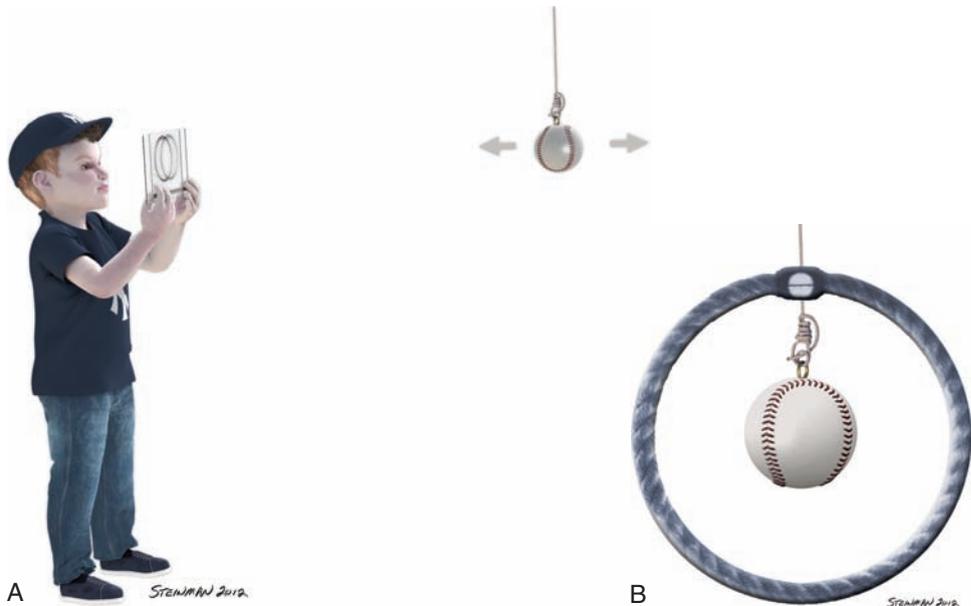
and, in most instances, will lead to excellent progress with divergence therapy. The patient is asked to stand several feet in front of a ball that has been suspended from the ceiling (Fig. 5.11). The height of this ball should be adjustable to permit the therapist to change the height so that it is at eye level for any given patient. A Quoit vectogram is placed in a clear holder, and the patient is instructed to hold the target at arm's length so that he or she can see the ball in the background, directly in the center of the quoit. As the quoit targets are slowly separated to create a divergence demand, the patient is asked to maintain fusion and describe where the target is floating. At this point, the therapist pushes the ball to create motion in an arc moving toward and away from the patient. The patient should perceive that the ball is moving in front and behind the quoit, which itself appears to be floating behind the plane of the actual vectogram targets. As the targets are separated, the patient will have to continue moving backward to keep the quoit floating out at the point at which the ball just swings in front of and behind the quoit. Once appreciated, this is quite a startling experience for the patient and provides the feedback necessary for him or her to understand that, when fusing during divergence therapy, he or she has to relax his or her eyes as if something were moving farther away.



■ **Figure 5.10** Selected targets that are printed on clear plastic: **A:** Quoit vectogram, (Continued)



■ Figure 5.10 B: tranaglyph, C: Free Space Fusion cards and Lifesaver cards, D: Eccentric Circles.



■ **Figure 5.11** **A:** Child working with Quoit vectogram held in a transparent holder, while viewing a distance object that is swinging forward and backward. **B:** Child's view of Marsden ball passing in front of and behind the Quoit vectogram held in a transparent holder.

Parallax

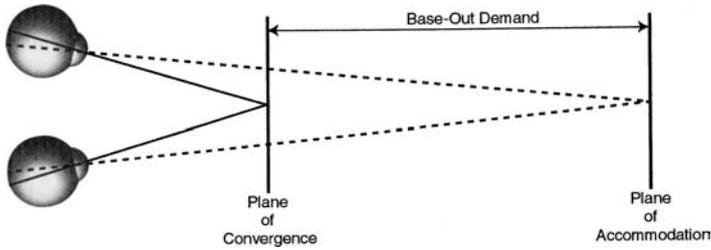
Parallax refers to the appreciation of movement of the fused target as the patient moves. Specifically, if a patient is fusing a target set for convergence and moves to the right, he or she should see the target move to the right. With a convergence demand, the target moves in the same direction as the patient. With divergence, the target should appear to move in the direction opposite to the patient's movement. Thus, if a patient is working in the divergence direction and moves to the left, the target should appear to move to the right. If the same patient moves away from the target by taking two steps backward, the target should appear to move away from him or her.

Knowledge of parallax can be used by the therapist as an aid to monitor the responses of a young child. The therapist can periodically ask the child to move right to left and back and forth and question the child about movement of the target. For the older patient, parallax becomes another feedback cue that can be used to provide information about whether the patient is accomplishing the desired task.

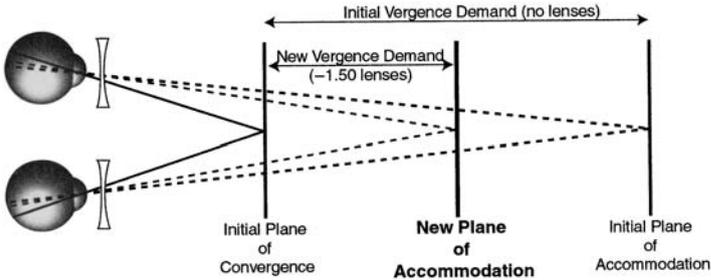
Binocular Vision Therapy: Underlying Concepts

Several basic concepts underlie all binocular vision therapy techniques. To increase fusional vergence ranges, a technique must do one of two things—either maintain accommodation at the plane of regard and change the stimulus to the vergence system or maintain vergence at the plane of regard and change the stimulus to accommodation. The most common approach used in binocular vision therapy techniques is to maintain accommodation at the plane of regard, which is generally 40 cm from the patient. While the patient keeps the target clear, the vergence demand is altered. With convergence, the plane of vergence is moved toward the patient, and with divergence, the plane of vergence is moved beyond the plane of accommodation. The greater the separation between the plane of accommodation and the plane of vergence, the greater the demand on the fusional vergence system.

These concepts are illustrated in Figures 5.12 and 5.13. An example of this type of procedure would be to ask a patient to fixate on a 20/30 letter held at 40 cm and maintain clear and single vision while you gradually increase the convergence demand. To maintain clarity, the patient must maintain accommodation at 40 cm. To maintain single binocular vision, the patient must converge as the base-out prism is added. The only way



■ **Figure 5.12** Planes of accommodation and vergence during convergence therapy.



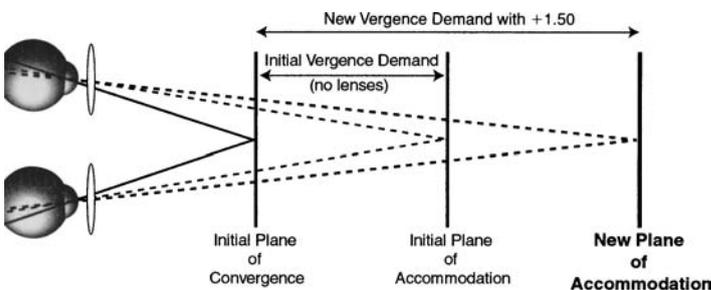
■ **Figure 5.13** Effect on the plane of accommodation when minus lenses are used during convergence therapy.

to converge while accommodation is held constant is to use PFV. The important concept to remember is that by forcing the patient to hold accommodation steady, accommodative convergence is also inhibited and the patient must use fusional vergence or will experience diplopia. Forcing the use of fusional vergence by controlling accommodation is the basis of many binocular vision therapy techniques.

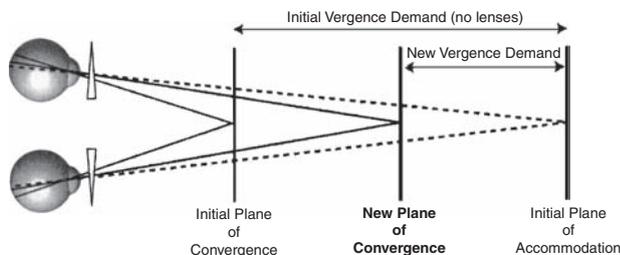
A fusional vergence technique could also be designed to maintain vergence at the plane of regard and change accommodation. An example of this design would be to ask a patient to maintain single vision while adding plus and minus lenses (accommodative facility). It is important to understand that either design essentially accomplishes the same objective.

Any technique that causes the planes of accommodation and convergence to move farther apart will increase the demand of the task. Conversely, if the therapist can move the two planes closer together, the task becomes easier to accomplish. These concepts are frequently used when working with a patient who is either having difficulty making progress or needs to work at a higher level. Two methods of changing the relationship between the plane of accommodation and plane of vergence are the use of lenses and prisms.

Figure 5.13 illustrates the use of lenses with a convergence technique. In this figure, the accommodation is at the plane of regard, while the vergence demand is 16 base-out. If the patient is having difficulty fusing at this level, minus lenses can be added, making the task easier because this moves the plane of accommodation closer to the plane of convergence, decreasing the convergence demand. If 16 base-out is too easy for the patient, the therapist can add plus lenses. As shown in Figure 5.14, this moves the plane of accommodation farther away from the patient and increases the distance between the plane of accommodation and the plane of vergence.



■ **Figure 5.14** Effect on the plane of accommodation when plus lenses are used during convergence therapy.



■ **Figure 5.15** Effect on the plane of vergence when base-in prism is added during convergence therapy.

Prism can also be used to change the relationship between the two planes (Fig. 5.15). In Figure 5.15, the patient is accommodating at the plane of regard and the vergence demand is base-out. If base-in prism is added, it moves the plane of vergence closer to the plane of accommodation and decreases the difficulty of the task. The addition of base-out will increase the separation between the two planes and increase the level of difficulty of the task.

Binocular Vision and Accommodative Therapy: Specific Guidelines

1. **Before beginning vision therapy, follow the other sequential considerations discussed in Chapter 3.** In all cases of accommodative and binocular disorders, it is important to consider optical correction of ametropia, added lens power, prism, and occlusion before beginning vision therapy.
2. **When developing the vision therapy program, always consider amblyopia and suppression therapy before beginning fusional vergence therapy.** Most patients with nonstrabismic binocular vision disorders have normal acuity in both eyes and only experience a mild degree of central suppression. With such patients, amblyopia and antisuppression procedures are not necessary. In fact, if you emphasize suppression cues initially with such patients, they may become frustrated by their inability to fuse without central suppression, leading to discouragement and lack of practice. Flax (16) suggests that as fusional vergence improves, suppression is no longer a necessary adaptation and is eliminated.

However, when amblyopia or deep suppression is present, it is important to prescribe procedures to eliminate the amblyopia and decrease the extent of the suppression before emphasizing fusional vergence. The decision to incorporate amblyopia therapy is easy and is based on the presence or absence of the diagnosis of amblyopia. The decision about prescribing suppression techniques is more difficult. The results of the diagnostic evaluation can be helpful. A patient who does not report diplopia during the near point of convergence and fusional vergence testing generally has deep enough suppression to affect performance during binocular vision therapy. In some cases, however, it is not possible to make a determination of the extent of suppression until vision therapy actually begins. As various procedures are attempted, it becomes obvious that attention needs to be devoted to eliminating the suppression. An example is a patient who can only intermittently fuse and reports either a green or red target, rarely being able to see both the red and green targets simultaneously.
3. **Begin therapy stressing the direction of difficulty.** For example, with convergence insufficiency, stress convergence therapy initially; for convergence excess, start with divergence therapy. However, it is often useful, in the very first visit or two, to actually begin therapy in the direction that is easiest for the patient. The purpose of this approach would be to demonstrate the various procedures and to achieve some early success.

The same concept applies to accommodative anomalies. For example, with accommodative excess, begin with an emphasis on plus; for accommodative insufficiency, emphasize minus.
4. **Begin working with a technique that is within the capabilities of the patient.** Again, the importance of achieving some early success cannot be overemphasized.
5. **Generally begin with peripheral targets with high stereopsis demand and gradually proceed to more central targets.** Patients with nonstrabismic binocular vision disorders generally function more effectively when viewing a target with stereopsis or third-degree fusion cues. Therefore, begin with targets that ensure early success and gradually proceed to targets that are more difficult. The sequence used for heterophoria problems is third-degree to second-degree to first-degree fusion tasks. In most heterophoria cases, first-degree fusion tasks are not even required.

6. **Allow some blur (inappropriate accommodative response) if it helps the patient.** Targets requiring precise accommodation represent a more difficult task initially. If a patient is trying to fuse a convergence demand and has limited PFV, he or she will often try to supplement his or her fusional vergence with accommodative vergence. If you use targets with precise accommodative detail, the patient will be unable to maintain clarity while fusing if he or she uses accommodative convergence. Since our primary initial goal is success, we use targets that do not require precise accommodation. Thus, in the early stages of therapy, patients are permitted to use some degree of accommodative vergence to supplement fusional vergence.
7. **Eventually train both PFV and negative fusional vergence (NFV) and relaxation and stimulation of accommodation, regardless of the original diagnosis.** It is not unusual to find that if therapy consists only of either convergence or divergence techniques, the patient begins losing the ability to function effectively in the direction not being trained. For example, a convergence insufficiency patient who has only done convergence therapy may present, at the end of the treatment, with improved PFV and a normal near point of convergence. NFV may be low and the patient may have a low positive relative accommodation (PRA), inability to clear 2.00 lenses with binocular accommodative facility testing, and a high monocular estimation method (MEM) retinoscopy finding. Although therapy successfully eliminated the convergence insufficiency, the patient may still be uncomfortable because of this newly induced problem. To avoid such situations, it is prudent to begin working in the vergence direction opposite the problem in the middle phase of therapy.
8. **Emphasize amplitude first and then facility of either the accommodative or fusional vergence response.** Binocular vision therapy can generally be performed two ways. The first method is *sliding* or *tonic vergence*. In a tonic vergence procedure, the vergence demand is increased in a very gradual manner. The second method is *phasic vergence training*, which is also referred to as *jump* or *step vergence training*. In this type of procedure, the vergence demand is changed in large, discrete steps. Research has been done comparing the efficacy of these two types of procedures (17). The evidence to date suggests that both procedures are effective in producing gains in fusional vergence, although phasic vergence training shows the greatest improvements. We recommend that both types of procedures be utilized and suggest beginning with sliding vergence techniques. These tend to be easier for the patient initially. It is not necessary to spend a considerable amount of time developing large fusional vergence amplitudes. Rather, once the patient has developed initial fusional vergence skills, step vergence procedures can be used and emphasized.
 In regard to accommodative therapy, it is important to first achieve normal accommodation and relaxation of accommodation with little to no emphasis on the speed of the response. A range of +2.50 to 6.00 untimed is a reasonable goal for schoolchildren and teenagers. This value is dependent on the amplitude of accommodation and age. Older patients should be able to achieve a range, with minus lenses, equal to one half the amplitude of accommodation. It is generally easiest to proceed from small to large ranges. Once the range has been normalized, the variable of time should be introduced. Start with +0.50/−0.50 lenses and gradually increase to the range that is appropriate for the age of the patient. The goal is to increase the speed and decrease the latency of the accommodative response.
9. **Emphasize quality, not quantity, when training fusional vergence and accommodation.** Evidence suggests that phasic training may be more effective than tonic procedures. Techniques that emphasize the speed of the fusional vergence and accommodative responses and step rather than smooth changes are most desirable.
10. **Equalize amplitude and facility of the right and left eyes when training accommodative skills.**

BINOCULAR VISION THERAPY: SPECIFIC GUIDELINES

- Begin therapy stressing the direction of difficulty.
- Generally begin with peripheral targets with high stereopsis demand, and gradually proceed to more central targets.
- Initially allow some blur (inappropriate accommodative response) if it helps the patient get started.
- Eventually train both PFV and NFV regardless of the original diagnosis.
- Emphasize amplitude first and then facility of the fusional vergence response.
- Emphasize quality, not quantity, when training fusional vergence.

ACCOMMODATIVE VISION THERAPY: SPECIFIC GUIDELINES

- Begin therapy stressing the direction of difficulty.
- Eventually train both relaxation and stimulation of accommodation, regardless of the original diagnosis.
- Emphasize amplitude first and then facility of the accommodative response.
- Emphasize quality, not quantity, when training accommodation.
- Equalize amplitude and facility of the right and left eyes when training accommodative skills.

OCULAR MOTOR THERAPY: SPECIFIC GUIDELINES

1. **Before beginning vision therapy, follow the other sequential considerations discussed in Chapter 3.** In all cases of ocular motility dysfunction, it is important to consider optical correction of ametropia and added lens power before beginning vision therapy.
2. **Begin working with a technique that is within the capabilities of the patient.** The importance of achieving some early success cannot be overemphasized.
3. **Emphasize accuracy first and then speed of either the saccadic or pursuit eye movement.** Many children with ocular motor dysfunction also have attentional problems and impulsive cognitive styles. In fact, sometimes it is not clear whether the impulsivity and inattention are the etiology for the poor fixation and ocular motility or whether the motility problems are the basis for the attentional and impulsivity problems. To try to slow the child down and work toward encouraging a more reflective, thoughtful, and analytical style, we recommend stressing accuracy of the response at first. As accuracy improves during therapy, speed can then be incorporated as a variable.
4. **For saccades, go from gross (large) to fine (small) eye movements.** For pursuits, the sequence is the opposite—from fine (small) to gross (large) eye movements.
5. **Begin motility therapy monocularly and continue until both eyes are approximately equal in ability.** Once monocular skills are equal, accurate, and fast, begin binocular ocular motility activities.
6. **Eliminate head movements during both pursuit and saccadic eye movements that can reasonably be accomplished without head movement.**
7. **Increase the complexity of the task to develop more reflexive automated pursuits and saccades.** This can be accomplished by adding a metronome, a balance board, or simple cognitive tasks during any ocular motility task.

OCULAR MOTILITY THERAPY: SPECIFIC GUIDELINES

- Emphasize accuracy first and then speed of either the saccadic or pursuit eye movement.
- For saccades, go from gross (large) to fine (small) eye movements. For pursuits, the sequence is the opposite—from fine (small) to gross (large) eye movements.
- Begin motility therapy monocularly and continue until both eyes are approximately equal in ability. Once monocular skills are equal, accurate, and fast, begin binocular ocular motility activities.
- Eliminate head movements during both pursuit and saccadic eye movements that can reasonably be accomplished without head movement.
- Increase the complexity of the task to develop more reflexive, automated pursuits and saccades.

ANTISUPPRESSION THERAPY: SPECIFIC GUIDELINES

1. **Before beginning antisuppression therapy, follow the other sequential considerations discussed in Chapter 3.**
2. **Structure the training environment so that the patient is least likely to suppress.** The level or depth of suppression for any given patient can vary from very light to very deep. A key factor in suppression

therapy is selecting the room illumination and stimulus to decrease the likelihood of suppression. One way of grading or measuring the depth or intensity of suppression is by determining the stimulus strength necessary to make a patient aware of both targets. The deeper or more intense the suppression, the greater the stimulus strength necessary to eliminate it.

Clinically, we have several ways of modifying the stimulus strength or characteristics of the stimulus:

- Changing target illumination
- Changing target contrast
- Changing target focus
- Moving the target
- Flashing the target.

If a patient is suppressing, we can decrease the likelihood of suppression by increasing target illumination, contrast, and focus and by moving the target. An example of environmental conditions that tend to make suppression difficult is the use of a bright moving light in a totally dark room. As therapy progresses, the patient is asked to maintain awareness of diplopia as the stimulus strength is made lower.

Relative stimulus strength is another important concept when trying to eliminate suppression. Clinically, it is more effective to alter the stimulus strength of the target for one eye than for both together. For example, if a patient tends to suppress the right eye, placing a red glass before the left eye (increasing the relative luminance of the right eye) is much more likely to overcome suppression than turning up the illumination (increasing binocular luminance).

Another way of thinking about this concept of modification of the environment is to talk about natural versus artificial environmental conditions. Patients tend to suppress under natural seeing conditions. When seeing conditions become less natural or more artificial, suppression becomes more difficult to sustain. The general clinical rule for antisuppression therapy, therefore, is that the more artificial the environment, the more difficult it will be for the patient to suppress. We usually begin suppression therapy in artificial conditions and gradually move toward more natural seeing conditions.

An example of this progression is the use of a penlight and red/green glasses for antisuppression treatment. With the patient wearing red/green glasses, the room illumination is turned off completely and the only visible target is the light of a transilluminator or penlight. This is a very artificial environment and will often be sufficient to eliminate suppression. If not, the light can be moved from side to side or the clinician can rapidly move an occluder from one eye to the other. Once the patient can maintain diplopia under these conditions, the room illumination can be gradually increased until the patient can maintain diplopia awareness with full room illumination. To make conditions more natural, the red/green glasses are then removed, which generally will result in suppression again. Therefore, the room illumination is again decreased until the patient experiences diplopia. Room illumination is gradually increased until the patient can finally appreciate diplopia with full illumination and without red/green filters. This process typically may require 2 to 4 weeks of both in-office and home therapy.

- **Changing target illumination:** Based on the concept of relative stimulus strength, it is best to use a brighter target for the suppressing eye. As the tendency to suppress decreases, gradually decrease the difference in illumination until the patient can maintain diplopia while targets of identical illumination are used.
- **Changing target contrast:** When target contrast is high, suppression is less likely. Working with a bright target in a dark room increases contrast. If two objects are used, always place the target with higher contrast before the suppressing eye.
- **Changing target focus:** If two targets are being used, the target seen by the dominant eye should be defocused, decreasing its stimulus strength.
- **Moving the target:** Whether one target or two are being used, movement will always tend to make suppression more difficult. Again, altering the relative stimulus strength is more effective. Therefore, if two targets are used, movement of the target seen by the suppressing eye is more helpful.
- **Flashing the target:** This technique is based on the fact that it takes a brief period of time after presentation of the stimulus for suppression to begin. Flashing the target allows us to present the stimulus for periods of time that are shorter than the latency, and it eliminates suppression under these conditions.

ANTISUPPRESSION THERAPY: SPECIFIC GUIDELINES

- Structure the training environment so that the patient is least likely to suppress.
- Utilize the concept of relative stimulus strength. It is more effective to alter the stimulus strength for one eye than for both simultaneously.
- Modify target contrast: At the beginning of therapy, use a bright light for a target in a dimly illuminated room to create high contrast.
- Modify target illumination: Increase illumination for the suppressing eye, while decreasing illumination before the dominant eye.
- Modify target focus: Defocus the target for the dominant eye, while focusing the target for the suppressing eye.
- Utilize movement of the target.
- Begin therapy under artificial conditions and, as therapy progresses, move to more natural seeing conditions.
- Begin therapy with large peripheral targets and gradually decrease the size of the targets.

Summary

The easiest aspect of vision therapy is to design the treatment program and list the procedures that should be performed for a particular patient. More difficult than the design of the program is the actual implementation. Teaching patients what they need to look for, how to overcome obstacles, and how to internalize changes is the key to successful implementation. The general concepts and information provided in this chapter are vital to the success of any vision therapy program.

Study Questions

1. List and describe the general principles that should be considered when performing vision therapy.
2. Draw diagrams that explain the SILO phenomenon.
3. Describe a psychological explanation for the SILO phenomenon.
4. What do you expect the patient to experience when performing (i) base-out vision therapy (ii) base-in vision therapy?
5. Explain the importance of SILO in vision therapy.
6. Can vision therapy still be successful if a patient does not appreciate SILO?
7. Explain the underlying principle of localization.
8. Explain how and why vision therapy works by describing the planes of accommodation and convergence.
9. Your patient is trying to fuse a vectogram using base-out vergence. He or she is struggling to do so. What type of lenses can you use to make the technique easier? What type of prism can you use to make the task easier? Draw the planes of accommodation and convergence to support your answer.
10. Your patient has a diagnosis of accommodative insufficiency. What type of lenses should be used at the beginning of vision therapy—plus or minus lenses?

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Fusional Vergence, Voluntary Convergence, and Antisuppression

Fusional Vergence Procedures: Anaglyphs, Polaroids, and Liquid Crystal Filters
 Variable Tranaglyphs
 Variable Vectograms
 Nonvariable Tranaglyphs
 Computerized Binocular Vision Therapy Procedures
 Office-Based Computer Vision Therapy Software for Binocular Vision

Fusional Vergence Procedures: Lenses, Prisms, and Mirrors
 Flip Prism or Loose Prism

Fusional Vergence Procedures: Septa and Apertures
 Aperture Rule
 Modified Remy Separator

Fusional Vergence Procedures: Paper, Pencil, and Miscellaneous Tasks
 Eccentric Circles, Free Space Fusion Cards A, and Lifesaver Cards
 Lifesaver Cards and Free Space Fusion Cards B

Fusional Vergence Procedures: Stereoscopes
 Brewster Stereoscopes
 Cheiroscope
 Wheatstone Stereoscope

Voluntary Convergence Procedures
 Brock String
 Barrel Card/3-Dot Card

Antisuppression Procedures
 Bar Reader
 TV Trainer
 Red/Green Glasses and Penlight
 Vertical Prism Dissociation
 Mirror Superimposition

Computer Home Therapy Procedures
 Home Therapy System
 Computer Aided Vision Therapy: Computer Vergences Program—Random Dot Stereograms

Fusional Vergence Procedures: Anaglyphs, Polaroids, and Liquid Crystal Filters

VARIABLE TRANAGLYPHS

Objectives

- Increase the amplitude of negative fusional vergence (NFV) and positive fusional vergence (PFV)
- Decrease the latency of the fusional vergence response
- Increase the velocity of the fusional vergence response

Equipment Needed

Bernell variable tranaglyphs^a (Series 500 and 600)
 Dual Polachrome illuminated trainer^a
 Horizontal holder^a
 Red/green glasses^a
 Red/green flip lenses^a
 Pointer

Description and Setup

All variable tranaglyph slides come in pairs, with one printed in red and the other in green. The two slides are identical except for the color and disparity. These targets are designed to enable one to create convergence or divergence demand by separating them horizontally. Figures 6.1 and 6.2 illustrate the different tranaglyphs. By convention, these procedures are performed with the red glass over the right eye and the green glass over the left. When the red/green glasses are worn in this way, the right eye sees only the green slide, while the left eye sees only the red target. A convergence demand is achieved by moving the green slide to the left and the red slide to the right. This forces the right eye to follow the green target moving left and the left eye to follow the red target moving right. As demonstrated in Figure 6.3, this leads to a convergence-type movement. If the green target is moved to the right and the red target to the left, divergence is stimulated.

All tranaglyph targets have a scale at the bottom that indicates the amount of prismatic demand at any given target separation (Fig. 6.4). However, this scale is only correct if the patient is viewing the target at a distance of 40 cm. If the patient moves closer or farther away, the scale is no longer accurate. It is therefore important to understand how the vergence demand is calculated.

The basis for this understanding is the definition of a prism diopter. A *prism diopter* demand is defined as a separation of 1 cm at a distance of 1 m. To determine how this applies to any other given distance, the following formula can be used:

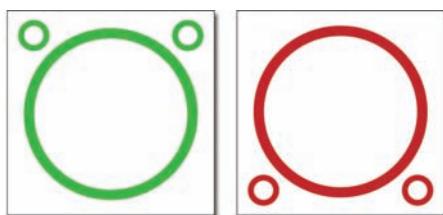
$$100 \text{ cm}/1 \text{ cm} = \text{working distance}/\text{target separation in cm}$$

If we want the working distance to be 40 cm, the formula is

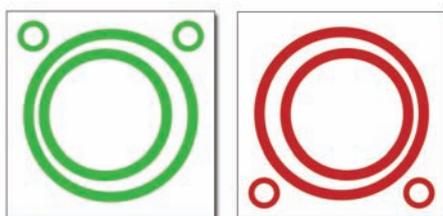
$$100 \text{ cm}/1 \text{ cm} = 40 \text{ cm}/x \text{ cm}$$

$$100x = 40 \text{ cm}$$

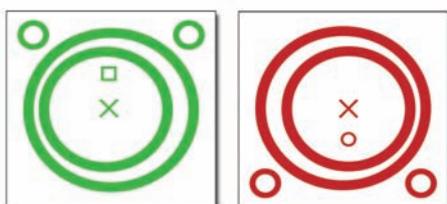
$$x = 0.4 \text{ cm, or } 4 \text{ mm}$$



BC/510-PF PERIPHERAL FUSION

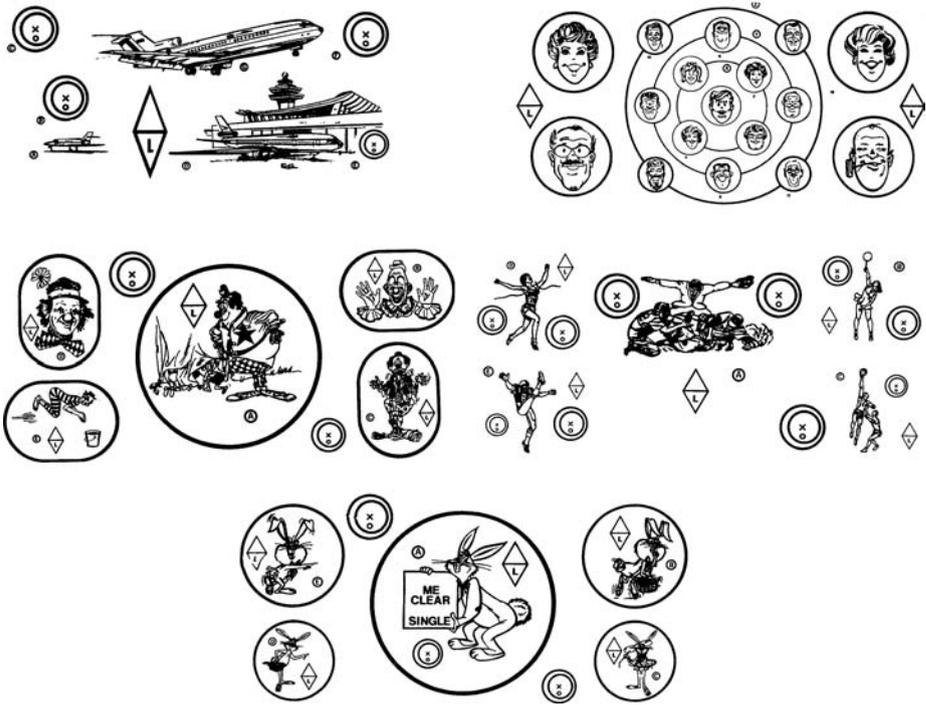


BC/515-PF S PERIPHERAL FUSION AND STEREOPSIS



BC/520-PF S PERIPHERAL, CENTRAL FUSION AND STEREOPSIS

■ **Figure 6.1** Peripheral tranaglyph targets.



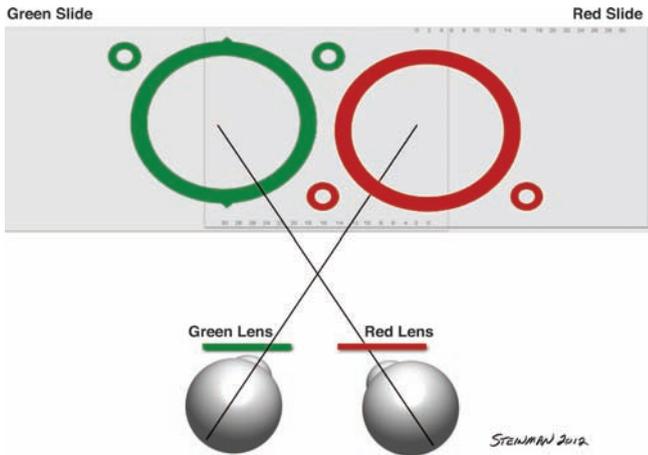
■ Figure 6.2 Central tranaglyph targets.

Therefore, at 40 cm, a 4-mm target separation is equal to 1 Δ. To use this information clinically, the therapist would simply measure the distance between similar points on the tranaglyph and divide the distance in millimeters by 4 to determine the demand in prism diopters (each 4-mm separation equals 1 prism diopter of demand).

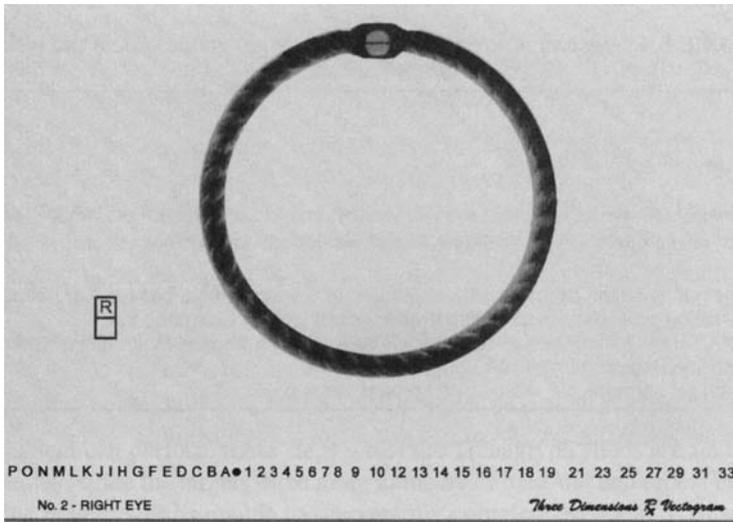
Similarly, if the working distance were shortened to 20 cm, a 2-mm separation would now equal 1 Δ. Thus, by decreasing the working distance, you increase the level of difficulty of the task for a given target separation.

There are currently eight variable tranaglyphs produced by Bernell (Figs. 6.1 and 6.2):

- 510: Peripheral fusion
- 515: Peripheral fusion and stereopsis
- 520: Peripheral fusion and central target



■ Figure 6.3 Peripheral tranaglyph target. Moving the green slide to the left and the red slide to the right creates a convergence-type demand.



■ **Figure 6.4** Scale at the bottom of a target indicating the prismatic demand at any given target separation.

- 601: Bunny
- 605: Spiral
- 606: Clown
- 607: Airport
- 610: Sport slide

Although the eight slides differ from one another in several ways, the primary differences are the size of the targets and whether the tranaglyph can be considered a central or peripheral target. When a stimulus is large and tends to have very little central detail (tranaglyphs 510, 515, and 520, illustrated in Fig. 6.1), it is referred to as a *peripheral target*. This type of target primarily stimulates peripheral fusion. Stimuli like the tranaglyphs shown in Figure 6.2 are considered *central targets* because there is more central detail and the lines and detail are finer than those shown in Figure 6.1.

Another difference in the tranaglyphs is the size of the detail in each target, and therefore the degree of control of accommodation. Tranaglyphs like those in Figure 6.1 have no fine detail, whereas those in Figure 6.2 have fine-line drawings. Depending on the stage and objectives of therapy, one type of tranaglyph may be more appropriate than another. For instance, early in therapy, it is often desirable not to use finely detailed central targets. Such targets require very precise accommodation on the part of the patient. In the early phases of therapy, it is easier for the patient to fuse if targets do not require precise accommodation. If a patient is being treated for a convergence insufficiency and has low PFV, it is best to initially permit the patient to use some accommodative convergence to help achieve fusion. If a target with fine accommodative detail is used, the patient will report blurred vision. Using a peripheral target without detail allows the patient to succeed initially. In later stages of vision therapy, it becomes important to use targets with as much fine detail as possible to ensure accurate accommodation.

The tranaglyphs also have varying degrees of disparity. The first tranaglyph shown in Figure 6.1 has no disparity at all, whereas those in Figure 6.2 have varying degrees of disparity from one area to another within the tranaglyph. All of the tranaglyphs with disparity are designed to present nonuniform disparity from one part of the slide to another.

For example, with slides 601 (bunny) and 606 (clown), the central picture is on the plane of regard and the surrounding large circle is ahead of the picture (more base-out). The targets on the right side are ahead (more base-out) of the central target and the pictures are ahead of the circles. (Picture C should appear closer than picture B.) The left-side targets are behind the center target (more divergence) and the pictures are behind the circles. (Picture D should appear further away than picture E.)

Because tranaglyphs allow one to vary the vergence demand, they are very useful early in therapy and are usually the first targets prescribed to expand the PFV and NFV systems. In the initial phase of therapy, it may be difficult for the patient to fuse in the direction of difficulty. For instance, with a convergence insufficiency

patient, any convergence demand may be difficult at first. The advantage of the variable tranaglyph technique is that it allows you to begin therapy in the divergence direction and gradually reduce the divergence demand.

Therapy Procedures Using Tranaglyph 515: Peripheral Fusion and Stereopsis

Step 1

The patient wears the red/green glasses, and the tranaglyph targets are set up in the dual Polachrome illuminated trainer (Table 6.1). While the patient views the target, ask the patient what he or she sees. The patient should be able to describe the picture, which consists of two large circles surrounded by four small circles. The patient should state that the inner large circle appears to be floating closer to him or her. If the patient does not voluntarily respond with these answers, ask leading questions to elicit this information. Once you are able to establish that the patient appreciates the “depth” in the circles, proceed to step 2.

Step 2

Tell the patient to ignore the four small surrounding circles and to concentrate on the two large circles. While the patient looks at the large circles, slowly separate the two sheets to create a small amount of convergence demand and then a small amount of divergence demand. Ask the patient to try to keep the circles clear and single and describe what he or she is seeing. The patient should say that the target becomes smaller and closer when you create convergence demand and larger and farther away with divergence demand. This is the “small in, large out” (SILO) response described in Chapter 5. If the patient is unable to spontaneously describe this, it is important to ask leading questions to obtain these responses. Typical questions would be as follows:

- Is the picture becoming larger or smaller?
- Is the picture coming closer or moving farther away?

Once you can establish that the patient is experiencing either SILO or “small out, large in” (SOLI), question him or her about diplopia, blur, float, localization, and parallax. Explain to the patient that these are all feedback cues that will be used throughout therapy to help monitor his or her responses.

Step 3

Now set the sheets at zero and explain to the patient that you are going to demonstrate the procedure that he or she will practice. It involves three distinct parts:

1. Tell the patient to separate the sheets to number 3 base-out and try to keep the circles single and clear. He or she should be able to appreciate the depth in the circles as well.

TABLE 6.1 RECOMMENDED PROCEDURES FOR ANAGLYPH AND POLAROID VISION THERAPY TECHNIQUES

Step 1

- a. The patient wears appropriate filters.
- b. Establish patient's ability to fuse.

Step 2

- a. Create small amount of base-out/base-in vergence demand and establish presence of appreciation of SILO response, clarity, parallax, float, localization, and absence of suppression.

Step 3

- a. Patient maintains fusion as targets are separated in 3 Δ increments base-out or base-in.
- b. Use localization procedure to establish awareness of looking close and far.
- c. Have patient break fusion, look away and look back or cover and uncover an eye, and then regain fusion for 10 seconds. Repeat this three times.
- d. Increase target separation by 3 Δ and repeat steps 3a–3c.

SILO, “Small in, large out.”

2. Instruct the patient to take the pointer and point to the location at which he or she sees the circles floating. Make sure the patient sees one pointer and one set of circles. Stress to the patient the importance of the kinesthetic awareness or feeling of “looking close” and “crossing his (or her) eyes.”
3. Now ask the patient to put the pointer down and look away from the circles to a point farther away for several seconds and then to regain fusion. Have the patient hold fusion for 10 seconds, look away, and look back again. Instruct the patient to repeat this three times.

Once the patient can perform these steps while the tranaglyph slides are set at 3 base-out, have the patient separate the targets three more numbers of base-out and repeat parts 1 to 3. At some level, the patient will be unable to successfully complete even part 1—seeing the circles clearly and singly. At this point, it is critical to teach the patient a method of overcoming this obstacle. To simply have the patient decrease the disparity until he or she can fuse again is not an effective therapy strategy. If the patient is experiencing diplopia, use the feedback technique of localization described in Chapter 5 to show him or her how to regain fusion.

Step 4

The same steps are followed for divergence therapy, except that the patient will be unable to physically point to the location at which he or she perceives the target. After 6 to 8 base-in, the apparent target location will be too far behind the targets for the patient to point. If the patient is experiencing difficulty, we suggest that you use the procedure for teaching divergence localization discussed in Chapter 5, using a Quoit vectogram and a Marsden ball.

Other Therapy Procedures That Can Be Performed with Tranaglyphs

In Chapter 5, we described the differences between tonic and phasic therapy procedures. The tranaglyph techniques described to this point emphasize the tonic or sliding method. They are useful in the initial phase of therapy and are designed to improve the amplitude of the fusional vergence response. Once the patient can achieve a moderate level of convergence and divergence (20 to 25 base-out and 10 to 15 base-in), the tranaglyphs can be used to create a step- or phasic-type demand to improve fusional facility (Table 6.2).

Phasic or Step Vergence Therapy

There are several ways to create a step vergence demand. These include the following:

1. **Changing fixation from the target to another point in space** Ask the patient to fuse the tranaglyph, then look away for several seconds, and look back and regain fusion.
2. **Breaking fusion by covering one eye** After the patient has fused the tranaglyph, have him or her cover one eye for 5 to 10 seconds to break fusion. The patient then uncovers his or her eye and has to regain fusion.
3. **Using loose prism or flip prism or lenses**
 - (a) While the patient is fusing the tranaglyph target at a particular convergence or divergence demand, additional prism can be placed in front of the patient’s eyes to create a large change in vergence demand.

TABLE 6.2

OTHER RECOMMENDED THERAPY PROCEDURES FOR BINOCULAR VISION THERAPY TECHNIQUES

Phasic/step vergence therapy

1. Change fixation from the target to another point in space.
2. Cover, uncover, and regain fusion.
3. Use loose prism or flip prism to change demand.
4. Use flip lenses to change demand.
5. Use two different targets with varying demand.
6. Use Polaroid or anaglyph flip lenses designed to alternate between divergence and convergence demand.
7. Use flip lenses to create a binocular accommodative demand.
8. Change fixation distance and move to distance of most difficulty.

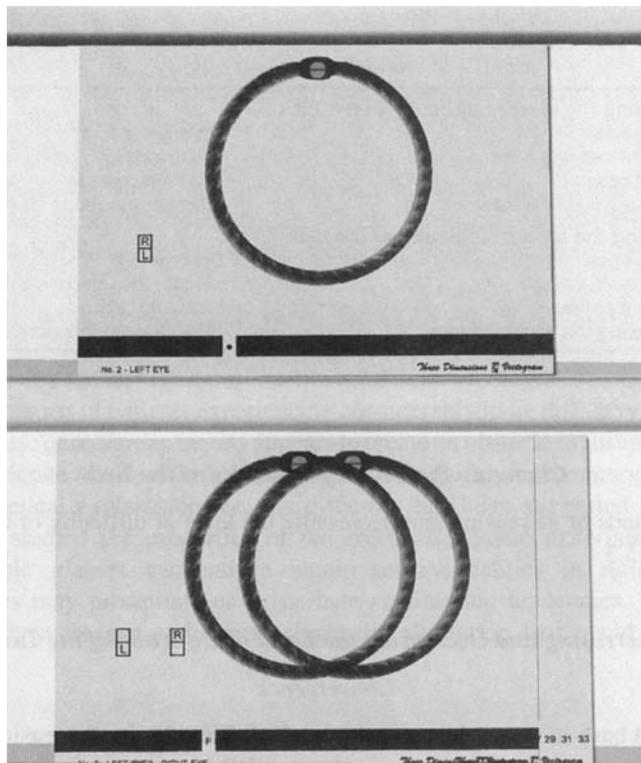
(b) Flip lenses can also be used to create a step vergence change in vergence demand. If +2.00 lenses are placed in front of a patient fusing 20 base-out, an additional convergence demand is generated. The exact demand is based on the AC/A ratio for the particular patient. The larger the AC/A ratio, the larger the vergence demand. For example, if the patient has an 8:1 AC/A ratio, the +2.00 lenses will force the patient to relax 2 D of accommodation to regain clarity. As a result, he or she will relax 16 Δ of accommodative convergence. To maintain single binocular vision, the patient will therefore have to use 16 Δ of PFV. Alternatively, the patient may not fully relax accommodation, thereby decreasing the amount of PFV necessary to maintain binocular vision. If this occurs, he or she will report one blurred target.

Another way to understand the effect of lenses on vergence demand is to visualize the planes of accommodation and vergence for the tranaglyph task as described in Chapter 5. When plus lenses are added, the plane of accommodation moves away from the patient while the plane of vergence remains in the same location. The effect is an increase in the distance between the two planes and an increase in convergence demand.

4. **Setting up two different targets in a dual Polachrome illuminated trainer (Fig. 6.5)** The one on top can be set at one convergence demand and the one on the bottom at a different convergence demand. Ask the patient to fuse the top target, hold it for 10 seconds, and then change fixation to the bottom target and hold fixation 10 seconds. This procedure can be repeated several times and then the demands changed.
5. **Using flippers designed with red on the right and green on the left on one side, and red on the left and green on the right on the other side** When the patient views the target through one side, the demand is in the convergence direction. When the glasses are flipped to the other side, the same target creates a divergence demand. Polaroid filters in flippers can also be used in a similar fashion.

Binocular Accommodative Facility Therapy

Tranaglyph targets can be used for binocular accommodative facility (BAF) therapy. Select a tranaglyph that has finely detailed targets and, with the patient fusing at any vergence demand, use flip lenses to create a binocular



■ **Figure 6.5** Two Quoit vectogram targets set at different prismatic demands in a Polachrome illuminated trainer.

accommodative demand. In this procedure, the patient must maintain vergence at the given demand and alter accommodation.

Vergence Therapy at Any Working Distance

Tranaglyphs can be used for vergence therapy at almost any working distance. In almost all cases, therapy is initiated at near (40 cm) because it tends to be easier to train vergence ranges at near. In cases such as divergence excess, divergence insufficiency, basic esophoria, and basic exophoria, vergence therapy at distances greater than 40 cm is necessary. A patient can be moved several feet away from the tranaglyph target. It is important to remember that as the working distance is increased, the demand for a given separation decreases, the accommodative demand decreases, and the target becomes more central. Therefore, the targets must be separated to compensate for the change in working distance.

After about 1 m (3 ft), however, the targets are no longer effective because they become too small for the patient to resolve detail. To work at distances greater than 1 m, an overhead projector can be used. The tranaglyph is placed in a clear horizontal holder and placed on an overhead projector. The patient can stand as far away as necessary, and the same procedures described previously can be performed.

Important Factors

In working with tranaglyphs, it is important to emphasize the following issues:

- The kinesthetic feeling of converging and diverging.
- The ability to clear the target and regain binocular vision as quickly as possible as the vergence demand is increased.
- The patient, not the therapist, should manipulate the targets.
- The glasses and targets are not doing anything; rather, the changes are internal, occurring within the patient's own visual system.
- The importance of maintaining clarity when fusing.

Changing the Level of Difficulty of the Task

The various methods of increasing and decreasing the level of difficulty of the task are summarized in Table 6.3.

Increasing and Decreasing the Level of Difficulty of the Task

Convergence

Minus lenses and base-in prism (BIM) decrease the level of difficulty by decreasing the separation between the planes of accommodation and vergence. BIM is an acronym used by clinicians to remember that base-in (BI) and minus lenses (M) have a similar effect on the level of difficulty of the task. Another way to decrease the demand is to increase the working distance. Recall that the prismatic demand created by any particular

TABLE 6.3 PROCEDURES FOR INCREASING AND DECREASING VERGENCE DEMAND WITH BINOCULAR VISION THERAPY PROCEDURES

Decreasing the level of difficulty of the task	
Convergence	Divergence
<ul style="list-style-type: none"> • Minus lenses • Base-in prism • Increase working distance 	<ul style="list-style-type: none"> • Plus lenses • Base-out prism • Increase working distance
Increasing the level of difficulty of the task	
Convergence	Divergence
<ul style="list-style-type: none"> • Plus lenses • Base-out prism • Decrease the work distance 	<ul style="list-style-type: none"> • Minus lenses • Base-in prism • Decrease the work distance

lateral separation of the targets is determined by the working distance. At a working distance of 40 cm, 4 mm equals 1 Δ. The same 4-mm separation is only 0.5 Δ at a distance of 80 cm.

Plus lenses, base-out prism, and decreasing the working distance increase the level of difficulty by increasing the separation between the planes of accommodation and vergence. BOP is an acronym used by clinicians to remember that base-out (BO) and plus lenses (P) have a similar effect on the level of difficulty of the task.

Divergence

Plus lenses, base-out prism (BOP), and increasing the working distance decrease the level of difficulty of the task, whereas minus lenses, base-in prism (BIM), and decreasing the working distance increase the level of difficulty of the task.

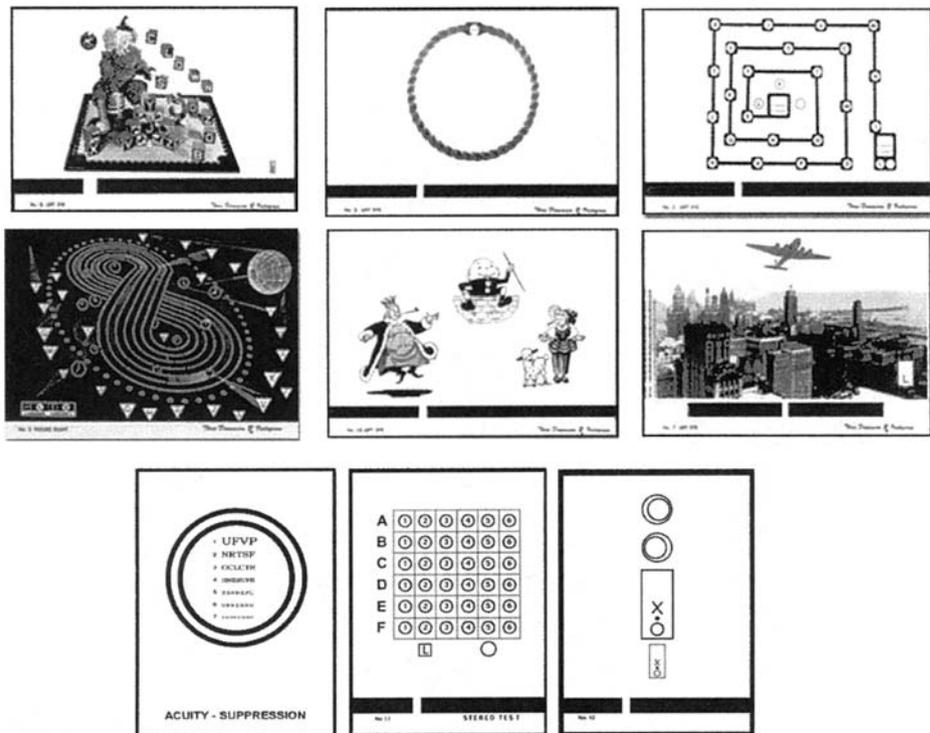
Endpoint

To determine when to discontinue this therapy technique, it is important to consider the original diagnosis and the size of the heterophoria. A general guideline is to discontinue this procedure when the patient is able to

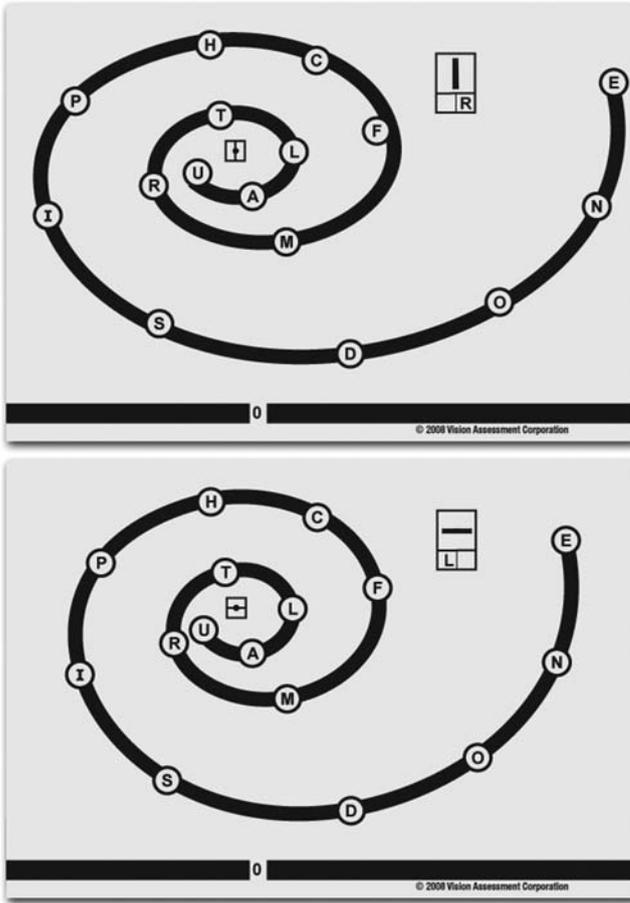
- Achieve 20 to 25 base-out and 10 to 15 base-in
- Alternate from 20 to 25 base-out to 10 to 15 base in 15 cpm.

VARIABLE VECTOGRAMS

The objectives and use of the variable vectograms^a are identical to those just discussed for variable tranaglyphs. In fact, the only real difference between the two techniques is that one type of target is printed in Polaroid material, whereas the other is red/green. Historically, variable vectograms preceded variable tranaglyphs by many years. The primary reason for the introduction of the tranaglyph targets was cost. One set of variable vectograms costs approximately 8 to 10 times more than one set of tranaglyph targets. The various targets available in the tranaglyph series closely match those available in the vectogram series (Fig. 6.6).

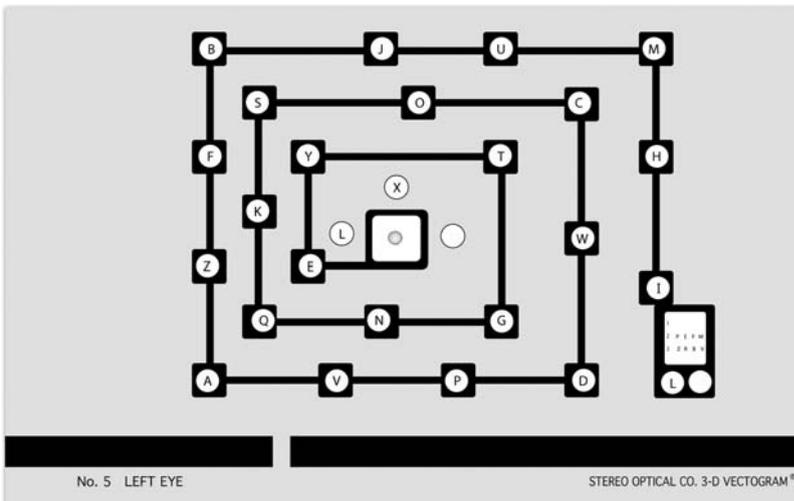


■ Figure 6.6 Variable vectograms.

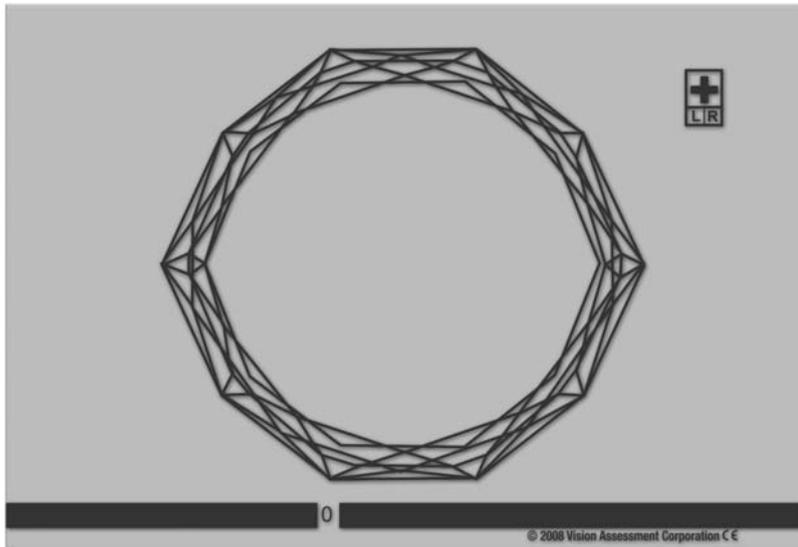


■ Figure 6.7 Vortex vectogram.

Recently three new vectogram targets have become available (Figs. 6.7–6.9). The objectives, description and setup, procedures, important factors, and all other issues discussed relative to the tranaglyphs apply to the variable vectograms as well (Tables 6.1–6.3).



■ Figure 6.8 Baseball vectogram.



■ **Figure 6.9** Gem vectogram.

Clinically, there is one important difference between the vectograms and the tranaglyphs. There have been reports of patients experiencing considerably more difficulty with tranaglyph-type targets. The use of red/green targets appears to create an obstacle to fusion, particularly for patients with moderate to severe suppression and with significant accommodative anomalies. A possible theoretical explanation for this difficulty has been suggested by Bogdanovich et al. (1). They studied the properties of red/green anaglyphic materials and found that currently available glasses can induce significant inequalities in retinal illuminance. These inequalities may precipitate or exacerbate suppression tendencies. They also found problems with ghost images and lateral chromatic aberration that could affect binocular vision.

NONVARIABLE TRANAGLYPHS

Objectives

The objectives of nonvariable tranaglyphs are identical to those described for variable tranaglyphs.

Equipment Needed

- Bernell nonvariable tranaglyphs^a (Series 500)
- Dual Polachrome illuminated trainer
- Horizontal holder
- Red/green glasses
- Red/green flip lenses
- Pointer

Description and Setup

The nonvariable tranaglyphs are a set of six plastic targets produced by Bernell (Fig. 6.10). The targets are red and green and are printed on a clear background. Unlike the 500 and 600 series, they are nonvariable. This means that each slide has a specific disparity. There is only one plastic slide per target, unlike the variable tranaglyphs, which have two slides for each target design. Thus, the disparity cannot be altered in the same manner as with the variable tranaglyphs. Rather, the demand is changed by having the patient switch fixation from one target to another on a particular slide. Another way to vary the demand is to use auxiliary lenses or prism or both.



■ **Figure 6.10** Nonvariable tranaglyphs.

To change the task from convergence to divergence, one simply switches the glasses from red over OD to red over OS. Alternatively, the slide can be turned around while the red lens remains over the right eye.

Unlike the variable tranaglyphs and the variable vectograms, all targets in this series present a fixed vergence demand and require an initial fusional vergence movement (jump or phasic vergence therapy) to obtain fusion. The variable tranaglyphs or vectograms, of course, can be set at ortho or zero initially, before the demand is increased. The nonvariable tranaglyphs are therefore considered a more difficult technique.

Therapy Procedures with Nonvariable Tranaglyphs Series 50

Step 1

The patient wears the red/green glasses, and the tranaglyph targets are set up in the dual Polachrome illuminated trainer. While the patient views the target, ask the patient what he or she sees. The patient should be able to describe that he or she sees the various stimuli at different planes. Some of the targets are seen in front of the plane of the tranaglyph, whereas others are seen behind the plane. On each nonvariable tranaglyph card, the divergence and convergence demands are printed directly next to the targets. These prismatic demands are only accurate when the technique is performed at 40 cm. To determine the prismatic demand at any other distance, use the formula described previously.

Step 2

Tell the patient to concentrate on the upper left-hand target and try to achieve one clear image. Have him or her hold fusion for 10 seconds. Instruct the patient to take the pointer and point to the location at which he or she sees each of the targets floating. Make sure the patient sees one pointer and one set of targets each time he or she points. Stress to the patient the importance of the kinesthetic awareness or feeling of “looking close” and “crossing his (or her) eyes.”

Step 3

Now ask the patient to put the pointer down and look away from the target to a point farther away for several seconds and then to regain fusion. Have the patient hold fusion for 10 seconds, look away, and look back again. Instruct him or her to repeat this three times. If the patient is unable to fuse a particular target, it is important to use the localization technique described previously with the variable tranaglyphs.

Have the patient switch fixation to the next target and try to fuse. He or she should continue changing fixation from one target to another for several minutes. Other therapy procedures that can be performed with nonvariable tranaglyphs, along with important factors to consider and methods of changing demand, are listed in Tables 6.2 and 6.3.

Endpoint

Discontinue this therapy technique when the patient is able to successfully achieve clear single binocular vision with all six slides in Series 500 for convergence and slides 1 to 4 for divergence.

COMPUTERIZED BINOCULAR VISION THERAPY PROCEDURES

Since the mid-1980s, computer software has been available for vision therapy. Programs are now available that contain techniques to train accommodation, fusional vergence, saccades, pursuits, and various visual perceptual functions. These techniques usually require the use of anaglyphic or liquid crystal glasses. Currently there are many computer-assisted software programs being used by optometrists for both home- and office-based vision therapy.

An important question is why we should even consider using computer programs for vision therapy. Many of the techniques described in this chapter are relatively inexpensive and have proven their effectiveness over many years. What are the advantages of computerization of vision therapy to warrant the much higher investment in hardware and software?

Cooper (2), Press (3), and Maino (4) have reviewed this issue. They noted the following problems associated with traditional noncomputerized techniques:

- Methods of changing stimulus parameters are slow and unreliable.
- Traditional techniques often require an experienced doctor or technician to interpret patients' responses and to use that information to alter stimulus conditions in order to improve binocular response.
- With young children or with older patients who are not responding accurately for a variety of reasons, traditional techniques become difficult and unreliable to use. The child who "learns" the expected response and has a strong desire to please the therapist may "give the right response," even though he or she is not achieving the desired objective.
- For learning to occur, feedback should be accurate, immediate, consistent, and unbiased. With traditional therapy techniques, the feedback is often provided by the therapist. Vision therapy is often conducted with one therapist working with two or more patients at a time. The feedback may therefore not always be as consistent and immediate as desirable.

The advantage of computerized vision therapy is that it overcomes each of the problems listed above. In addition, computer techniques allow for standardization of therapy techniques and thereby improve intra- and inter-therapist reliability and, from our clinical experience, represent a valuable motivational tool. Both children and adults seem to enjoy and look forward to computer techniques compared with traditional procedures. There has also been some investigation that demonstrates the efficacy of computerized vision therapy for improving visual function (2,4–13).

It is beyond the scope of this book to attempt to review every available computer-based vision therapy program. We advise readers to refer to the Bernell and Optometric Extension Program catalogs to try and be current with the release of new programs. However, we review a few of the more popular programs.

OFFICE-BASED COMPUTER VISION THERAPY SOFTWARE FOR BINOCULAR VISION

Computer Orthoptics VTS4 Liquid Crystal System

One software package that we have found to have significant value is the Computer Orthoptics VTS4 Liquid Crystal System.^c It involves the use of liquid crystal filters and is, therefore, described in this section. This software package has a wide variety of procedures that are useful for office-based vision therapy for accommodative, vergence, and eye movement disorders. We do not attempt to present an exhaustive description of the software. Rather, we concentrate on the procedures using random dot stereograms. Programs are continually being revised and added, and anyone interested in vision therapy should be in contact with all of the companies listed at the end of the chapter (see Sources of Equipment).

Multiple Choice Vergence Program

Objectives

- Increase the amplitude of NFV and PFV
- Decrease the latency of the fusional vergence response
- Increase the velocity of the fusional vergence response.

Equipment Needed

PC-compatible computer
 50-inch large screen monitor
 Computer Orthoptics VTS4 Liquid Crystal System software
 Liquid crystal glasses

Description and Setup. This program uses high-speed liquid crystal glasses that result in complete cancellation of the targets. The circuitry developed for the high-speed liquid crystal glasses allows binocular stimuli to be alternately darkened 60 times per second (60 Hz). The glasses are matched to a color monitor that also alternates left and right eye view at 60 Hz. This allows vivid color binocular targets to be presented to each eye with almost no ghosting. These glasses eliminate the problems associated with red/green and red/blue filters, such as poorer-quality fusion due to color rivalry, different accommodative demands from chromatic aberration, and chromostereopsis. The Computer Orthoptics VTS4 software is currently used with a 50-inch plasma screen television monitor and can also be used with a projector to create large peripheral targets and can be helpful in the initial stages of therapy or when working with a patient with a distance-related binocular vision disorder.

The random dot stereopsis feature of this software has several advantages that make it one of the more powerful binocular vision therapy procedures currently available:

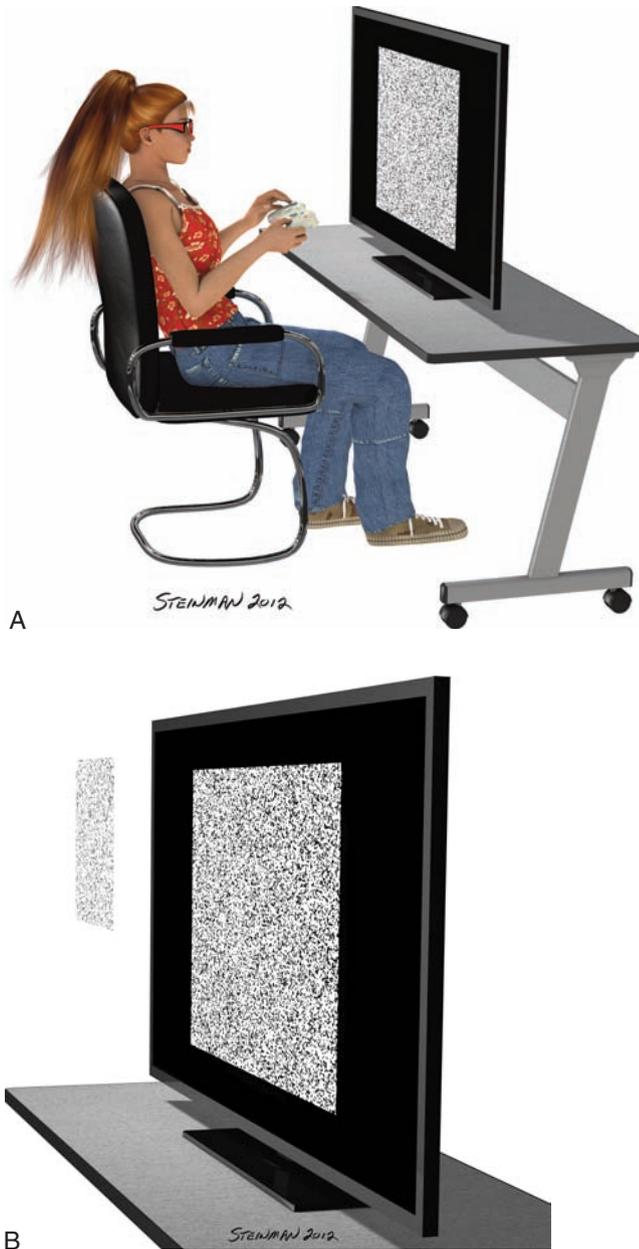
- It is one of the few available techniques that utilize random dot stereopsis targets.
- The liquid crystal technology tends to minimize suppression.
- The method of changing stimulus parameters is fast and reliable. The vergence demand is automatically increased 1 Δ if the patient responds correctly, and it is reduced by 2 Δ if the response is incorrect.
- Because the stimulus is a random dot stereopsis target, the patient can only perform the task if he or she is fusing appropriately. The procedure is therefore objective and does not depend on the patient's ability to communicate about what he or she is seeing and experiencing. This makes this technique valuable for younger, less verbal children. The therapist is better able to manage the child who "learns" the expected response on other techniques and has the desire to please the therapist.
- Feedback is accurate, immediate, consistent, and unbiased.
- A patient can work independently on the computer, freeing the therapist to work with another patient.
- Scoring is automatically done by the computer.

The Multiple Choice Vergence program is a basic binocular vision therapy program that can be used at the very early phase of vision therapy. It is most comparable to the use of variable tranaglyphs and variable vectograms. The demand is initially set at zero and can be set in the vergence direction that is easiest for the patient.

The stimulus for this program is a large square with a smaller random dot stereopsis square embedded within it, located either on the top, bottom, right, or left of the larger square. The patient is instructed to move a joystick in the direction in which he or she sees the small square. Five target sizes are available (extra large, large, medium, small, and extra small).

The technique is designed for use at 40 cm. The vergence demand indicated by the computer is based on the premise that the patient is sitting 40 cm from the screen. If the working distance is shorter or longer, you must adjust these numbers based on the formulas reviewed on page 161.

Therapy Procedures. Have the patient sit 40 cm from the screen, wearing the red/blue glasses. Select the Random Dot program from the submenu for vergence. We recommend that the length of the therapy setting be changed to 3 minutes. All other parameters can be left at the default setting. Select base-in or base vergence based on the patient's diagnosis. Instruct the patient that he or she is to determine where the small square is located and to move the joystick to this location. If the small square is on top, he or she moves the joystick forward; if it is on the right, he or she moves the joystick to the right, and so forth (Fig. 6.11).



■ **Figure 6.11** **A:** Child working with the Computer Orthoptics Random Dot Stereopsis program. **B:** Patient's view of the Computer Orthoptics Random Dot Stereopsis target.

The key to this program is that if the patient is not able to fuse, there is no way for him or her to succeed at this task or to make the therapist think that he or she is succeeding. With most vision therapy techniques, it is rather easy for a patient to learn the expected responses. Children trying to please the therapist may give this expected response even if they cannot actually succeed at the task.

Other Therapy Procedures That Can Be Performed with Computer Orthoptics Software. Once the patient has been able to reach 40 to 50 base-out and about 10 to 15 base-in, select the program that emphasizes vergence facility and presents a phasic or jump vergence-type demand, called Step-Jump Vergence. This program automatically switches from a convergence to a divergence demand in a stepwise fashion. For example, you may begin at 10 base-out and 5 base-in. After the patient correctly responds to 10 base-out, the computer

TABLE 6.4 IMPORTANT FACTORS TO EMPHASIZE DURING BINOCULAR VISION THERAPY PROCEDURES

Kinesthetic feeling of converging and diverging.
Ability to clear the target and regain binocular vision as quickly as possible as the vergence demand is increased.
The patient, not the therapist, should manipulate the targets.
The glasses and targets are not doing anything; rather, the changes are internal, occurring within the patient's own visual system.
Importance of maintaining clarity when fusing.

switches to 5 base-in and then to 11 base-out, 6 base-in, 12 base-out, 7 base-in, and so forth. When the patient can successfully reach 40 base-out and 16 base-in, you can select the Jump-Jump Vergence program. This program presents an alternating demand between convergence and divergence in a random (rather than stepwise) manner. Several variations in technique can be prescribed to vary the activity and increase the level of difficulty. These include the same techniques described in detail for other binocular vision therapy techniques.

Important Factors. When performing this procedure, it is important to emphasize the issues listed in Table 6.4.

Changing the Level of Difficulty of the Task. The various methods of increasing and decreasing the level of difficulty of the task are summarized in Table 6.3.

Endpoint. Discontinue this therapy technique when the patient is able to achieve clear single binocular vision with 40 to 50 base-out and 10 to 15 base-in.

Computer Aided Vision Therapy: Computer Vergences Program

Another effective software package is Computer Aided Vision Therapy (CAVT). The Computer Vergences program from this software package can be used to work with vergence problems. In contrast to the Computer Orthoptics program, this program requires the use of red/blue filters. The Computer Vergences software program offers a selection of 10 procedures. The one we find most useful is Random Dot Stereograms. It is particularly effective because of its use of random dot stereopsis stimuli, whose advantages were described previously.

CAVT Random Dot Stereograms: Jump Vergences

Objectives

- Increase the amplitude of NFV and PFV
- Decrease the latency of the fusional vergence response
- Increase the velocity of the fusional vergence response

Equipment Needed

PC-compatible computer
 Computer Aided Vision Therapy: Computer Vergences program^d
 Red/blue glasses

Description and Therapy Procedures. In this procedure, the targets consist of random dot stereograms. Two targets are presented. Each target contains a hidden shape with disparity. When the two images are fused, the hidden shape should emerge from the dots and appear to float above the pattern of random dots. The patient selects the matching shape from one of eight patterns. The program automatically increases the target disparity after a correct response and decreases the disparity if a response is incorrect.

Important Factors. When performing this procedure, it is important to emphasize the issues listed in Table 6.4.

Changing the Level of Difficulty of the Task. The computer program automatically increases or decreases the level of difficulty of the task

Endpoint. Discontinue this therapy technique when the patient is able to achieve clear single binocular vision with 40 to 50 base-out and 10 to 15 base-in.

Fusional Vergence Procedures: Lenses, Prisms, and Mirrors

FLIP PRISM OR LOOSE PRISM

Objectives

The objective of using loose or flip prisms is to supplement other fusional vergence therapy techniques. Prism can be used to increase or decrease the level of difficulty of the task. Prism, therefore, is very valuable in all phases of vision therapy. In the initial stages of therapy, when a patient may be experiencing difficulty getting started, prism can be used to help the patient achieve fusion. At later stages, prism can be used to increase the prismatic demand of techniques described in this chapter, such as tranaglyphs, vectograms, the Aperture Rule, and Eccentric or Free Space Circles. Prism flippers can also be used in the middle and final phases of vision therapy to create a fusional facility demand.

Equipment Needed

- Loose hand-held prism
- Flippers with prism base-out on one side and base-in on the other^a
- Any binocular target with suppression controls, such as Brock string,^a tranaglyphs,^a vectograms,^a Aperture Rule,^a Eccentric Circles,^b Free Space Fusion Cards,^a Lifesaver cards^b

Description and Setup

With any of the binocular procedures listed above, simply use loose or flip prisms to increase or decrease the level of difficulty. For example, if a patient is working with a Quoit vectogram doing convergence therapy and finds the task very easy, additional base-out prism could be used to increase the level of difficulty of the task. Alternatively, if the patient was experiencing difficulty even getting started with convergence therapy, base-in prism could be used to decrease the difficulty of the task.

In the middle and final stages of therapy, it is important to create a phasic-type vergence demand. This concept is discussed in depth in Chapter 5. The use of prism in flippers is an ideal method of accomplishing this objective. While the patient is fusing at any particular vergence demand, flip prisms can be placed before the patient's eyes. This forces the patient to make a rapid change from one vergence demand to another. The objective is to decrease the amount of time necessary for the patient to make these vergence changes.

Fusional Vergence Procedures: Septa and Apertures

APERTURE RULE

Objectives

- Increase the amplitude of NFV and PFV
- Decrease the latency of the fusional vergence response
- Increase the velocity of the fusional vergence response

Equipment Needed

- Bernell Aperture Rule trainer and cards^a
- Flip lenses^a
- Flip prisms^a
- Pointer

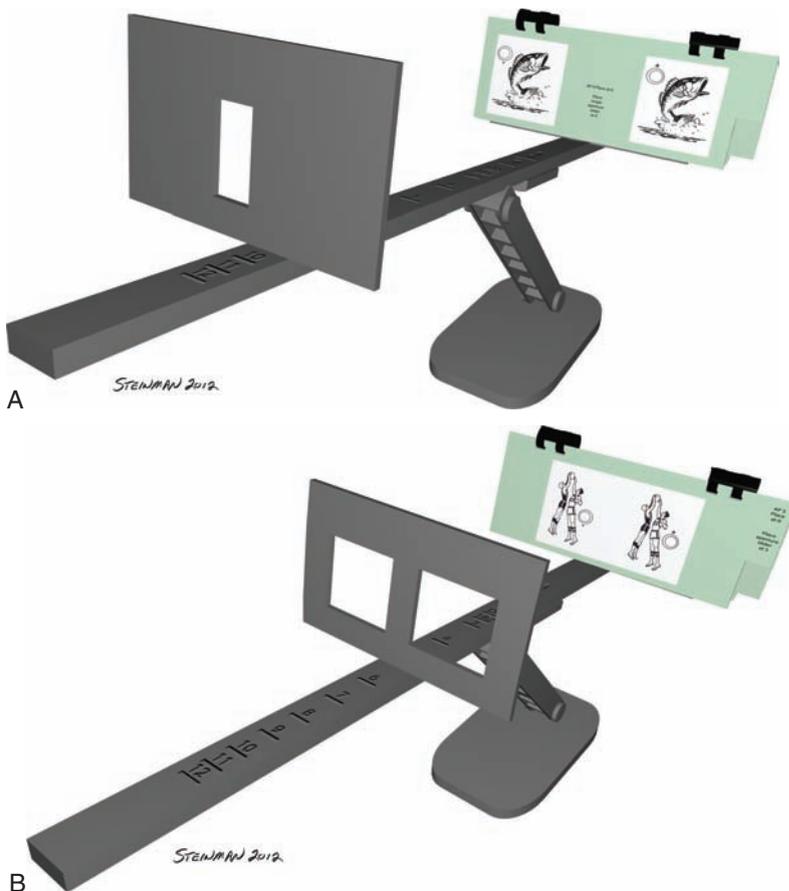
Description and Setup

Unlike anaglyphic and Polaroid techniques, red/green or Polaroid glasses are not necessary with this technique. Rather, fusion occurs through chiasmotic (base-out) or orthopic (base-in) fusion. *Chiastopic fusion* occurs when the patient's visual axes are crossed relative to the fixation distance of the targets being used. In *orthopic fusion*, the visual axes are uncrossed relative to the fixation distance of the targets. Chiastopic and orthopic fusion are explained in more detail later in this chapter.

The Aperture Rule is a more difficult technique than the variable tranaglyphs or vectograms because even at the initial setting a finite divergence or convergence demand is present. With the tranaglyphs or vectograms, the targets can be initially set at zero demand or even moved in the vergence direction that is easiest for the patient.

The Aperture Rule consists of a rulerlike apparatus, two plastic slides—one with a single aperture and the other with a double aperture (Fig. 6.12)—and 12 cards with varying disparities, ranging from 2.5Δ to 30Δ (Fig. 6.12). The same targets are used for both convergence and divergence. To change from convergence to divergence, the therapist substitutes the double-aperture slide (base-in) for the single-aperture slide (base-out).

The cards are a combination of second-degree (flat fusion) and third-degree (stereopsis) targets. Each card also contains antisuppression cues and accommodative controls. There is a set of cards for very young children, called the Bernell-N-Stein Bears, and a standard set of cards, called the Sports/Action targets (Fig. 6.13). Each card has a small set of eccentric circles that act as a third-degree fusion target. When the patient fuses, he or she should report that the inner circle comes closer with convergence and the outer circle comes closer with divergence. In addition, above these circles is a small cross that is seen by one eye and a small dot seen by the other eye. These targets act as suppression controls. These third-degree and



■ **Figure 6.12** **A:** Aperture Rule with single aperture for convergence therapy. **B:** Aperture Rule with double aperture for divergence therapy.



■ **Figure 6.13** Aperture Rule Sports/Action cards for adults and Bernell-N-Stein Bears for pediatric use.

antisuppression targets are very important feedback devices for the patient and also can be used by the therapist to monitor the accuracy of the patient's responses.

The technique is designed for use at 40 cm. Based on the formula discussed earlier, we know that, at 40 cm, a 4 mm disparity is equal to 1 Δ . Measuring the distance between similar points on card 1, one finds a 1 cm disparity. Therefore, card 1 represents a 2.5 Δ demand. The separation on card 12 is 12 cm, and the vergence demand is 30 Δ . Bernell produced the cards so that the number of each card represents the distance in centimeters between centers of the targets. Thus, to compute prismatic demand of any particular target, multiply the card number by 2.5.

Therapy Procedures

Place the single aperture at the number 2 mark on the Aperture Rule and the cards at the setting marked "place aperture cards here." Turn to card 2. Clinically, card 2 is easier to fuse than card 1. We therefore recommend starting with this card. Have the patient place the end of the Aperture Rule against the bridge of his or her nose (Fig. 6.14). Alternately cover the patient's right and left eyes and demonstrate that he or she will see one target with the right eye and one with the left eye (Fig. 6.15A,B). Remove the cover paddle and ask the patient what he or she sees with both eyes open (Fig. 6.15C). The patient will report double vision, suppression, or will be able to fuse the two targets and report that he or she sees one target. Explain that the objective is to achieve clear single vision. If the patient is unable to fuse, you can use the same techniques that were suggested for the previous binocular vision therapy procedures. These include kinesthetic awareness of looking close and far, localization, lenses, and prism (Table 6.1).

To use the localization technique with the Aperture Rule, have the patient hold the pointer directly behind the single aperture. Instruct him or her to look directly at the pointer. If the patient does this, he or she will report one pointer and one target. To understand this, it is important to think about the concept of the planes of accommodation and convergence that was discussed in Chapter 5. When using the Aperture Rule for convergence therapy,



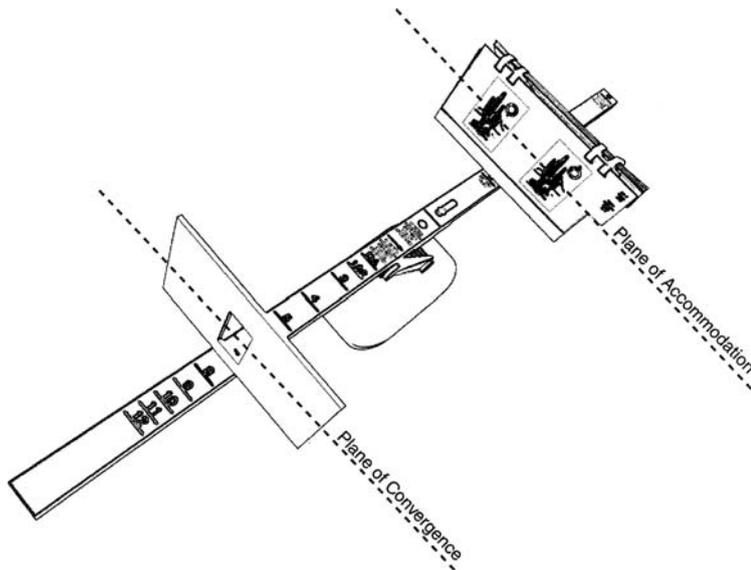
■ **Figure 6.14** Aperture Rule for convergence therapy.



■ **Figure 6.15 A:** Right-eye view of Aperture Rule card. **B:** Left-eye view of Aperture Rule card. **C:** View of Aperture Rule card with both eyes.



the plane of accommodation is approximately at the plane of the cards. The plane of convergence is right at the point at which the single aperture is placed. By moving the pointer to this location and instructing the patient to fixate the pointer, fusion is likely to occur. Once the patient realizes where he or she must look, try removing the pointer. With some practice, the patient will soon be able to fuse without the additional support of the pointer.



■ **Figure 6.16** Location of the plane of accommodation and convergence during convergence therapy using the Aperture Rule.

Once fusion is reported, question the patient regarding the clarity of the target, the antisuppression cues, and whether he or she appreciates the depth in the circles. Ask the patient to hold fusion for a count of 10, look away momentarily, and then try to regain fusion as quickly as possible. This procedure should be repeated several times. The next card is then exposed, the single aperture is moved to its appropriate position, and the entire procedure is repeated.

The same general procedures are performed for divergence therapy, except that the double-aperture slide is substituted for the single-aperture slide.

Figure 6.16 shows the location of the plane of accommodation and the plane of convergence when the patient is using the single aperture. The greater the separation between these two planes, the greater the demand on fusional vergence. Of course, as you change from one card to the next, the single aperture is moved closer to the patient, indicating that the demand is becoming greater. When using the Aperture Rule for divergence therapy, the plane of accommodation is still at the stimulus cards, but the vergence plane is behind the stimulus cards. Other therapy procedures, important factors to consider, and methods of increasing and decreasing the demand are listed in Tables 6.2, 6.3, and 6.4.

Endpoint

Discontinue this therapy technique when the patient is able to successfully achieve clear single binocular vision with all 12 cards with convergence, and card 6 with divergence.

MODIFIED REMY SEPARATOR

Objectives

- Increase the amplitude of NFV and PFV
- Decrease the latency of the fusional vergence response
- Increase the velocity of the fusional vergence response

Equipment Needed

Septum made from cardboard
Lifesaver cards,^b Free Space Fusion Cards A or B,^a or stereograms^{a,b}

Description and Setup

The modified Remy separator is based on the principle of a Remy separator, which is a vision therapy device that uses a septum. Because of the physical setup of the instrument, its primary value is for divergence therapy. Unless auxiliary base-out prism is used, Remy separator-type instruments only present a divergence demand. The amount of divergence demand can be calculated based on the formula presented earlier in this chapter for the Aperture Rule. For example, if the targets are separated by 40 mm, the divergence demand is 10 base-in ($4 \text{ mm} = 1 \Delta$ at 40 cm). The base-in demand is increased by separating the targets and decreased by moving them closer together. The two principal companies that manufacture vision therapy equipment in the United States do not currently produce a Remy separator. This instrument can be purchased from European companies.

It is possible, however, to easily make a Remy separator by using stereogram targets or Free Space Fusion Cards A and B or Lifesaver cards (Fig. 6.17) along with a septum. Simply cut a septum from cardboard, making sure that the length of the septum is 40 cm, and place it against the stereogram or other target.

Therapy Procedures

The modified Remy separator is used for divergence therapy. Because the patient must make a step vergence change, this technique is more difficult than variable tranaglyphs or vectograms. For some patients, it may be easier than working with Eccentric Circles or Free Space Fusion Cards B. The main difference between the modified Remy separator and Eccentric Circles or Free Space Fusion Cards A is that the septum eliminates the annoying two side images that are perceived with the Eccentric Circles and Free Space Fusion cards.

This technique is useful for home therapy after the patient has already made some progress in vision therapy and has successfully begun to use the Aperture Rule for divergence therapy. If the patient experiences any difficulty, plus lenses are helpful to get started. Have the patient attempt to fuse the targets and hold fusion for 10 seconds, then look away and regain fusion.

As the patient progresses, reduce the amount of plus. The divergence demand can also be increased by separating the targets, adding minus lenses, or using base-in prism. The divergence demand can be decreased by moving the targets together, using plus lenses, and using base-out prism.

Endpoint

Discontinue this technique when the patient can achieve fusion with a divergence demand of about 15 base-in.



■ **Figure 6.17** Modified Remy separator using a septum and Lifesaver card.

Fusional Vergence Procedures: Paper, Pencil, and Miscellaneous Tasks

ECCENTRIC CIRCLES, FREE SPACE FUSION CARDS A, AND LIFESAVER CARDS

Objectives

- Increase the amplitude of NFV and PFV
- Decrease the latency of the fusional vergence response
- Increase the velocity of the fusional vergence response

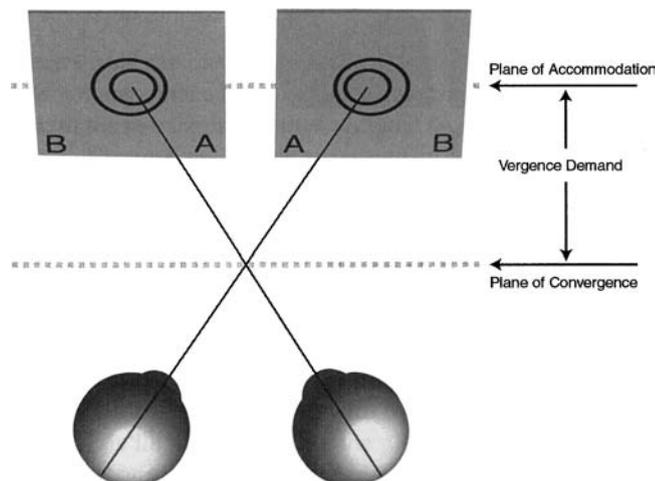
Equipment Needed

Keystone opaque Eccentric Circles^c
 Keystone transparent Eccentric Circles^c
 Keystone transparent Lifesaver Cards^c
 Keystone opaque Lifesaver Cards^c
 Bernell opaque Free Space Fusion Cards A^a
 Bernell transparent Free Space Fusion Cards A^a
 Flip lenses^a
 Flip prism^a
 Pointer

Description and Setup

This is another free space, chiastopic, or orthopic technique. Prisms, lenses, or glasses are not required. Rather, the patient fuses by converging in front of the plane of accommodation (chiastopic) or diverging beyond the plane of accommodation (orthopic). Figure 6.18 illustrates the Eccentric Circle setup and the location of the planes of accommodation and vergence when the patient is converging. During convergence (Fig. 6.18), accommodation is approximately at the cards, whereas vergence is in front of the cards. With divergence, accommodation is still approximately at the plane of the cards, whereas vergence is behind the cards. The cards present a third-degree fusion (stereopsis) target. Each card also contains antisuppression cues and accommodative controls.

If one compares this procedure to the Aperture Rule technique, it should be clear that both procedures are based on the same principle. Both are examples of chiastopic/orthopic fusion. When the patient is working



■ **Figure 6.18** Eccentric Circles setup for convergence therapy, illustrating planes of accommodation and vergence.

with the Eccentric Circles and Free Space Fusion Cards A with convergence, the right eye views the left card and the left eye views the right card. While the right eye fixates the left target, the image of the right card is projected on the nasal retina of the right eye. The right eye will therefore perceive two targets. The same is true of the left eye. The left eye fixates the right target, and the left card image is projected on the nasal retina of the left eye. When the patient converges to the appropriate plane, the two middle images will overlap and the patient will achieve chiasmatic fusion. However, he or she will also perceive two other targets: one to the left and one to the right of the “fused” target. Because of the eccentricity of the inner circles on the cards, retinal disparity will be created and the patient should perceive stereopsis or an impression of depth.

For convergence therapy, the Eccentric Circles and Free Space Fusion Cards A may be more difficult initially than the Aperture Rule for a patient because, when fused properly, the patient sees three sets of circles rather than one set. For divergence therapy, the Eccentric Circles and Free Space Fusion Cards A are usually easier than the Aperture Rule for the patient because they are transparent and allow the patient to look through the target. The only difference between the Aperture Rule and Free Space Fusion Cards A is the single or double aperture, which serves to eliminate the annoying two side images.

One of the more common misconceptions about the Eccentric Circles is that the letters “A” and “B” printed on the bottom of the cards represent the method of changing the task from convergence to divergence. It is incorrect to think that holding the cards with the “As” together is a convergence task, whereas holding the “Bs” together a divergence task. An understanding of the underlying principles of the task dispels this idea. The “A” and “B” markings are simply present to help the therapist monitor the patient’s responses. When the cards are held with the “As” together and the patient is fusing base-out, he or she should perceive the outer circle floating closer (Fig. 6.19A). When fusing with a divergence demand with the “As” together, the patient will perceive the inner circle floating closer. This perception of stereopsis or float will be exactly the opposite when the cards are held with the “Bs” together (Fig. 6.19B). Thus, the target is used for divergence or convergence therapy. The only variable is what the patient does with his or her eyes.

Unlike the other binocular vision therapy procedures discussed previously, with the Eccentric Circles and Free Space Fusion Cards A there is no scale to indicate the prismatic demand. Rather, the therapist must use the formula discussed earlier in this chapter to determine the prismatic demand at a given separation of the cards. The demand at any separation will depend on the working distance and the distance between similar points on the two cards. For example, if the cards are held at a working distance of 40 cm and separated by 12 cm, the demand would be 30 Δ (at 40 cm, 4 mm = 1 Δ).

Sequentially, the Eccentric Circles and Free Space Fusion cards are often used after a patient successfully completes the variable tranaglyphs, nonvariable tranaglyphs, and Aperture Rule procedures. There are patients, however, who are able to work with these procedures even in the early stages of treatment. In fact, many patients find the Eccentric Circles and Free Space cards easier than the Aperture Rule, particularly with divergence therapy. It is important to be flexible when implementing a vision therapy program. We have proposed a specific sequence in Chapters 9 to 13, but other sequences may work as well in specific

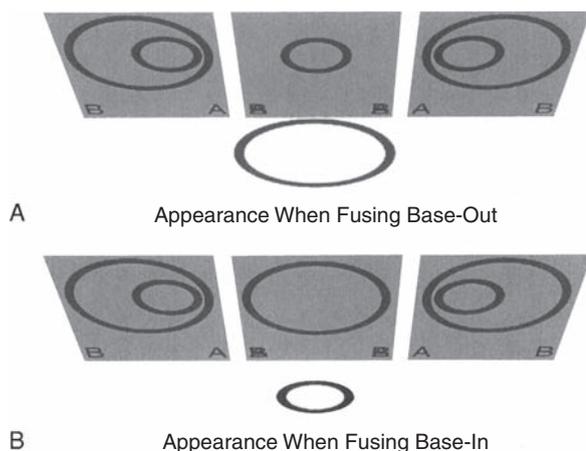


Figure 6.19 **A:** Patient’s perception of Eccentric Circles setup with the “As” during chiasmatic fusion. The outer rings appear to be floating closer. **B:** Patient’s perception of Eccentric Circles setup with the “Bs” during orthoptic fusion. The inner rings appear to be floating closer.

cases. Also, it is important to keep in mind that an objective of vision therapy is to successfully complete the treatment as quickly as possible. Thus, if a patient can easily accomplish one of the procedures in the recommended sequence, it should be skipped. The clinician should use the sequence suggested in this chapter as a guide only. The objective is to empirically find procedures that the patient can barely perform and skip those that are easy.

If the Eccentric Circles and Free Space Fusion Cards A are introduced toward the end of the therapy program, it is usually rather simple to teach the patient to fuse them. By this time, the patient is so familiar with all of the methods used previously to help him or her fuse during convergence and divergence therapy that he or she is often able to apply these skills to any new technique.

Therapy Procedures

Either have the patient hold the cards or place them in the Polachrome illuminated trainer, the horizontal holder, or any other suitable device. The cards should be held about 40 cm from the patient. Begin with the two cards together, with the “As” touching. The patient should see two cards at this point. Now ask the patient to try to cross his or her eyes and get the feeling of looking closer. If the patient cannot do this voluntarily, use localization with a pointer to demonstrate the point to which he or she must converge to achieve fusion. Tell the patient that when he or she achieves fusion, he or she will see “three sets of circles.” Explain that the patient is to concentrate only on the middle set and ignore the two side images. Ask the patient about the middle set of cards. The patient should be able to spontaneously indicate that he or she sees two circles, one larger than the other, and that the larger one appears to be floating closer to him or her. In addition, the patient should see the word “clear” in focus. If he or she does not spontaneously respond with this information, ask leading questions to elicit this information. It is important to make the patient aware that this perception of depth is a feedback cue to him or her about his or her performance. If the patient is successfully performing chiasmatic fusion with the “As” together, the larger ring will appear to float closer.

Once the patient can achieve fusion, ask him or her to hold the position for 10 seconds, look away momentarily, and look back at the cards and regain fusion. Instruct the patient to repeat this 10 times and then separate the cards about 1 cm and repeat the entire procedure. Continue until the patient is able to achieve fusion and look away and back with the cards separated about 12 cm.

Another procedure that can be performed with the Eccentric Circles and Free Space Fusion Cards A is to have the patient use two or more sets of the cards. The cards should be placed in different positions of gaze, and the patient must alternately look from one position of gaze to another and fuse the cards. You can instruct the patient to first perform orthopic and then chiasmatic fusion as he or she changes fixation from one set of cards to the other. The objective of this procedure is to combine vergence therapy with saccades. This tends to make the task more comparable to real seeing conditions.

The same general procedures are performed for divergence therapy, except that the patient must now diverge behind the plane of the cards. Because it is difficult for some patients to visualize looking behind an opaque object, translucent Eccentric Circle cards are available for divergence therapy. Patients often initially experience some difficulty with this procedure. It is helpful to show them where they must look to achieve orthopic fusion. To accomplish this, tape a pointer to the wall at the patient’s eye level. Have the patient stand about 3 to 4 ft away from the wall and hold the translucent Eccentric Circle cards about 25 cm away from his or her eyes. Instruct the patient to look at the pointer on the wall and, while doing so, be aware of the circles. The patient should be able to see three sets of circles. If the patient cannot, have him or her walk 6 in. closer or farther away, until he or she does appreciate three circles. Tell the patient to concentrate on the middle set and ignore the side images. Once the patient can achieve this, have him or her repeat the same procedures described for convergence therapy. The only difference is that because of the lower physiologic limit for divergence, the final separation will be smaller. Fusion with a 6 to 8 cm separation is considered adequate.

The final task is to instruct the patient to achieve clear chiasmatic fusion, hold it for 10 seconds, and then switch to clear orthopic fusion and hold it for 10 seconds. Instruct the patient to continue alternating back and forth for several minutes. The objective is for the patient to be able to achieve 20 cpm of alternation with the cards separated to the maximum level possible for the patient. This maximum separation is dependent on the size and direction of the phoria, the AC/A ratio, and the working distance.

Other therapy procedures, important factors to be considered, and methods of increasing and decreasing the demand are similar to those listed in Tables 6.2, 6.3, and 6.4.

Endpoint

Discontinue this therapy technique when the patient is able to:

- Successfully achieve clear chiasmatic fusion with a card separation of 12 cm and clear orthopic fusion with a card separation of 6 cm. These are only guidelines, and it is important to be flexible and realize that the final endpoint for any given patient will be dependent on the size and direction of the phoria, the AC/A ratio, and the working distance.
- Switch between chiasmatic and orthopic fusion with the cards held 6 cm apart, 20 cpm.
- Maintain chiasmatic and orthopic fusion with a card separation of 6 cm, while moving the cards laterally or in a circular fashion.

LIFESAVER CARDS AND FREE SPACE FUSION CARDS B

Objectives

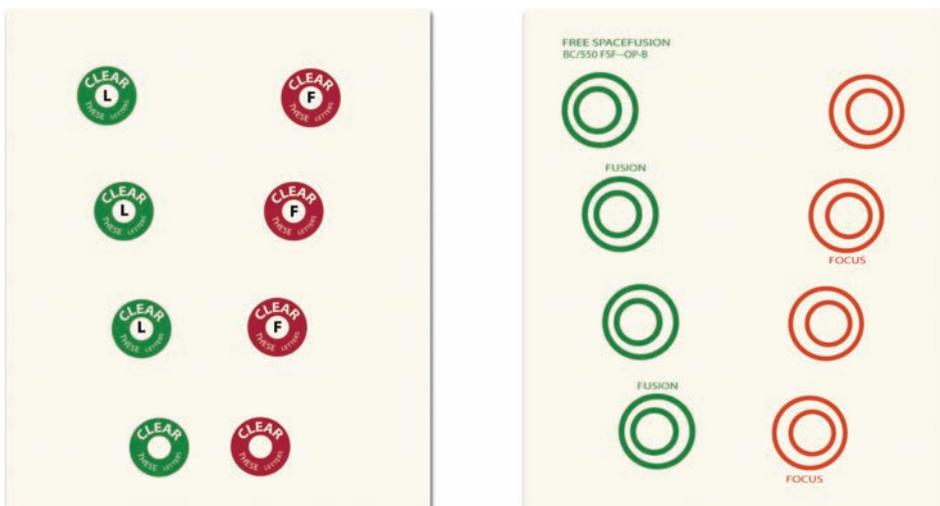
- Increase the amplitude of NFV and PFV
- Decrease the latency of the fusional vergence response
- Increase the velocity of the fusional vergence response

Equipment Needed

Keystone opaque Lifesaver cards^c
 Keystone transparent Lifesaver cards^c
 Bernell opaque Free Space Fusion Cards B^a
 Bernell transparent Free Space Cards B^a
 Flip lenses^a
 Flip prism^a
 Pointer

Description and Setup

Lifesaver cards and Free Space Fusion Cards B are essentially identical to the Eccentric Circles and Free Space Fusion Cards A. The only significant difference is that instead of altering the demand by increasing the separation of the cards, various target separations are preprinted on the cards (Fig. 6.20). Figure 6.21 illustrates the new Lifesaver cards.



■ **Figure 6.20** Lifesaver and Free Space Fusion Cards B.



■ **Figure 6.21** New Lifesaver Cards.

Therapy Procedure

When performing convergence therapy with the Lifesaver cards and Free Space Fusion Cards B, the patient is asked to fuse the bottom target, which has the least demand, hold it for 10 seconds, and then jump to the next target and fuse. This is repeated for all of the targets on the card for several minutes at a time. To work with divergence therapy, the clear cards are generally used. If the patient experiences difficulty with either chiasmatic or orthopic fusion, use the procedures discussed for the Eccentric Circles and Free Space Fusion Cards A to assist him or her.

Other therapy procedures, important factors to consider, and methods of increasing and decreasing the demand are similar to those listed in Tables 6.2, 6.3, and 6.4.

Endpoint

Discontinue this therapy technique when the patient is able to:

- Successfully achieve clear chiasmatic and orthopic fusion with all of the targets on the Lifesaver cards and Free Space Fusion Cards B.
- Switch between chiasmatic and orthopic fusion with all of the targets on the Lifesaver cards and Free Space Fusion Cards B.
- Maintain chiasmatic and orthopic fusion with all targets on the Lifesaver cards and Free Space Fusion Cards B, while moving the cards laterally or in a circular fashion.

Fusional Vergence Procedures: Stereoscopes

BREWSTER STEREOSCOPES

Objectives

- Increase the amplitude of NFV and PFV
- Decrease the latency of the fusional vergence response
- Increase the velocity of the fusional vergence response

Equipment Needed

Keystone stereoscope^b
 Bernell-O-Scope^a
 Bernell Variable Prismatic Trainer^a
 Stereoscopic cards
 Bioptograms^a
 Bernell prism base-in/base-out slides^a
 Keystone AN series^b
 Keystone BU series^b
 Other
 Flip lenses^a
 Flip prisms^a
 Pointer

Description and Setup

A Brewster-type stereoscope is a device designed to separate the fields of the two eyes using a septum (Fig. 6.22). The optical system consists of +5.00 D spheres. The optical centers are usually separated by 95 mm, which induces base-out prism because the separation is wider than the average patient's interpupillary distance. Stereoscope targets can be placed at varying distances, from a distance setting (20 cm if lenses are 5 D) to any near point setting. The therapist therefore is able to vary both the accommodative demand and convergence demand.

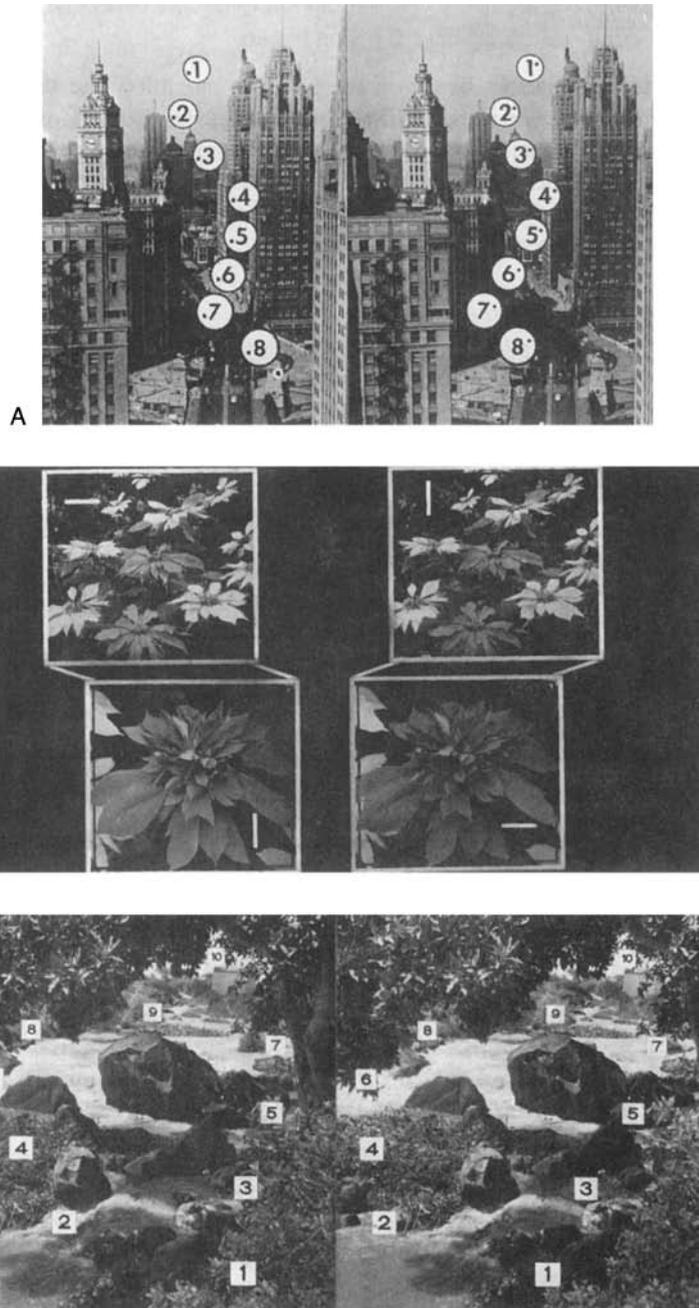
Different targets are currently produced by Keystone and Bernell (Fig. 6.23). There are numerous series of cards designed to:

- Create convergence and divergence therapy demand
- Create jump vergence demand
- Allow for eye–hand coordination techniques
- Permit accommodative therapy
- Permit antisuppression therapy
- Present first-, second-, and third-degree fusion targets

Specific cards are selected based on the patient's condition and the specific objectives of the therapy program. For instance, in the early stages of therapy for a divergence excess patient, third-degree targets would be selected. As therapy progresses, the objective would be to move from third-degree to second-degree to first-degree cards. The working distance selected is also dependent on the patient's specific problem. With



■ **Figure 6.22** Bernell-O-Scope.



■ **Figure 6.23** Sample stereograms. **A:** Base-out Biotograms. **B:** Keystone cards AN 9 and AN 77.

a divergence excess patient, we begin therapy at a near point setting and move toward a distance setting as therapy progresses.

Determination of Accommodative and Convergence Demands at Different Settings

When using a Brewster-type stereoscope, it is important to be able to determine the accommodative and convergence demands.

Accommodative Demand

Because the power of the stereoscope lenses is known and the distance of the target from the lens plane is known, one can easily calculate the accommodative demand, using the following formula:

$$A = (1/TD) - P$$

where

- A = accommodation (D)
- TD = distance between target and lens plane (m)
- P = power of stereoscope lenses (D).

Example 6.1

You are working with a stereoscope with +5.00 D lenses and a 95 mm lens separation. If you place the stereoscopic card at 20 cm, what is the accommodative demand?

Answer

$$\begin{aligned} A &= (1/TD) - P \\ A &= (1/0.2) - 5 \\ A &= 5 - 5 = 0 \end{aligned}$$

At a working distance of 20 cm, there is no accommodative demand. This is the distance setting for this particular stereoscope.

Example 6.2

If the target is now moved to a working distance of 13 cm, what is the accommodative demand?

Answer

$$\begin{aligned} A &= (1/TD) - P \\ A &= (1/0.13) - 5 = 7.6 - 5 = 2.6 \text{ D} \end{aligned}$$

At a working distance of 13 cm, the accommodative demand is about 2.6 D.

Convergence Demand

Flax (14) presented a formula that is applicable to any Brewster-type stereoscope and permits rapid calculation of the vergence demand in a manner simple enough for routine clinical application. The formula is also independent of the patient's interpupillary separation.

$$C = (P \times LS) - (TS/TD)$$

where

- C = vergence demand in prism diopters
- P = power of stereoscope lenses
- LS = separation of optical centers of stereoscope lenses (cm)
- TD = distance of stereogram from stereoscope lenses (m)
- TS = separation of corresponding points of the stereogram (cm).

Plus values represent a convergence demand, and minus values a divergence demand. One of the reasons this formula is simple to use is that part of the equation, $(P \times LS)$, becomes a constant value when using a specific instrument with a fixed lens separation. Thus, as long as you use the same instrument, this part of the equation is a given.

Example 6.3

You are working with a stereoscope with +5.00 D lenses and a 95 mm lens separation. What is the vergence demand for a 60 mm target set at 20 cm?

Answer

$$C = (P \times LS) - (TS/TD)$$

$$C = (5 \times 9.5) - (6.0/0.2) = 47.5 - 30 = 17.5 \text{ base-out}$$

Example 6.4

If you use the same stereoscope as in Example 6.3 and the same card, now set at a working distance of 13 cm, what is the vergence demand?

Answer

$$C = (P \times LS) - (TS/TD)$$

$$C = 47.5 - (6.0/0.13) = 47.5 - 46.0 = 1.5 \text{ base-out}$$

Therapy Procedures

When training nonstrabismic binocular vision disorders, stereoscopes are generally used only toward the middle to the end of the therapy program. By the time these instruments are introduced, the patient has a good kinesthetic awareness of converging and diverging and has reasonably well-developed fusional vergence ranges. Stereoscopes are used to move the patient to a slightly higher level by challenging him or her with different types of targets in a less natural setting. They are also used to provide a greater variety of techniques and maintain a high level of interest and motivation for the patient.

The specific stereoscope card and working distance are selected based on the vision disorder being treated and the objectives of therapy. Instruct the patient to look into the stereoscope and describe what he or she sees. You want the patient to report whether the target is clear and single, and to describe any depth he or she sees. Many of the cards have a series of letters or numbers, each of which has a different disparity. Ask the patient to change fixation from one number to another and hold fixation at each number for 5 seconds. Some cards have jump vergence targets, meaning that there are two or more separate targets with different disparities. When using a jump vergence card, instruct the patient to fixate one target for 10 seconds, keeping it single and clear, and then to change fixation to the other. Repeat this several times and then select a card with a slightly greater demand.

Another procedure that is popular with stereoscopes is tromboning. In this procedure, the patient slowly slides the card from distance to near and tries to maintain single and clear binocular vision. The card can then be moved back to the distance setting.

Other therapy procedures that can be performed, along with important considerations and methods of increasing and decreasing the level of difficulty of the task, are similar to those listed in Tables 6.2, 6.3, and 6.4.

Endpoint

Discontinue this therapy technique when the patient is able to successfully achieve clear single binocular vision with the selected cards at the selected distance.

CHEIROSCOPE

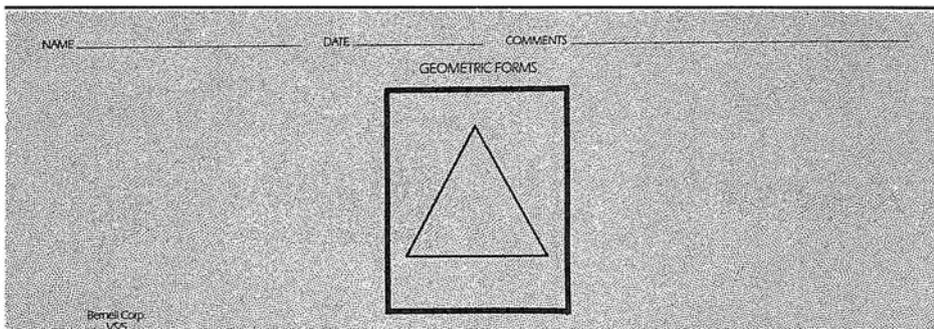
Brewster-type instruments have been developed that serve a somewhat different purpose (Keystone Correct-Eye Scope). This instrument, sometimes referred to as a cheiroscope, can be used as a diagnostic tool to assess binocular stability, binocular alignment, and the presence and extent of suppression. It is used as a therapy device to improve binocular stability and reduce or eliminate suppression. The instrument is shown in Figure 6.24.

Diagnostic Procedure

The target used for the cheiroscope is shown in Figure 6.25. One side of the paper has a target and the other side is blank. The paper is placed on the cheiroscope at the distance setting, with the blank side in front of the eye that corresponds to the dominant hand. Ask the patient to look into the cheiroscope and trace the target that he or she sees, using the blank paper in front of him or her and a pencil.



■ **Figure 6.24** Keystone Correct-Eye Scope setup for cheirosopic tracing.

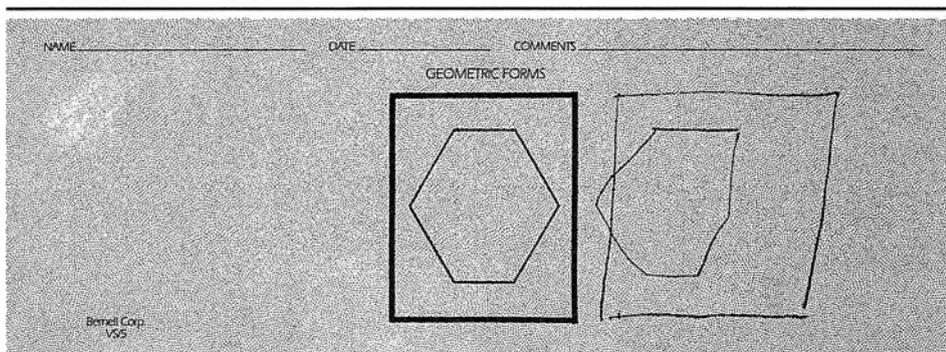


■ **Figure 6.25** Cheirosopic tracing forms.

Interpretation

As the patient is tracing, he or she should be asked if either the pencil or any part of the picture appears to be disappearing. When the tracing is complete, measure the separation between corresponding points. A separation of 77 to 80 mm represents an orthophoria response. A separation greater than 80 mm is an exophoria posture, and less than 77 mm is an esophoria posture. A vertical phoria can be detected if the tracing is higher or lower than the original. If the target is traced with the left hand in front of the left eye and is higher, a left hyperphoria is present.

Binocular instability is indicated if you observe the patient shifting his or her hand while attempting to trace, or actual drifts in the tracing are evident (Fig. 6.26). Suppression is present if the patient



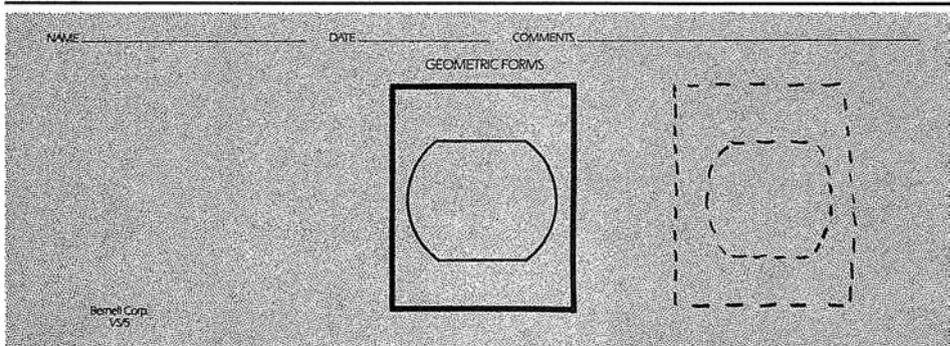
■ **Figure 6.26** Illustration of drifting during cheirosopic tracing.

reports parts of the picture or the pencil disappearing. With some patients, suppression is so deep that they are unable to trace the picture. Another problem that occurs with very high esophoria or exophoria is that the object appears to drift so far to the left or right of the paper that the patient is also unable to trace it.

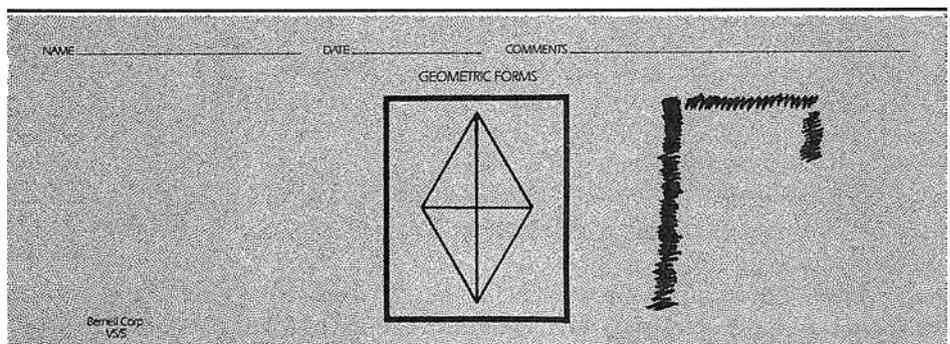
Therapy Procedure

Place a cheirosopic target on the cheiroscope and set the instrument at the distance setting. Place the target to be traced before the eye corresponding to the nondominant hand. Instruct the patient to look into the instrument and trace the target. If suppression or instability is evident, the following suggestions are generally helpful:

- If the patient is unable to trace because the image is drifting off the page or too close to the septum, draw the corners of the tracing on the blank side of the paper. This provides some structure and support and tends to reduce the instability. Draw the corners so that similar points are about 80 mm apart. If the patient has a high exophoria, draw the corners farther away, at 90 mm or so. Conversely, if the patient has a high esophoria, draw the corners closer together, at about 70 mm. As the patient's abilities improve, eliminate one corner at a time and move the drawings closer to the orthophoria setting of 80 mm.
- If the patient is intermittently suppressing, it is helpful to suggest that he or she make a short pencil stroke, lift the pencil off the paper, and then make another short pencil stroke (Fig. 6.27). Have the patient continue this until the tracing is complete. As the patient's skills improve, he or she can make longer and longer pencil strokes.
- Another procedure that is sometimes helpful if the patient is suppressing is using horizontal scrubbing-type strokes of the pencil (Fig. 6.28).



■ **Figure 6.27** Illustration of the use of short pencil strokes during cheirosopic tracing.



■ **FIGURE 6.28** Illustration of the use of scrubbing during cheirosopic tracing.

WHEATSTONE STEREOSCOPE

Objectives

- Increase the amplitude of NFV and PFV
- Decrease the latency of the fusional vergence response
- Increase the velocity of the fusional vergence response

Equipment Needed

- Bernell Variable Prismatic Stereoscope^a
- Stereoscopic cards^{a,b}
- Flip lenses^a
- Flip prisms^a

Description and Setup

Instead of using the Brewster-type stereoscope design of a septum to separate the two fields, Wheatstone stereoscopes accomplish this by using two tubes with either individual targets or mirrors. The most commonly used Wheatstone stereoscope for the treatment of nonstrabismic binocular vision disorders is the Bernell Variable Prismatic Stereoscope, illustrated in Figure 6.29.

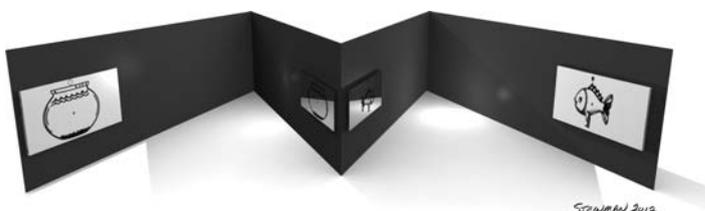
The major amblyoscope is another Wheatstone-type stereoscope, used primarily for the diagnosis and treatment of strabismus. Although it is an important instrument for the diagnosis and treatment of strabismus, it is rarely used in the treatment of nonstrabismic binocular disorders. We therefore do not discuss the major amblyoscope in this text and limit our discussion in this chapter to the Bernell Variable Prismatic Stereoscope. The working distance for this instrument is 33 cm, and, because there are no lenses, the accommodative demand is 3 D. This can be altered with either plus or minus lenses. The vergence demand is determined by the separation of the stereoscope. The actual prismatic demand can be read directly off the scale of the instrument. As the stereoscope is moved apart, base-in vergence demand is generated; when moved together, base-out vergence demand is generated.

Therapy Procedures

The Bernell Variable Prismatic Stereoscope can be used with nonstrabismic patients to develop fusional ranges and facility. The primary value of this instrument is to provide some variety to a vision therapy program and maintain a high level of interest and motivation for the patient.

A variety of cards come with this instrument and vary from first- to third-degree fusion targets. The specific cards selected are based on the objective of therapy. Once the cards are selected, they are placed on the right and left sides of the instrument. Ask the patient to place his or her nose against the tip of the instrument and describe what he or she sees (Fig. 6.30). Once it is apparent that the patient has clear single binocular vision, have him or her slowly move the stereoscope in and out to create base-out and base-in demand. Tell the patient to try to maintain clear single vision for as long as he or she can. Another procedure is to have the patient separate the target several centimeters, regain clear single vision, look away momentarily, and look back. Have the patient repeat this several times at each level.

Other therapy procedures, important factors to consider, and methods for increasing and decreasing the level of difficulty of the task are similar to those listed in Tables 6.2, 6.3, and 6.4.



■ **Figure 6.29** Variable Prismatic Stereoscope.



■ **Figure 6.30** Patient working with Variable Prismatic Stereoscope.

Endpoint

Discontinue this therapy technique when the patient is able to successfully achieve clear single binocular vision with the selected cards to 30 base-out and 15 base-in.

Voluntary Convergence Procedures

BROCK STRING

Objectives

- Develop the kinesthetic awareness of converging and diverging
- Develop the ability to voluntarily converge
- Normalize the near point of convergence

Equipment Needed

Brock string^a
 Flip lenses^a
 Flip prism^a
 Pencil

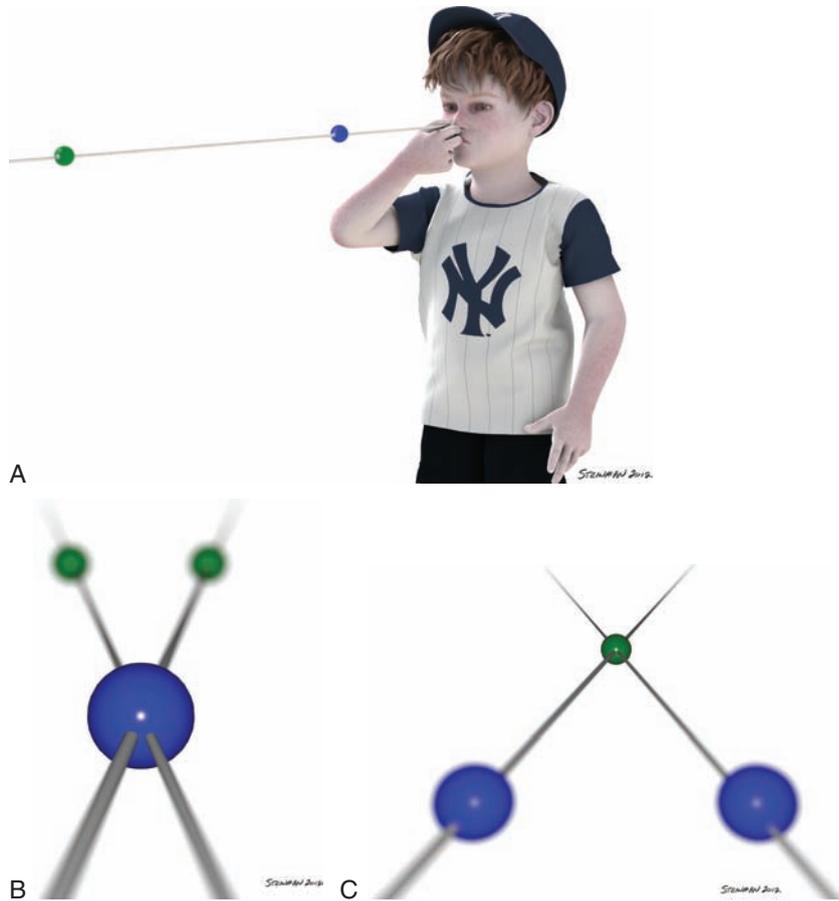
Description and Setup

The Brock string is simply a long white cord with three attached wooden beads of different colors. It is used primarily with convergence insufficiency patients to create the feeling and awareness of converging and to normalize the near point of convergence. It can also be used with esophores to teach accuracy of the vergence response. To use the Brock string, one end is tied to a door knob or other convenient secure location, and the patient holds the other end of the string at the bridge of his or her nose (Fig. 6.31A).

Therapy Procedures

Step 1

We recommend using just two beads and about 4 ft of string. Instruct the patient to hold the string taut and against the bridge of his or her nose. Set one bead (red bead) about 2 ft from the patient and the other (green bead) about 1 ft away. Ask the patient to look at the closer bead and describe what he or she sees. Because of physiologic diplopia, the patient should report that he or she sees one green bead and two red



■ **Figure 6.31** **A:** Patient working with Brock string. **B:** Patient's perception when looking at the near, or **C:** far bead when using the Brock string.

beads (Fig. 6.31B). In addition, the patient should perceive two strings crossing at the green bead, with one string extending from his or her right eye and the other appearing to extend from his or her left eye. Ask the patient to fixate the far bead (red), and he or she should now report one red bead with the strings crossing at the red bead (Fig. 6.31C). The patient will also see two green beads. It is important to explain the meaning of all of this to the patient. We suggest the following explanation:

This is a procedure that teaches you how to improve your ability to cross your eyes. The technique is set up to provide you with feedback about what your eyes are doing at all times. The way the visual system works is that wherever your eyes are pointing, you perceive single vision. All other objects in front or behind the object you are looking at will be seen as double. Look at the green bead and you will see one green bead, two red beads behind it, and a string that crosses right at the green bead and forms the letter “X.” The strings should look as if they are extensions of your right and left eyes. Where you perceive the two strings cross is actually where your eyes are aimed. Thus, if you are trying to look at the green bead, but the strings appear to cross farther away than the bead, this is an indication that you are looking too far away. Use this information to try to correct your eye position and look closer.

If the patient experiences difficulty accomplishing any of the goals listed above, there are several techniques that the therapist can use to help him or her overcome this obstacle.

- Have the patient touch the bead that he or she is trying to fuse. This kinesthetic feedback is sometimes enough to help the patient achieve single vision.
- Use minus lenses to stimulate accommodative convergence.
- Suggest that the patient try to get the feeling of looking close and crossing his or her eyes.

Once the patient is able to fuse the near and far beads, instruct him or her to hold fixation at the near bead for 5 seconds and then switch fixation to the far bead and hold for 5 seconds. Have the patient repeat this three times and then move the near bead 1 in. closer while always maintaining the far bead at 2 ft. Have the patient repeat the step of alternately fixating the far and near beads for 5 seconds three times. Continue moving the near bead closer, until the patient can successfully converge at a distance of 2 in. from his or her nose.

Step 2

If the patient can now converge within 1 to 2 in. in front of his or her nose, he or she should have a relatively good sense of what it feels like to converge, look close, or cross his or her eyes. The next step is called “bug on string” and is performed with the same setup described above, except that the beads are removed from the string. The objective of this second step is to continue to develop the ability to converge as some of the structure of the therapy task is eliminated. Instruct the patient to fixate the very end of the string and to try to see that the two strings cross at the end of the string. Now have the patient very slowly fixate closer and closer, until he or she is fixating 1 in. in front of his or her nose. It is important to emphasize to the patient that the change in fixation from far to near should be very gradual. After the patient can converge all the way to his or her nose, reverse the process and have the patient gradually diverge to the end of the string. Repeat this procedure for several minutes.

Step 3

The final procedure is to eliminate the use of the string entirely. Instruct the patient to try to get the feeling of looking close and to try to converge his or her eyes voluntarily. This convergence should be very slow and gradual.

Other Therapy Procedures That Can Be Done with the Brock String

The Brock string can be used in several other ways. Flip prism can be used to increase the level of difficulty of the task. While the patient is converging to any point on the string, prism can be inserted before his or her eyes, and he or she must maintain fusion as the prism is alternated from base-in to base-out.

The Brock string can also be used for saccadic and pursuit therapy. In the last phase of therapy for ocular motor dysfunction, an important objective is to combine saccades and pursuits with changes in vergence and accommodation.

One common procedure for saccadic therapy is to use multiple Brock strings. Set up three strings, for instance, all having an origin in a different position of gaze. One would be to the patient’s right, a second straight ahead, and the third to the patient’s left. Instruct the patient to hold the ends of all three strings against the bridge of his or her nose. Because each string has two beads, there will be six fixation targets that vary in location, both from left to right and from far to near. Instruct the patient to look from target to target in any given pattern that you specify. The objective is for the patient to quickly regain single binocular vision after each fixation change. To increase the level of difficulty, a metronome can be used. Ask the patient to change fixation every fifth click, for example, of the metronome. The actual origin of the various Brock strings can be varied to include the vertical dimension as well.

A frequently used procedure for pursuit therapy is to tie the end of the string to a pencil and have the patient hold the pencil at arm’s length (Fig. 6.32). Instruct the patient to slowly rotate the string in a circular fashion while he or she maintains fusion at the far or near bead. This setup integrates pursuits with vergence and saccadic changes.

Important Factors

When performing this procedure, it is important to emphasize the following issues:

- The kinesthetic feeling of converging and diverging.
- The ability to regain fusion binocular vision as quickly as possible.
- The patient, not the therapist, should manipulate the string and beads.
- Emphasize that the string and beads are not doing anything; rather, the changes are internal, occurring within the patient’s own visual system.



■ **Figure 6.32** Brock string setup for vergence and pursuits.

Changing the Level of Difficulty of the Task

Decreasing the Level of Difficulty of the Task

Minus lenses and base-in prism decrease the level of difficulty. Another way to decrease the difficulty is to move the beads farther away from the patient.

Increasing the Level of Difficulty of the Task

Plus lenses, base-out prism, and decreasing the working distance increase the level of difficulty.

Endpoint

Discontinue this therapy technique when the patient is able to:

- Successfully converge to 1 in. from his or her nose
- Appreciate the feelings of converging and diverging
- Voluntarily converge
- Accurately converge and diverge.

BARREL CARD/3-DOT CARD

Objectives

The objectives of the Barrel Card/3-Dot Card are identical to those of the Brock string.

Equipment Needed

Barrel Card^a
Albee 3-Dot Card

Description and Setup

The Barrel Card setup is illustrated in Figure 6.33. It is a white card with three colored barrel-shaped targets on each side of the card. The barrels are red on one side and green on the other. It is used primarily with

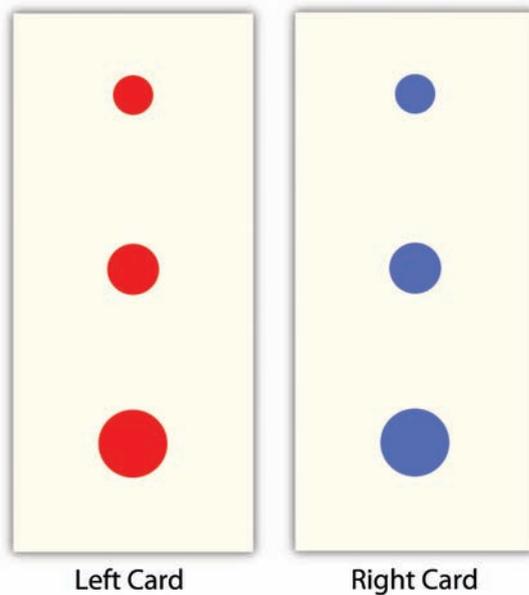


■ **Figure 6.33** Patient working with Barrel Card.

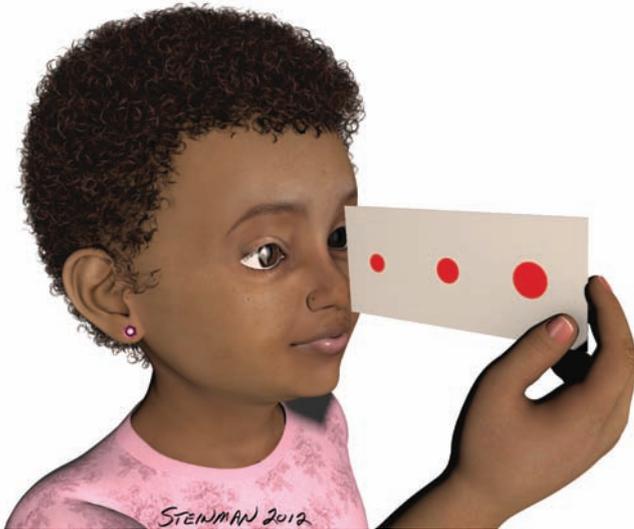
patients with convergence insufficiency to create the feeling and awareness of converging and to normalize the near point of convergence. The concept and underlying principles are identical to the Brock string. We generally use the Barrel Card after the patient has completed the Brock string sequence of activities, or for variety. The Albee 3-Dot Card illustrated in Figures 6.34 and 6.35 is similar to the Barrel Card using circles instead of barrels.

Therapy Procedures

Instruct the patient to hold the Barrel Card against the bridge of his or her nose and to fixate on the barrel farthest away from him or her. The patient should be able to report one barrel that is a mixture of the red and green colors. The patient then fixates on the middle barrel, holds for



■ **Figure 6.34** Albee 3-Dot Card.



■ **Figure 6.35** Patient working with Albee 3-DotCard.

10 seconds, and then fixates on the nearest barrel and holds for 10 seconds. Instruct the patient to continue alternating fixation from one barrel to the other.

Important factors to consider and methods for increasing and decreasing the task are identical to those discussed for the Brock string.

Endpoint

Discontinue this therapy technique when the patient is able to:

- Successfully converge to 1 in. from his or her nose
- Appreciate the feelings of converging and diverging
- Voluntarily converge.

Antisuppression Procedures

BAR READER

Objectives

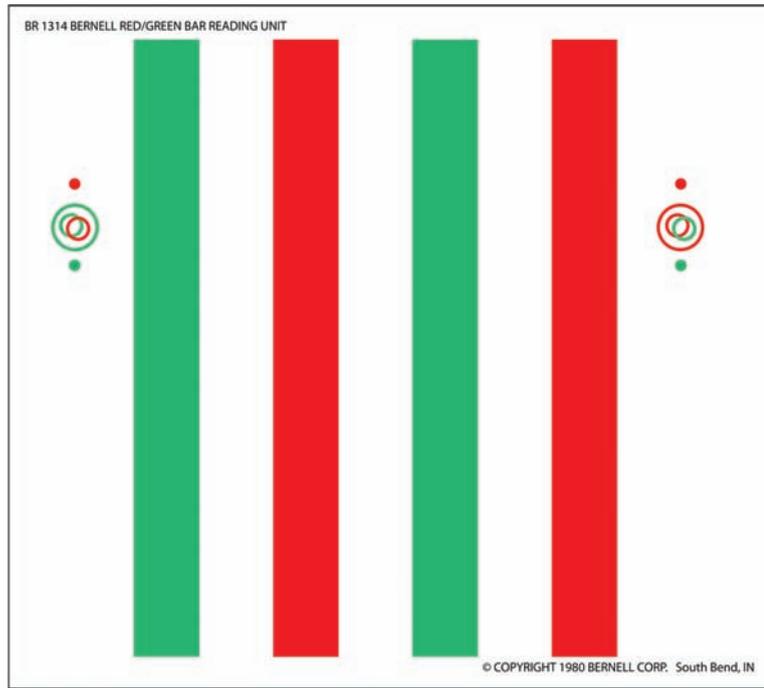
The objectives of the bar reader are to provide a suppression check during BAF therapy or fusional facility therapy.

Equipment Needed

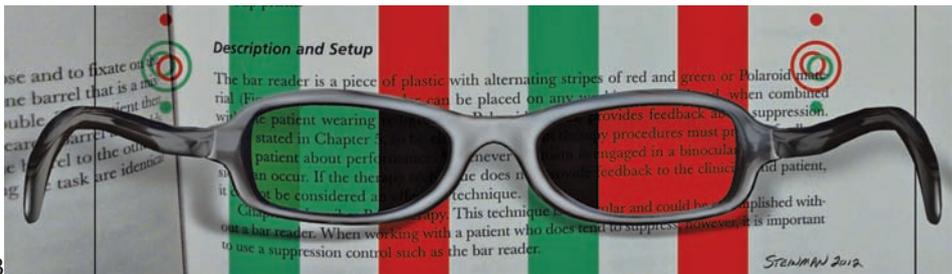
- Red/green bar reader or Polaroid bar reader^a
- Red/green glasses or Polaroid glasses^a
- Age-appropriate reading material
- Flip lenses^a
- Hand-held loose prism^a
- Flip prisms^a

Description and Setup

The bar reader is a piece of plastic with alternating stripes of red and green or Polaroid material (Fig. 6.36). The bar reader can be placed on any working material and, when combined with the patient wearing red/green



A



B

■ **Figure 6.36** Red/green bar reader (alternating bars are green and red).

or Polaroid glasses, provides feedback about suppression. As stated in Chapter 5, to be effective, all vision therapy procedures must provide feedback to the patient about performance. Whenever a patient is engaged in a binocular task, suppression can occur. If the therapy technique does not provide feedback to the clinician and patient, it cannot be considered an effective technique.

Chapter 7 describes BAF therapy. This technique is binocular and could be accomplished without a bar reader. When working with a patient who does tend to suppress, however, it is important to use a suppression control such as the bar reader.

Therapy Procedures

Refer to Chapter 7 for examples of therapy techniques during which the use of a bar reader is helpful. These include the following:

- BAF
- Loose prism jumps
- Flip prism

For all three of these procedures, the bar reader can be used to treat suppression, as well as vergence or accommodation.

TV TRAINER

Objectives

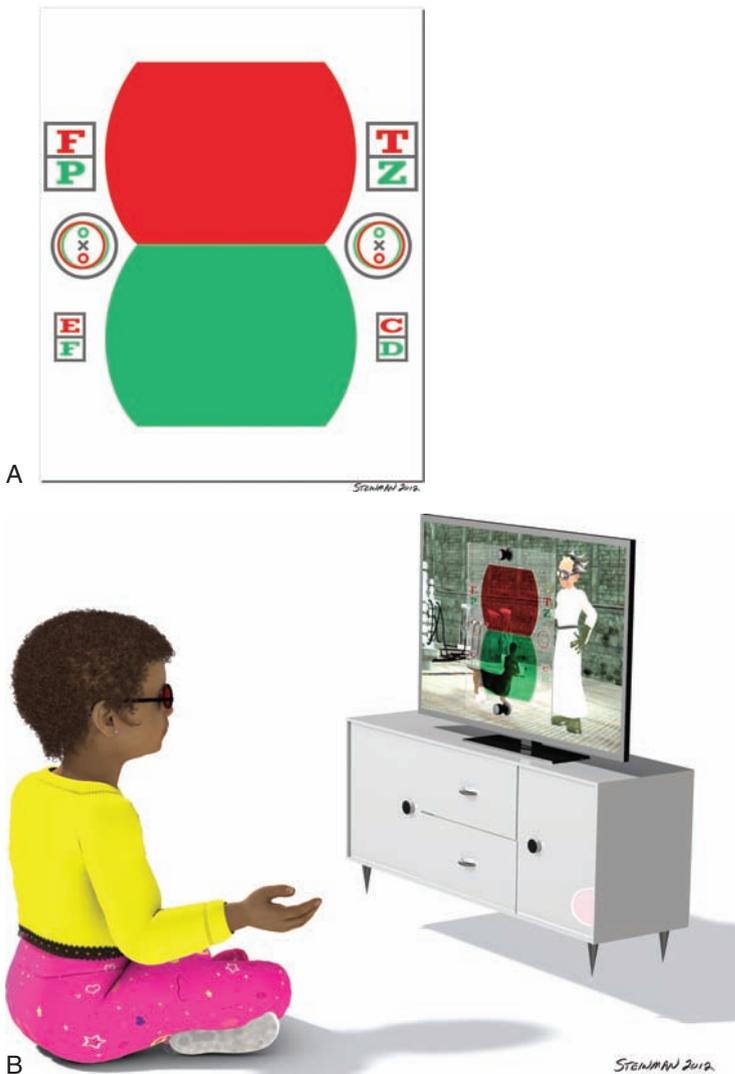
The objectives of the TV trainer are to decrease the intensity and frequency of suppression.

Equipment Needed

- TV trainer^a
- Red/green glasses
- Television set

Description and Setup

The TV trainer is a sheet of plastic with one side all green and the other side all red. This plastic sheet usually comes with two suction cups attached so that it can be easily attached to a television (Fig. 6.37A). The device is attached to the television, and the patient must wear red/green glasses (Fig. 6.37B). The eye behind the



■ **Figure 6.37** A: TV trainer. B: TV trainer positioned on TV.

red filter sees through the red side of the TV trainer, while the eye behind the green filter sees through the green side of the TV trainer. If the patient is suppressing while watching television, one side of the TV trainer will turn black. For instance, if the right eye is suppressing, the television picture behind the red half of the TV trainer will be impossible to see.

TV trainers also are made from Polaroid material. The Polaroid version has one serious drawback that is common to all Polaroid techniques. If the child tilts his or her head to the left or right shoulder, the entire screen can be visible through the TV trainer even if suppression is present. Because the TV trainer is often used for young patients, this problem is very significant. If the child cannot or will not maintain an upright head posture when using the TV trainer, its usefulness diminishes.

The TV trainer is a device that provides feedback to the patient about suppression. The patient is encouraged to try to eliminate the suppression by blinking, trying to converge or diverge (based on the underlying diagnosis), or by moving closer or farther away from the television.

Therapy Procedures

The TV trainer is considered a passive form of therapy. The patient simply watches television as usual, except that the TV trainer is placed on the television. The patient is encouraged to try to see through both sides of the plastic. Watching television becomes impossible if suppression occurs. This calls attention to suppression and a need for the patient to do something to eliminate the suppression.

Changing the Level of Difficulty of the Task

To increase or decrease the level of difficulty of the task, lenses and prism can be used or the working distance can be increased or decreased.

Varying the Working Distance

Many patients tend to suppress more at one distance than at others. For example, a patient with divergence excess will suppress when objects are placed at a distance, but will have normal binocular vision at near. The convergence insufficiency patient will do the opposite. When using the TV trainer with a divergence excess patient, begin with a short working distance initially. If the patient can succeed at short distances, the working distance can be gradually increased.

Lenses

While working with the TV trainer at any particular distance, minus lenses can be used binocularly to increase or decrease the level of difficulty of the task. If the patient is exophoric, minus lenses will generally make fusion and avoidance of suppression easier. If the patient is esophoric, minus lenses will increase the level of difficulty of the task by placing a greater demand on NFV. If an accommodative problem such as accommodative insufficiency or infacility is present, the use of minus lenses may not be effective. Plus lenses have limited value because the TV trainer is generally used at a working distance of 5 ft or greater.

Prism

Prism can also be used to increase or decrease the level of difficulty of the task. Both base-in and base-out prism can be used. Using a flipper with base-out on one side and base-in on the other, fusional facility therapy can be done while the child watches television. In this case, the TV trainer represents a suppression control for the fusional facility technique. Prism is also useful to help the patient eliminate the suppression. If a patient has high exophoria at distance and suppresses while using the TV trainer, base-in prism may facilitate fusion and decrease suppression.

Endpoint

The endpoint for this technique is reached when the patient can maintain single binocular distance without suppression at the distance of concern.

RED/GREEN GLASSES AND PENLIGHT

Objectives

The objectives of the red/green glasses and penlight are to decrease the intensity and frequency of suppression. Because the patient is dissociated during this procedure, pathologic diplopia occurs. This procedure therefore should not be used if the patient is strabismic and has anomalous correspondence.

Equipment Needed

- Red/green glasses
- Penlight or transilluminator
- 6 Δ loose prism
- A rheostat to control room illumination, or several sources of room illumination that can be controlled independently

Description and Setup

To perform this therapy activity, the patient wears red/green glasses and holds a 6 Δ prism base-down before his or her dominant eye while viewing a penlight or transilluminator. The important factor in this procedure is the ability to control room illumination. It is best to perform this technique in a room with a rheostat. As described in Chapter 5, one of the main issues in suppression therapy is to structure the therapy environment so that the patient is least likely to suppress. Clinically, there are several ways of modifying the stimulus to decrease the likelihood of suppression. These include:

- Changing target illumination
- Changing target contrast
- Changing target focus
- Moving the target
- Flashing the target.

The rheostat allows the clinician to vary the room illumination and reach the level of illumination to achieve the best result. We usually begin suppression therapy in artificial conditions and gradually move toward more natural seeing conditions. Red/green glasses and penlight is an example of a therapy procedure using this progression for antisuppression treatment.

Therapy Procedures

With the patient wearing red/green glasses and holding the 6 Δ prism before one eye, the room illumination is turned down until the only visible target is the light of a transilluminator or penlight. Ask the patient how many lights and what color lights are seen. This is a very artificial environment and will often be sufficient to eliminate suppression. If not, the light can be moved from side to side, or the clinician can rapidly move an occluder from one eye to the other. Once the patient can maintain diplopia under these conditions, the room illumination can be gradually increased until the patient can maintain diplopia awareness with full room illumination. To make conditions more natural, the red/green glasses are then removed, which generally will result in suppression again. If this occurs, the room illumination is again decreased until the patient experiences diplopia. Room illumination is gradually increased until the patient can finally appreciate diplopia with full illumination and without red/green filters. This process typically may require 2 to 4 weeks of both in-office and home therapy.

Endpoint

Discontinue this procedure when the patient can maintain diplopia without the red/green glasses in normal room illumination.

VERTICAL PRISM DISSOCIATION

Objectives

The objective of vertical prism dissociation is to decrease the patient's tendency to suppress. The vertical prism is used to create diplopia during binocular viewing.

Vertical prism dissociation is used for patients who have moderate to strong suppression. This is common in anisometropia and high degrees of heterophoria or intermittent strabismus. In such cases, the suppression interferes with fusional vergence therapy. If techniques such as vectograms, tranaglyphs, the Aperture Rule, and the Eccentric Circles or Free Space cards are used, the patient may be frustrated and unable to progress because of intermittent suppression.

Equipment Needed

Penlight or an isolated letter that is within the resolution capacity of the patient
6 to 8 Δ hand-held prism

Description and Setup

When treating suppression, it is important to select room illumination and a target with characteristics that will tend to limit suppression. These concepts were reviewed in Chapter 5.

Usually the procedure begins with low room illumination and a penlight. Place a penlight at a distance of about 5 to 10 ft. Choose the specific distance based on the patient's problem. If the patient's suppression is worse at distance, begin this technique at a close distance. If the suppression is worse at near, begin at a greater distance. The general rule is to begin at a distance at which the patient can succeed and gradually move to the distance at which the patient experiences difficulty.

Ask the patient to look at the target and place a 6 Δ prism base-down before the dominant eye (the dominant eye is the eye that does not tend to suppress). It is best to have the patient hold the prism if he or she is old enough. The patient should now experience diplopia. While the patient maintains diplopia, gradually turn up the illumination in the room. This is most easily accomplished if the illumination is controlled by a rheostat. If not, having several light sources available may be effective. The objective is for the patient to be able to maintain awareness of diplopia as the room illumination changes from low to normal lighting.

It is also possible to combine the use of vertical prism with saccadic and pursuit procedures to increase the level of difficulty of the task. Multiple targets can be used, and the patient must maintain diplopia as he or she makes saccades from one target to another. A commonly used procedure is to use the Hart chart and have the patient call off the first row of letters by viewing the top image and the next row when viewing the bottom image. The patient continues to alternate back and forth between the two images.

A target can also be placed on a rotating device (Chapter 8), and the patient, while maintaining diplopia, alternates between the top and bottom images, trying to maintain accurate fixation of the rotating target.

This antisuppression technique can also be used while working to develop the feelings of convergence and divergence. While the patient experiences diplopia, ask him or her to try to make the images move laterally by converging and diverging. For example, if the patient is exophoric and the bottom image is seen by the right eye, he or she will experience crossed diplopia with the bottom image to the left of the top image.

Ask the patient to try to make the bottom image move to the right of the top image by converging. Once the patient can alternate from crossed diplopia to uncrossed diplopia, it is useful to use a metronome. Instruct the patient to converge and hold for five beats, then try to vertically align the images for five beats, and finally to diverge and hold for five beats of the metronome. This technique can be performed for several minutes.

Endpoint

Discontinue this therapy technique when the patient is able to maintain diplopia under normal room illumination conditions.



■ **Figure 6.38** Mirror superimposition procedure.

MIRROR SUPERIMPOSITION

Objectives

The objectives of mirror superimposition are to decrease the intensity and frequency of suppression.

Equipment Needed

- Small mirror (about 2 in. × 2 in.)
- Variety of fixation targets

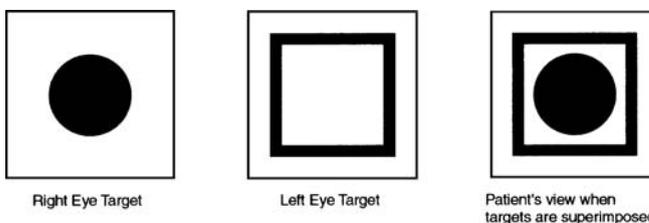
Description and Setup

To perform mirror superimposition, the patient holds a small mirror at a 45-degree angle in front of one eye and views a target through the mirror. With the other eye, he or she views another target. The patient must try to superimpose one image on top of the other.

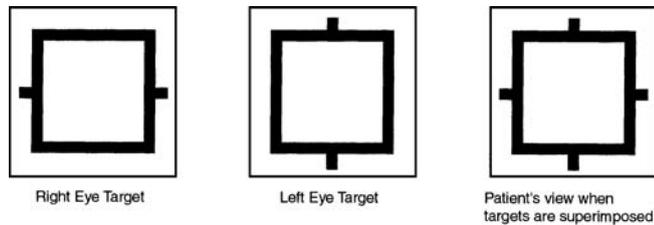
This technique is generally only necessary when suppression is intense enough to interfere with binocular vision therapy procedures such as tranaglyphs, vectograms, the Aperture Rule, and the Eccentric Circles or Free Space cards.

Therapy Procedures

While the patient fixates a target with one eye, he or she holds the mirror at about a 45-degree angle before the other eye and views another target (Fig. 6.38). The objective is for the patient to maintain awareness of both images simultaneously. A variety of targets can be used with mirror superimposition to vary the difficulty of the task. Usually, first- and second-degree targets are used. Samples of each are illustrated in Figures 6.39 and 6.40.



■ **Figure 6.39** First-degree targets used with mirror superimposition.



■ **Figure 6.40** Second-degree target used with mirror superimposition.

First-degree targets, also referred to as superimposition targets, involve the use of two totally different targets. Figure 6.39 shows a typical set of first-degree targets used with mirror superimposition. Using these targets, the patient should report seeing both the circle and the square simultaneously. Such targets are difficult to suppress and are generally used in the early phases of antisuppression therapy.

Second-degree, or flat fusion targets, are identical targets that incorporate suppression checks into their design. An example of a second-degree target is illustrated in Figure 6.40. When such targets are used for mirror superimposition, the patient sees the square with the vertical and horizontal suppression checks.

Another variable that is important for mirror superimposition is the size of the target. Chapter 5 reviewed the various factors that must be considered in antisuppression therapy. One of these factors is the size of the target. We generally begin antisuppression therapy using large peripheral targets and gradually make the targets smaller and more central.

Endpoint

This procedure is usually continued until the patient can maintain awareness of both images even when small central first-degree targets are used. Another criterion that can be used to decide when to discontinue this technique is the patient's performance on other binocular vision tasks. If the patient can successfully work with tranaglyphs, vectograms, the Aperture Rule, and Eccentric Circles or Free Space cards, mirror superimposition is no longer necessary.

Computer Home Therapy Procedures

The use of traditional (noncomputerized) vision therapy procedures for home therapy has always been challenging to implement. These techniques require the parent or patient to interpret responses and use that information to alter stimulus conditions in order to overcome obstacles in therapy. Parents and patients do not generally have the skills necessary to make these decisions. In addition, with young children or with older patients who do not respond accurately for a variety of reasons, traditional techniques may become difficult and unreliable to use. The patient who “learns” the expected response and has a strong desire to please may “give the right response,” even though he or she is not achieving the desired objective. Home-based versions of the computerized vision therapy techniques described earlier for office use are now available and represent a viable alternative for home-based vision therapy.

HOME THERAPY SYSTEM

A popular computer-assisted vision therapy software program designed for home-based vision therapy is the Home Therapy System (HTS).^c It includes a four-step sequential treatment program for vergence therapy that is an excellent way to supplement office therapy. HTS also has programs for accommodative, saccadic, and pursuit therapy. An outstanding feature of this program is the option to monitor the patient's performance at home and modify the program when necessary over the Internet.

COMPUTER AIDED VISION THERAPY: COMPUTER VERGENCES PROGRAM—RANDOM DOT STEREOGRAMS

CAVT^d has home therapy programs for binocular vision, eye movement, and visual information processing therapy. We have found the Computer Vergences program useful for home-based vision therapy for vergence disorders. The Random Dot Stereograms procedure from this program is the one we suggest for home-based therapy.

Study Questions

1. List four procedures that can be used to improve convergence. For each procedure, describe how you would set up the technique and a therapy sequence you would follow.
2. How could you make the task easier for a patient who is struggling to fuse with the Brock string (other than moving the beads away from the face)?
3. The Quoit vectogram targets are separated by 20 mm for a patient seated 40 cm from the target. What is the prismatic demand?
4. How do you create base-out and base-in demand with vectograms and tranaglyphs?
5. A patient is fusing the Quoit vectogram set at 20 base-out. If the target is single and clear, where is the plane of accommodation and the plane of convergence?
6. Describe the differences among the Quoit, Clown, and Spirangle vectograms.
7. If you increase the working distance, you _____ the base-out demand and you _____ the base-in demand.
8. Describe four ways to increase and decrease the prismatic demand when using vectograms and tranaglyphs.
9. Explain how a chiasmatic fusion technique works.
10. Explain how an orthopic fusion technique works.
11. Why is the Aperture Rule more difficult than the vectograms or tranaglyphs?
12. How do you compute the prismatic demand using the Aperture Rule?
13. If a patient reports clear single vision with card 5 when using the double aperture on the Aperture Rule, where is the plane of accommodation and where is the plane of convergence?
14. How can you help a patient who is having difficulty fusing base-out on the Aperture Rule?
15. How can you increase the demand for a patient during base-in fusion on the Aperture Rule?
16. Describe how you would explain to a patient how to fuse base-in with the Eccentric Circles.
17. What is the significance of the letters “A” and “B” on the Eccentric Circles?
18. If a patient reports clear single vision while fusing base-in with the Eccentric Circles, where is the plane of accommodation and where is the plane of convergence?
19. The Eccentric Circles are separated by 5 cm. What is the prismatic demand if the working distance is 20 cm?
20. Name three advantages of the Computer Orthoptics Random Dot Stereopsis Program. What is the most important advantage?

SOURCES OF EQUIPMENT

- (a) Bernell Corporation: 4016 North Home Street, Mishawaka, IN 46545; 800-348-2225.
 (b) Keystone View Company: 2200 Dickerson Road, Reno, NV 89503; 800-806-6569.
 (c) Computer Orthoptics: 6788 Kings Ranch Rd, Ste 4, Gold Canyon, AZ 85218; 800-346-4925; www.visiontherapysolutions.net.
 (d) Computer Aided Vision Therapy, from Bernell Corporation: 4016 N Home St, Mishawaka, IN 46545; 800-348-2225.

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14. Flax N. Simple formulas for computation of prism vergence and accommodation stimulation in a Brewster stereoscope. *Am J Optom Physiol Opt* 1976;53(6):297–302.

Accommodative Techniques

Anaglyphs, Polaroids, and Liquid Crystal Filters	Biocular Loose Lens Rock
Red–Red Rock	Binocular Accommodative Facility
Computer Orthoptics Vts3 Liquid Crystal System:	Paper, Pencil, and Miscellaneous Tasks
Accommodative Program	Hart Chart Distance-to-Near Accommodative Rock (Monocular)
Lenses, Prisms, and Mirrors	Computer Home Therapy Procedures
Lens Sorting (Monocular)	Home Therapy System
Loose Lens Rock (Monocular)	

Anaglyphs, Polaroids, and Liquid Crystal Filters

RED–RED ROCK

Objectives

Red–red rock is an example of an anaglyphic procedure whose objectives are to improve accommodative amplitude and facility. Although both eyes are open for this task, the conditions are not truly binocular because central fusion is not possible; thus, it is referred to as a *biocular task*. Red/green glasses are placed before the eyes, and because of the nature of the targets, neither eye can see both targets.

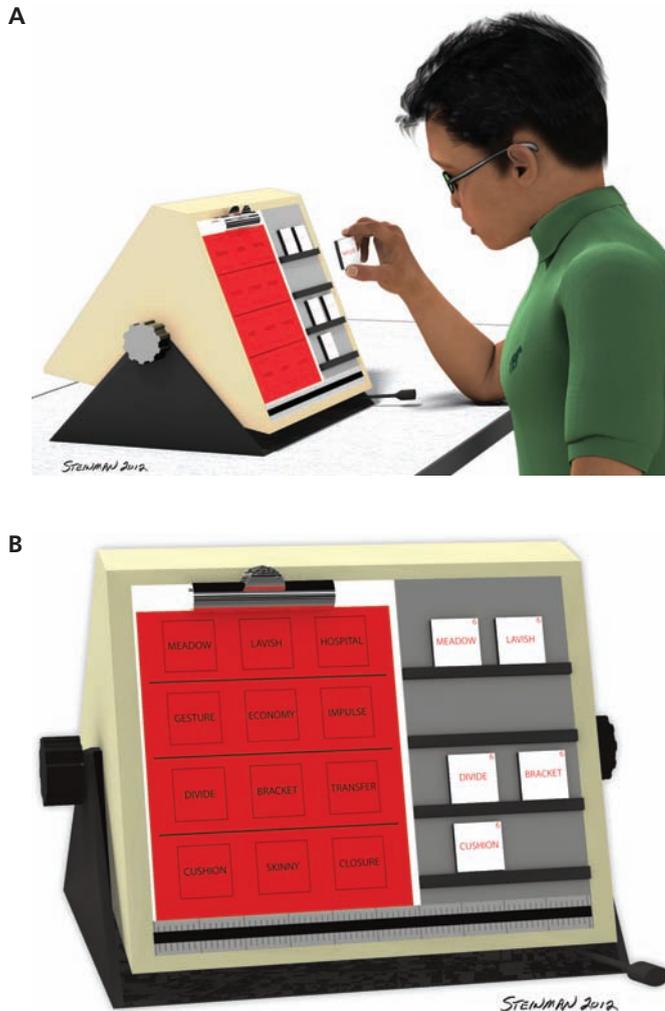
Equipment Needed

- Cheiroscope with red–red rock attachment^c
- Red–red rock tiles^c
- Red/green glasses
- Halberg-type clips
- Trial lenses

Description and Setup

The setup for this procedure is illustrated in Figure 7.1A. The therapist selects white tiles and a matching red transparent slide with black lettering. The tiles and slide are shown in Figure 7.1B. The red transparent slide with black lettering is attached to the rear-illuminated screen of a cheiroscope. The patient wears red/green glasses with the red lens over his or her right eye and the green lens over the left. Give the patient a set of white tiles that have words printed on them in red. On the transparent red slide (40 cm in front of the patient), these same words appear in black lettering. The eye with the red lens sees only the words on the red slide, whereas the eye with the green lens sees only the words on the white opaque tiles. The patient looks at the first white tile and clears the print (eye with green lens) in order to identify the word that must be found on the red slide. The patient then tries to find the matching word on the red slide. To do so, the patient must use his or her right eye with the red filter. Thus, although both eyes are open, central fusion is not possible. Rather, to perform the task, the patient alternates from the right to the left eye.

The addition of clip-on lenses over the red/green glasses introduces the accommodative component to the task. A plus lens is placed before the right eye and a minus lens before the left. As the patient shifts from



■ **Figure 7.1** **A:** Cheiroscope with red-red rock therapy procedure (slide on left-hand side). **B:** Close-up of red-red rock tiles and slide.

the tiles to the red slide and back to the next tile, he or she must alternately inhibit and stimulate accommodation. The power of these lenses is increased in small increments, until the patient can perform the task through $+2.50$ and -6.00 .

- **Level 1:** Ask the patient to complete the matching task with no time consideration. The plus and minus lenses can be alternated from visit to visit so that the right eye is sometimes viewing the target through plus lenses and, at other times, through minus lenses.
- **Level 2:** To increase the level of difficulty of the task, add the variable of time.

Important factors to consider and methods of increasing and decreasing the level of the task are listed in Tables 7.1 and 7.2.

Endpoint

For patients younger than 20 years, discontinue this therapy technique when the patient is able to successfully clear $+2.50$ and -6.00 , 20 cpm. For patients older than 20 years, the endpoint depends on the amplitude of accommodation. Discontinue this procedure when the patient is able to clear minus lenses equal to one half the amplitude of accommodation.

TABLE 7.1 IMPORTANT FACTORS TO EMPHASIZE WHEN PERFORMING ACCOMMODATIVE THERAPY

<p>The feeling of stimulating and relaxing accommodation.</p> <p>The ability to clear the target as quickly as possible when changing lenses.</p> <p>The patient, not the therapist, should hold and manipulate the lenses.</p> <p>Changes must occur within the patient's own visual system.</p> <p>Equalize the performance in the two eyes.</p> <p>The awareness of diplopia during biocular techniques.</p>

COMPUTER ORTHOPTICS VTS3 LIQUID CRYSTAL SYSTEM: ACCOMMODATIVE PROGRAM

Objectives

The objective of this procedure is to improve accommodative amplitude and facility. Although both eyes are open for this task, this procedure is designed as a biocular task. Liquid crystal glasses are used, and neither eye can see both targets. Thus, it is a technique designed to improve the monocular accommodative amplitude and facility.

Equipment Needed

- Computer Orthoptics software: Accommodative program^b
- Liquid crystal glasses
- Computer Orthoptics flippers A, B, and C

Description and Setup

The computer program presents four boxes with the letter “C” inside. Only the right eye first views the stimulus. The letter “C” is randomly pointing up, down, left, or right. The patient is instructed to move the game pad switch in the direction in which the letter “C” is pointing for each box, starting from left to right. Correct responses result in a “beep” tone, and incorrect responses in a “boop” tone. After all responses are made to the first four boxes, a second set of boxes appears; these are seen only by the left eye. While the patient is viewing the targets, accommodative flippers (supplied with the software) are held before the patient's eyes. One eye views the target through a minus lens, while the other views the target through a plus lens. For example, the level 1 accommodative flipper has a +0.75 D lens before one eye and a -1.50 D lens before the other eye, whereas the level 6 accommodative flipper has a +2.50 D lens and a -5.00 D lens.

TABLE 7.2 PROCEDURES TO MODIFY THE LEVEL OF DEMAND OF ACCOMMODATIVE TECHNIQUES

Decreasing the level of difficulty of the task

- Decrease power of lenses.
- Increase size of print.
- For plus lenses, decrease the working distance.
- For minus lenses, increase the working distance.

Increasing the level of difficulty of the task

- Increase power of lenses.
- Decrease size of print.
- For plus lenses, increase the working distance (this is limited to reciprocal of lens power).
- For minus lenses, decrease the working distance.

Endpoint

For patients younger than 20 years, the endpoint is completing the program using the level 6 accommodative flippers.

Lenses, Prisms, and Mirrors

LENS SORTING (MONOCULAR)

Objectives

Lens sorting is a monocular accommodative technique designed to develop an awareness of the ability to relax and stimulate accommodation. A second objective is to teach the patient to voluntarily accommodate or relax accommodation.

Equipment Needed

- Loose uncut lenses
- Accommodative Hopping cards^e (Fig. 7.2)
- Accommodative rock cards^a (Fig. 7.3) or other age-appropriate reading material in various print sizes from 20/80 to 20/30
- Eye patch

Description and Setup

The actual lenses used for this procedure depend on the age of the patient. In all instances, care should be taken to select minus lenses that are less than one half of the patient's amplitude of accommodation. When working with a 30-year-old patient with an amplitude of accommodation equal to 8 D, the highest minus lens used would be 4 D. For the example below, we assume the patient is younger than 20 years. With one eye occluded, the patient is instructed to view age-appropriate reading material with about 20/30-size print. A moderate-power minus lens (-3.00 to -5.00) is placed before the patient's right eye, and he or she is asked to clear the print. The minus lens is removed and is replaced by a low plus lens ($+1.00$ to $+1.50$). The patient is again asked to clear the print through the plus lens.

After repeating this several times, the patient is asked to describe the differences he or she experiences through the minus and plus lenses. The questions should be open-ended initially. If the patient is unable to describe any differences, ask the following questions:

- With which lens is the print larger or smaller?
- With which lens do you feel more strain or effort?
- Does this lens make you look close or far?

The objective is for the patient to realize that he or she can either stimulate or relax the accommodative system and learn to do this voluntarily. Any other questions that will lead the patient to this objective would be appropriate.

Once the patient can consistently describe that the print becomes smaller with the minus lenses and appears either closer or farther away, the second objective is to help the patient develop a kinesthetic awareness of accommodation. We want the patient to be able to appreciate the difference in feeling between relaxing and stimulating accommodation. Often it is necessary to ask specific questions and spend some time explaining what the patient is experiencing. The following is an example of such an explanation: "Does it feel like you are working harder or straining your eyes now? That is the feeling of focusing. If you cannot see clearly through this lens, try to get the feeling of straining, looking close, or focusing your eyes." (Conversely, with plus lenses you would ask the patient to get the feeling of looking far away, relaxing the eyes, or drifting off to sleep.)

Once the patient can appreciate the differences between looking through a plus and minus lens, he or she is ready to begin the actual procedure of lens sorting. The therapist now places six to eight unmarked

Accommodative Hopping Card -- A

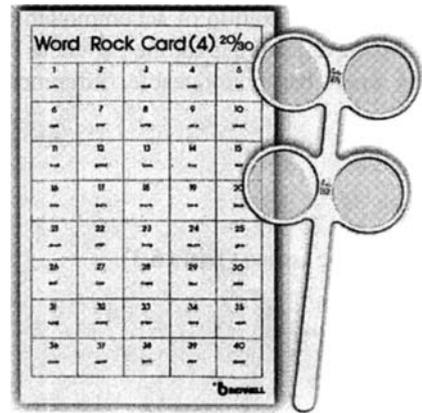
Switch lenses after each word as you follow the directions in the column to the left.

Find words starting with P	Shoe	Pig	Ice	Please	Rice	People	Lake
Find the body parts	Hand	Ear	School	Arm	Go	Eye	Lace
Find things that fly	Airplanes	Flies	Cat	Birds	Dog	Rock	Bug
Find things that you wear on your hands	Blue	Rings	Gloves	Jelly	Pencil	Sock	Butter
Find the numbers	Four	Door	Man	Run	Twelve	Ten	Three
Find the flowers	Rose	Daisy	Dirt	Worm	Tulip	Ice	Food
Find the clothes	Pencil	Look	Shirt	Back	Pants	Stove	Shoes
Find the Colors	Blue	Yellow	Think	People	Orange	Paper	Black
Find the seasons of the year	Winter	Birds	Snow	Spring	Have	Look	Fall
Find the days of the week	Monday	Ice Cream	Mother	Tuesday	Dog	Tire	Friday
Find the fruits	Fire	Peach	Beans	Trumpet	Banana	Tomato	Bread
Find words ending with m	Mom	Night	From	Run	Clock	Log	Beam
Find the States	Texas	Milk	Jump	Ohio	Write	Idaho	Atlanta
Find the parts of a car	Trunk	Engine	Tires	Day	Three	Radio	Window
Find the coins	Nickels	Dimes	Girl	After	Pennies	Juice	Red
Find things that make noise	Car	Dog	Apple	Tree	Thunder	Ladybug	Rain
Find things with wheels	Worm	Wagon	Pencil	Puppy	Mailbox	Plane	Sled
Find things that are orange	Carrots	Clouds	Trees	Sweet potato	Barn	Pig	Van

■ **Figure 7.2** Accommodative Hopping cards.

uncut lenses on the table in front of the patient. The patient is asked to sort the lenses from strongest to weakest—the strongest being the lens that makes him or her focus the most, the weakest being the lens that causes the greatest relaxation. Begin with large increments, such as +2.50, +1.25, -1.00, -2.00, -3.00, or -4.00. As the patient's ability to feel and distinguish the difference between stimulation and relaxation of accommodation improves, use smaller and smaller increments. Ultimately, the objective is for the patient to be so sensitive that he or she will be able to recognize very small, barely noticeable differences such as a 0.5 D increment.

■ **Figure 7.3** Accommodative rock cards can be used as a target for the loose lens rock procedure.



Important Factors

When performing this procedure, one must stress the following issues (Table 7.1):

- The feeling of stimulating and relaxing accommodation
- The ability to work with smaller and smaller increments
- The ability to sort the lenses as quickly as possible

Changing the Level of Difficulty of the Task

Decreasing the Level of Difficulty of the Task

Occasionally a patient will be unable to clear the plus lenses or the minus lenses because of an accommodative insufficiency or accommodative excess problem. To overcome this problem, simply use lenses with which the patient can succeed. For example, if the patient has an accommodative excess problem and cannot clear even low levels of plus, use only minus lenses. Here the goal would be for the patient to be able to differentiate between low and high degrees of minus lenses. As therapy proceeds and accommodative ability improves, plus lenses can be gradually introduced. Another way to overcome this obstacle is to use the lenses that the patient has difficulty with, but with larger print size.

For a patient with accommodative infacility and difficulty with both plus and minus lenses, the best method for making the task easier is to use larger print size. The therapist must proceed slowly with this procedure; as the patient begins to show improvement in accommodative facility, the print size can be made smaller and the standard technique utilized.

Increasing the Level of Difficulty of the Task

To make this task more difficult, the increments can be made as small as 0.25 D. Another approach is to introduce the variable of speed and determine how quickly the patient can sort eight lenses.

Endpoint

Discontinue this therapy technique when the patient is able to successfully sort eight lenses with 0.5 D increments in order from most minus to most plus.

LOOSE LENS ROCK (MONOCULAR)

Objectives

The objectives of the loose lens rock are to restore normal accommodative amplitude and facility. Both the range over which the patient can accommodate and the speed of the accommodative response are considered important in this technique.

Equipment Needed

Age-appropriate reading material of varying print sizes from 20/80 to 20/30
 Uncut plastic lens blanks from -6.00 to $+2.50$, in 0.25 D increments
 Accommodative Hopping cards (Fig. 7.2)
 Eye patch

Description and Setup

- Level 1:** The setup for this procedure is illustrated in Figure 7.4 (revise with hopping cards). Occlude the patient's left eye and ask him or her to follow the instructions on the Accommodative Hopping cards held at 40 cm through plus and minus lenses that are alternately held in front of his or her eye. The initial lenses selected are empirically determined based on the results of the diagnostic testing.

In the initial phase of this technique, give the patient as much time as necessary for him or her to clear and complete the task. The goal is merely to achieve clear vision, without regard to the time factor. For children and teenagers, once the patient can clear $+2.50$ to -6.00 , speed becomes the next objective. For adults, the strongest minus lens value used should be equal to one half the expected amplitude of accommodation.

- Level 2:** Now ask the patient to regain clarity as quickly as possible and complete the Accommodative Hopping task. Begin with low-power lenses and ask him or her to clear the print through $+0.50$ and -0.50 , 20 cpm. When this can be accomplished, increase the power of the lenses until the patient can perform 20 cpm, with $+2.00$ and -4.00 . (For adults, this minus lens value should not exceed one half the expected amplitude of accommodation.)

Important factors that should be considered and methods of increasing and decreasing the level of difficulty of the task are listed in Tables 7.1 and 7.2.

Endpoint

For patients younger than 20 years, discontinue this therapy technique when the patient is able to successfully clear $+2.50$ and -6.00 , 20 cpm. For patients older than 20, the endpoint depends on the amplitude of accommodation. Discontinue this procedure when the patient clears minus lenses equal to one half the amplitude of accommodation.



■ Figure 7.4 Loose lens rock procedure.

BIOCULAR LOOSE LENS ROCK

Objectives

The objectives of this procedure are to restore normal accommodative amplitude and facility while eliminating suppression. Both the range over which the patient can accommodate and the speed of the accommodative response are considered important in this technique. Although this procedure is often unnecessary, we do recommend its use when elimination of suppression is a therapy objective.

Equipment Needed

Accommodative Hopping cards^c, or other age-appropriate reading material of varying print sizes from 20/80 to 20/30
Uncut plastic lens blanks from -6.00 to $+2.50$ in 0.25 D increments
Halberg clips^a
 6Δ loose prism

Description and Setup

- **Level 1:** The setup for this procedure is essentially identical to that just described for the loose lens rock. The main difference is that both eyes are open, and the patient wears a 6Δ vertical prism before one eye to dissociate the two eyes. This can be accomplished using a trial frame or Halberg clips with the patient's current prescription or glasses with plano lenses. Because of the weight of a trial frame, even if the patient does not wear glasses, it is best to have plano training glasses available.

Use 20/20- to 20/30-size print that is appropriate for the patient's reading level. The working distance should be 40 cm. With the vertical prism in place, add low plus lenses before one eye and low minus before the other eye. The patient should report diplopia. Ask the patient to attend to the lower target first and clear the print. After reading one line, the patient should now clear the print on the upper target and read one line. In the initial phase of this technique, give the patient as much time as necessary to clear and read the print. The goal is merely to achieve clear vision without regard to the time factor. Once the patient can clear $+2.50$ to -6.00 , speed becomes the next objective.

- **Level 2:** Now ask the patient to regain clarity as quickly as possible. Begin with low-power lenses and ask him or her to clear the print through $+0.50$ and -0.50 , 20 cpm. When this can be accomplished, increase the power of the lenses until the patient can perform 20 cpm, with $+2.00$ and -4.00 .

Important factors to be considered and methods for increasing and decreasing the level of difficulty of this task are listed in Tables 7.1 and 7.2.

Endpoint

For patients younger than 20 years, discontinue this therapy technique when the patient is able to successfully clear $+2.50$ and -6.00 , 20 cpm. For patients older than 20, the endpoint depends on the amplitude of accommodation. Discontinue this procedure when the patient clears minus lenses equal to one half the amplitude of accommodation.

BINOCULAR ACCOMMODATIVE FACILITY

Objectives

The objectives of binocular accommodative facility (BAF) are to decrease the latency and increase the speed of the accommodative response under binocular conditions.

Equipment Needed

Flip lenses in various powers: ± 0.50 , ± 0.75 , ± 1.00 , ± 1.25 , ± 1.50 , ± 1.75 , ± 2.00 , ± 2.25 , and ± 2.50 ^a
Accommodative Hopping cards

Accommodative rock cards^a or other age-appropriate reading material in various print sizes from 20/80 to 20/30
 Polaroid or red/green bar reader^a
 Polaroid or red/green glasses^a
 Any binocular vision target, such as vectograms,^a tranaglyphs,^a the Aperture Rule,^a Eccentric Circles,^c or Free Space Fusion cards^d

Description and Setup

Procedure 1

This procedure is illustrated in Figure 7.5. A red/green bar reader and red/green glasses are used along with age-appropriate reading material. The patient, wearing red/green glasses, is instructed to view age-appropriate reading material with about 20/30-size print. The bar reader is placed on top of the reading material. Start with $+0.50/-0.50$ lenses and empirically determine the lenses that the patient can just clear with minimal effort. This will be the starting point. It is common for some patients to have more difficulty with either plus or minus at this stage, depending on their underlying problem. Flip lenses are held before the patient's eyes, and he or she is instructed to clear the print. The patient reads one line of print, and the flip lenses are flipped to the other side, presenting a new accommodative stimulus. The patient is again asked to clear the print and read one line through the flip lenses. The therapist emphasizes that the reading material should always be visible through the four stripes of the red/green material.

After repeating this several times, the patient is asked to describe the differences he or she experiences through the minus and plus lenses. The questions should be open-ended at first. If the patient is unable to describe any differences, ask the following questions:

- With which lens is the print larger or smaller?
- With which lens do you feel more strain or effort?
- Does this lens make you look close or far?
- With which lens is it easiest to see all four lines?

The objective is for the patient to realize that he or she can either stimulate or relax the accommodative system and to learn to do this voluntarily. Any other questions that will lead the patient to this objective would be appropriate.

Once the patient can consistently describe that the print becomes smaller with the minus lenses and appears either closer or farther away, the second objective is to help the patient develop a kinesthetic awareness of accommodation. We want the patient to be able to appreciate the difference in feeling between relaxing and stimulating accommodation. Often it is necessary to use questions and statements such as the



■ **Figure 7.5** Binocular accommodative facility using a bar reader.



■ **Figure 7.6** Aperture Rule used for binocular accommodative facility.

following: “Does it feel like you are working harder or straining your eyes now? That is the feeling of focusing. If you cannot see clearly through this lens, try to get the feeling of straining, looking close, or focusing your eyes.” (Conversely, with plus lenses you would ask the patient to get the feeling of looking far away, relaxing the eyes, or drifting off to sleep.)

The same procedure can be performed using Polaroid glasses and a Polaroid bar reader.

Procedure 2

BAF therapy can also be performed using any fusional vergence therapy target. Procedures such as vectograms, tranaglyphs, the Aperture Rule, and Eccentric Circles are all very valuable techniques for BAF (Fig. 7.6). These techniques are described in Chapter 5.

Important factors to be considered and methods of increasing and decreasing the level of difficulty of the task are listed in Tables 7.1 and 7.2.

Endpoint

Discontinue this therapy technique when the patient is able to successfully clear $+2.50$ and -2.50 , 20 cpm, without suppression.

Paper, Pencil, and Miscellaneous Tasks

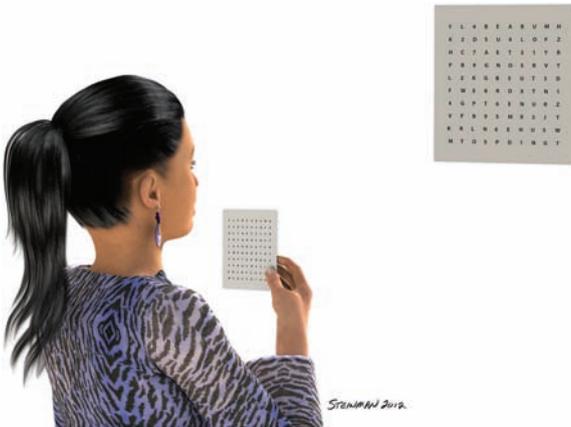
HART CHART DISTANCE-TO-NEAR ACCOMMODATIVE ROCK (MONOCULAR)

Objectives

The objectives of Hart chart rock are to restore normal accommodative amplitude and facility. Both the range over which the patient can accommodate and the speed of the accommodative response are considered important in this technique.

Equipment Needed

- Large Hart chart suitable for distance viewing^a
- Small Hart chart suitable for near viewing^a
- Eye patch



■ **Figure 7.7** Hart chart for accommodative rock.

Description and Setup

The setup for this procedure is illustrated in Figure 7.7.

- **Level 1:** Have the patient cover his or her left eye with the eye patch. Ask the patient to hold the small chart at 40 cm, focus on the top line, and read the line aloud when it is clear. After reading the top line on the near chart, ask him or her to look at the second line of the far Hart chart and read it aloud when it is clear. The patient continues to alternate from the near to the far Hart chart for several minutes. Repeat the entire sequence with the right eye covered and the left eye open.
- **Level 2:** Ask the patient to hold the small chart at arm's length and to call off the letters on the top line as he or she slowly moves the chart closer. When the patient can no longer keep it clear, have him or her shift to the second line of the larger chart, which is placed at about 10 ft. Have the patient repeat the procedure with the third line of the small chart, moving it closer as he or she calls off the letters. Repeat the procedure with the patch moved to the right eye.
- **Level 3:** To increase the level of difficulty, ask the patient to hold the near chart 1 to 2 in. farther away than the point at which he or she reports blurred vision and switch fixation from the larger distance chart to the smaller near chart. Each time the patient switches fixation, he or she reads a line.

Important factors to consider and methods of increasing and decreasing the level of difficulty of the task are listed in Tables 7.1 and 7.2.

Endpoint

For patients younger than 20 years, discontinue this therapy technique when the patient is able to successfully clear the near chart when it is held 3 in. from his or her eyes and then change fixation and clear the far Hart chart held at 10 ft. For patients older than 20, the endpoint depends on the amplitude of accommodation. Discontinue this procedure when the patient can successfully clear the near chart, which is held at a distance equal to half of his or her amplitude.

Computer Home Therapy Procedures

HOME THERAPY SYSTEM

A popular computer-assisted vision therapy software program designed for home-based accommodative therapy is the Home Therapy System (HTS).⁶ It includes a procedure for monocular accommodative facility therapy. The program comes with several flippers that allow the patient to slowly progress from

lower to higher amounts of lens power. Like the HTS vergence program, the therapist or optometrist has the option to monitor the patient's performance at home and modify the program when necessary over the Internet.

Study Questions

1. How can you increase the level of difficulty with red–red rock?
2. Would you expect a patient to have more difficulty sorting five lenses with 0.5 D increments or 1 D increments? Explain your reasoning.
3. Describe two methods of decreasing the level of difficulty of the lens-sorting task.
4. Describe two techniques you could use to help a patient who is experiencing difficulty with the BAF procedure.
5. How can you increase the level of difficulty of the Hart chart procedure?

SOURCES OF EQUIPMENT

- (a) Bernell Corporation: 4016 North Home Street, Mishawaka, IN 46545; 800-348-2225.
- (b) Computer Orthoptics: 6788 Kings Ranch Rd, Ste 4, Gold Canyon, AZ 85218; 800-346-4925; www.visiontherapysolutions.net.
- (c) Keystone View Company: 2200 Dickerson Road, Reno, NV 89503; 800-806-6569.
- (d) Computer-Assisted Vision Therapy, available from Bernell Corporation: 4016 N Home St, Mishawaka, IN 46545; 800-348-2225.
- (e) Gulden Ophthalmics 225 Cadwalader Ave, Elkins Park, Pennsylvania 19027; (800) 659-2250, <http://www.guldenophthalmics.com/>

Ocular Motility Procedures

Lenses, Prisms, and Mirrors

Loose Prism Jumps

Paper, Pencil, and Miscellaneous Tasks

Hart Chart: Saccadic Therapy

Letter and Symbol Tracking

Visual Tracing

Rotator-Type Instruments

Flashlight Tag

Computer Software/Advanced Technology

Procedures

Afterimage Techniques

Afterimages

Computer Home Therapy Procedures

Computer Orthoptics

Lenses, Prisms, and Mirrors

LOOSE PRISM JUMPS

Objectives

The objectives of loose prism jumps are to improve the accuracy and speed of saccadic eye movements. The procedure is always performed monocularly.

Equipment Needed

Loose prisms with the following powers: 12, 10, 8, 6, 5, 4, 3, 2, 1, and 0.5 Δ ^{a,b}

A variety of fixation targets to be used at distance and near, ranging in size from 20/60 to 20/20

Description and Setup

While the patient views a target monocularly, a prism is placed before the fixating eye. Because the prism displaces the image of the fixation object off the fovea, a saccade will be necessary to regain foveal fixation. The objectives are for the patient to be able to quickly and accurately regain fixation. In addition, an important goal is for the patient to be sensitive to very small amounts of prism. As discussed earlier, the goal of the therapy with saccades is to move from large, gross saccadic movements to small, fine movements. The procedure should therefore begin with a large magnitude prism, with a gradual reduction in the magnitude of the prism until the patient successfully works with 0.5 Δ . Another important variable is the size of the fixation object. Begin with larger targets (20/60) and decrease the target size until the patient can work with 20/20-size print with 0.5 Δ .

When the therapist works with the patient, the placement of the base of the prism should be varied each time (base-up, base-down, right, left, and any combination). Thus, the required direction of the saccadic eye movement will not be known in advance.

Endpoint

Discontinue this therapy technique when the patient is able to make an accurate rapid saccade using 0.5 Δ and a 20/20 target at both a distance and near-working distance.

Paper, Pencil, and Miscellaneous Tasks

HART CHART: SACCADIC THERAPY

Objectives

The objectives of the Hart chart for saccadic therapy are to increase the speed and accuracy of saccadic fixation.

Equipment Needed

- Large Hart chart for distance viewing
- Eye patch

Description and Setup

Place the Hart chart about 5 to 10 ft from the patient. Occlude the patient's left eye with an eye patch and instruct the patient to call out the first letter in column 1 and then the first letter in column 10, the second letter from the top in column 1 and the second letter from the top in column 10, the third letter from the top in column 1 and the third letter from the top in column 10, and so forth. Continue until the patient has called out all letters from columns 1 and 10. As the patient calls out the letters, write down the responses and, when the task is completed, have the patient check his or her accuracy. Requiring the patient to check for errors is, in itself, another saccadic therapy technique. Now the patient will have to make saccades from far to near to check for errors.

Once the patient is able to complete this task in about 15 seconds without any errors, you can increase the level of difficulty in several ways. Ask the patient to continue calling out letters in the other columns. Specifically, after completing columns 1 and 10, have the patient call out columns 2 and 9, 3 and 8, 4 and 7, and 5 and 6. The inner columns are more difficult because they are surrounded by other targets.

An even greater level of difficulty can be achieved by requiring saccades from the top of one column to the bottom of another. Instead of a left-to-right and right-to-left saccade, the patient will have to make an oblique saccade. For example, ask the patient to call out the top letter in column 1 and then the bottom letter in column 10, the second letter from the top in column 1 and the second letter from the bottom in column 10. Continue this pattern through the entire chart.

Many other variations to increase the level of difficulty are possible, including the use of multiple Hart charts and split Hart charts, incorporating the click of a metronome, and requiring the patient to maintain balance on a balance board while engaged in the task.

LETTER AND SYMBOL TRACKING

Objectives

The objectives of letter and symbol tracking are to increase the speed and accuracy of saccadic fixation. These procedures are generally used with children.

Equipment Needed

- Letter and symbol tracking workbooks^a
- Plastic sheet, 8.5 × 11 in.
- Paper clip
- Pen used for overhead transparencies (washable type)
- Eye patch

Description and Setup

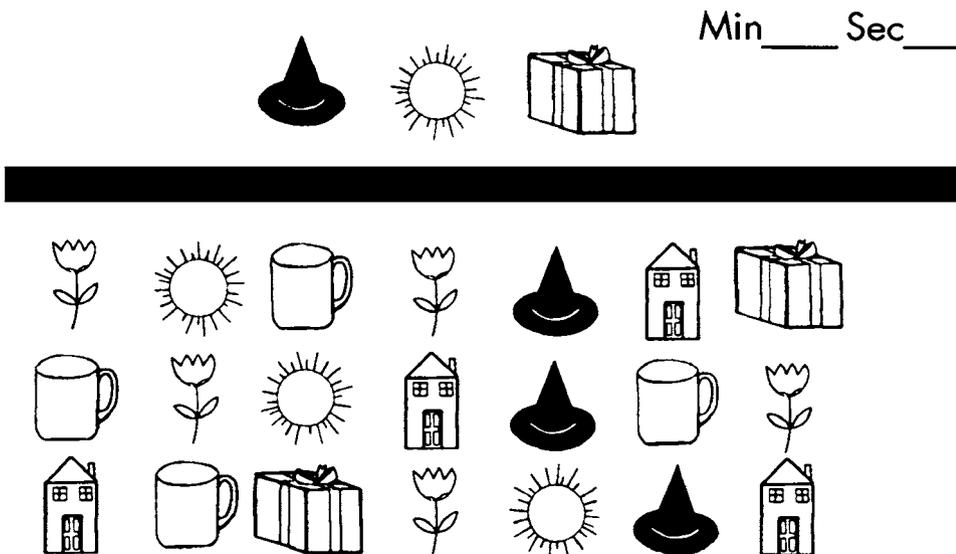
Figures 8.1 and 8.2 illustrate the two workbooks. Both are designed to improve saccadic accuracy and speed. To permit the repeated use of the workbooks, we suggest that you cover the page being used with a plastic sheet and secure the plastic with a paper clip. We use overhead transparency sheets for this purpose.

ABCDEFGHIJKLMNOPQRSTUVWXYZ 19
 abcdefghijklmnopqrstuvwxyz

Iln chako evi nomd zeby thipg nare.
 Zuth pirm nuroc dif stok.Nileg myt
 loIf.Tixs nom raus zab tuin lugah.
 Marb sewt rotsir puje. Yonak nesud
 voz alee. Xart chod bugm turh sref
 trea gen foru. Vab reps tique kowj.
 Dagh meulb fwer ilg sida. Ubc they
 bouf yed neoph vaik.Wolen kig peab
 nad tenc xerb.Rait rebey fal zibt
 _____Min. _____Sec.

■ Figure 8.1 Letter tracking workbook.

As you can see from Figure 8.1, each page of letter tracking has two or more paragraphs of what appear to be random letters. Occlude one of the patient’s eyes and tell the patient to begin at the upper right and scan from left to right to find the first letter “a” and to make a line through that letter. Ask the patient to then find the very first “b,” cross it out, and continue through the entire paragraph, finding the letters of the alphabet in order. The goal is to complete this task as quickly as possible. The therapist should time the therapy procedure. The patient’s accuracy can also be evaluated. If the patient is scanning for the very first letter “d,” for instance, and inadvertently misses it and finds a “d” later in the paragraph, he or she will be unable to find the entire alphabet sequence in the paragraph. The workbook has five different sizes of letters, creating another level of difficulty. We suggest that after the child finds and marks a specific letter, the pen be lifted off the page so that the patient will have to use saccades to find the next letter.



■ Figure 8.2 Symbol tracking workbook.

If the child experiences difficulty with this task, symbol tracking (Fig. 8.2) can be used. Children in the first grade will sometimes have difficulty because of a lack of familiarity with the alphabet. This can cause great frustration and make the therapy technique very unpleasant for the child. In such cases, use symbol tracking, which utilizes large pictures, symbols, numbers, and fewer letters. The task is therefore considerably easier and is very useful with younger children or those with very severe ocular motility disorders.

Endpoint

Discontinue this technique when the performance in each eye is approximately equal and when the patient can successfully complete the paragraphs in about 1 minute.

VISUAL TRACING

Objectives

The objectives of this technique are to improve the accuracy and speed of pursuit eye movements.

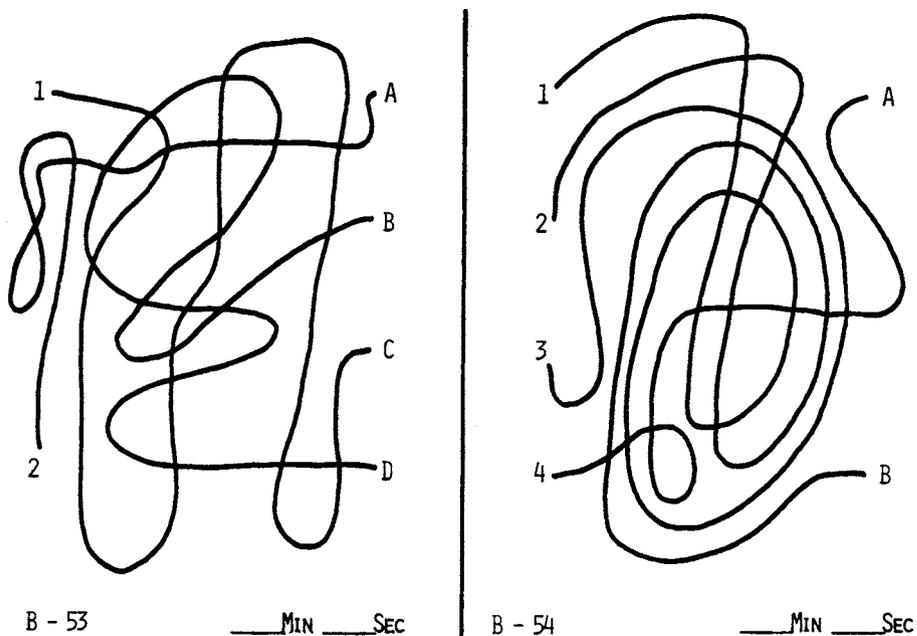
Equipment Needed

- Visual tracing workbooks^a
- Plastic sheet, 8.5 × 11 in.
- Paper clip
- Pen used for overhead transparencies (washable type)
- Eye patch

Description and Setup

Figure 8.3 shows the visual tracing workbooks. The workbook contains tracing tasks that gradually increase in level of difficulty from the beginning to the end of the book. There are two therapy methods that can be used.

The easiest procedure is to occlude one of the patient's eyes and ask the patient to place the pen on the letter "A" and to trace along the line until the end of the line. The objective is for the patient to determine the



■ **Figure 8.3** Visual tracing workbook.

number at the end of the line beginning with the letter “A.” Instruct the patient to then continue until he or she finds the answer for each line.

As the patient’s accuracy and speed improve, the next level of difficulty can be added. In this technique, the patient must perform the same task using just his or her eyes. The patient must make a pursuit eye movement without the support of following the line with the pen.

Endpoint

There are no specific clinical guidelines for this procedure. We continue this technique until the patient can perform with a reasonable degree of accuracy and speed.

ROTATOR-TYPE INSTRUMENTS

Objectives

The objectives of this technique are to improve the accuracy and speed of pursuit eye movements.

Equipment Needed

- Rotating pegboard^a
- Automatic rotating device^a
- Golf tees
- Eye patch

Description and Setup

Figures 8.4 and 8.5 illustrate two automatic rotating devices that can be used to treat pursuit eye movement disorders. The instrument in Figure 8.4 is called the rotating pegboard. Many different procedures can be performed with this instrument. After occluding one of the patient’s eyes, instruct the patient to place a golf tee into a hole in the pegboard. Stress that you want the patient to first find the specific hole he or she will be using and then, in one motion, place the peg in the hole. Once the patient can accomplish this, turn on the rotating pegboard. Now instruct the patient to locate the first hole and hold the golf tee directly over the hole (although not touching it) for one full rotation. After the patient successfully matches the speed of the rotating pegboard for one revolution, instruct him or her to insert the peg in the hole with one motion. Have the patient continue this until all of the holes are filled with golf tees. Of course, the holes on the innermost part of the rotating pegboard are the easiest to work with, and the outer holes are the most difficult.

To combine saccadic eye movements with pursuit eye movements, you can draw a pattern for the patient to follow on a wall directly behind the rotating pegboard. A typical pattern might require the patient to only place a peg in every third hole. The code itself can be simple or complex depending on the capability of the patient.

Endpoint

Discontinue this procedure when the patient can accurately complete the entire pegboard following a peg placement code.



■ **Figure 8.4** Rotating pegboard (concentric circles are different colors: red, yellow, and blue).



■ **Figure 8.5** Automatic rotator.

FLASHLIGHT TAG

Objectives

The objectives of this procedure are to improve the speed and accuracy of pursuit eye movements.

Equipment Needed

- Two flashlights
- Eye patch

Description and Setup

This is a simple technique in which the therapist holds one flashlight and the patient holds the other. The technique is performed monocularly. Using the flashlight, you simply need to create a pattern on the wall and instruct the patient to follow your pattern, keeping his or her flashlight superimposed on yours. Begin with predictable, repeatable patterns and gradually introduce random, unpredictable patterns.

COMPUTER SOFTWARE/ADVANCED TECHNOLOGY PROCEDURES

One of the important changes in vision therapy equipment in recent years has been the introduction of computer. Computers are ideally suited for creating the stimuli and variability necessary for vision therapy techniques. This is particularly true for eye movement training. There are several excellent programs for this purpose. The primary systems available are the products from Computer Orthoptics,^b Computer-Aided Vision Therapy,^a and Wayne Engineering.^c

Computer Orthoptics

Computer Orthoptics Liquid Crystal Automated Vision Therapy (VTS4)^b

This program has outstanding procedures for binocular vision and accommodative therapy, and it also has one procedure for saccadic and one for pursuit therapy.



■ **Figure 8.6** Sanet Vision Integrator—Saccadic procedure.

Computer Perceptual Therapy (CPT)^b

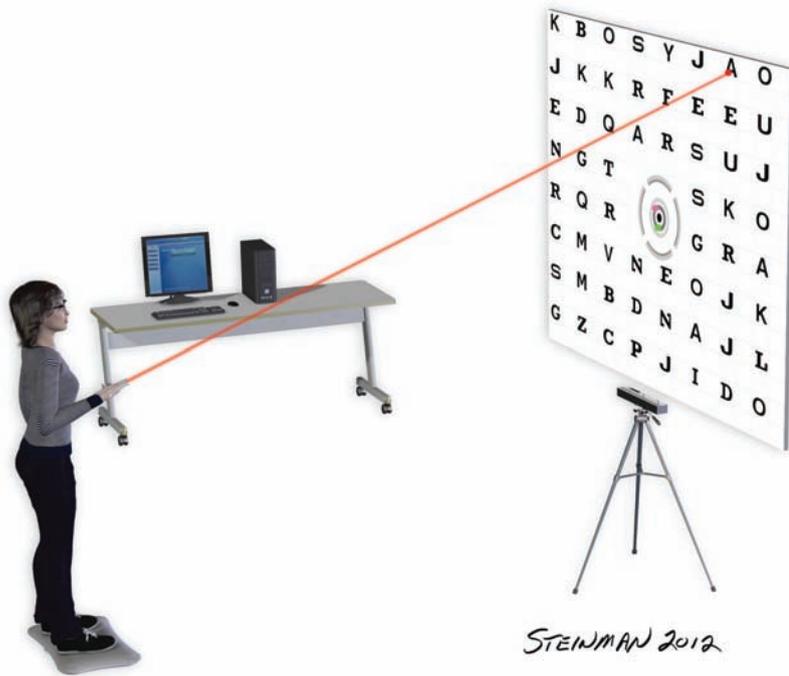
Although designed as a therapy program for visual information processing disorders, the program also includes a number of excellent saccadic fixation therapy procedures.

Sanet Vision Integrator (SVI)

SVI has numerous procedures designed to improve both saccades and pursuits (Fig. 8.6). It is one of the few systems that allows for sequential treatment of pursuits (Fig. 8.7). The software allows the clinician to vary a wide range of parameters and accurately monitor progress.



■ **Figure 8.7** Sanet Vision Integrator—Pursuit procedure.



■ **Figure 8.8** Patient working with NVR equipment/software program.

Neurovision Rehabilitator (NVR)

The NVR Therapy Modules use Wii remotes and sensors which provide real space interactive feedback, thus integrating vision, auditory, proprioception, balance, and visuomotor control while the patient is engaged in saccadic and pursuit procedures (Fig. 8.8). This provides the patient with motivating auditory and tactile feedback as he or she interacts with the program.

The Perceptual Visual Tracking Program (PVT)

This is a home-based software program designed to improve saccadic problems. Five computer procedures are included: Matching Targets, Moving Box, Moving Line, Hidden Targets, and Saccadic Tracking (Fig. 8.9).

Computer-Aided Vision Therapy

Track and Read

Track and Read contains 12 therapy procedures for developing saccadic eye movements. Track and Read uses “Autopacing” that allows each procedure to self-adjust to the patient’s individual skill levels. With Autopacing on, the therapy procedure becomes more difficult each time a correct response is made and easier with each wrong response.

We highly recommend incorporation of computerized vision therapy equipment. For detailed information about these programs, we suggest viewing the detailed informational websites that can be accessed by searching the internet using the name of the software product.

Wayne Engineering

It is a computerized instrument for developing, evaluating, and testing accurate and rapid eye-hand coordination, spatial integration, and reaction times (Fig. 8.10). It is the new version of the original Wayne Saccadic Fixator (“Circle of Lights”)—the developmental optometric and sports vision professions’ standard for over 37 years.



■ **Figure 8.9** Patient working with the PVT program.

Wayne Membrane Saccadic Fixator

Visual Stick-ups

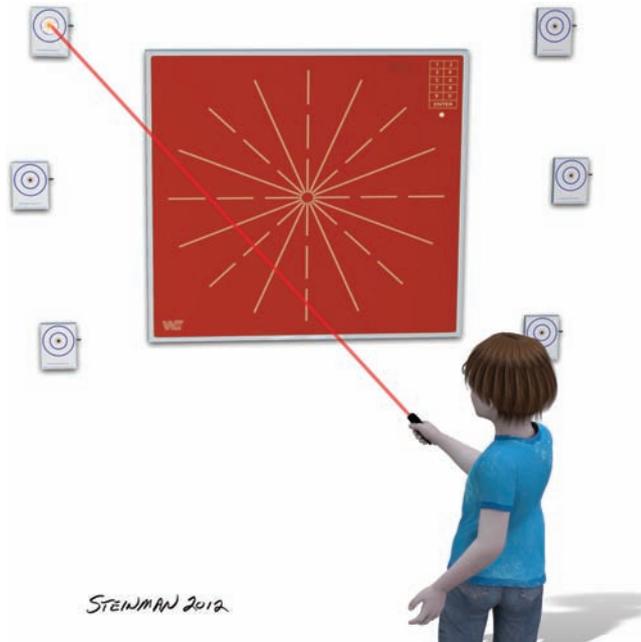
It is a small box with a photo-sensitive light which acts as an extension of a light on the Saccadic Fixator. Hitting the light with a light beam “presses the button” on the Fixator. It allows all Saccadic Fixator activities to be performed in real space (Fig. 8.11).

Objectives

The objectives of these techniques are to improve the accuracy and speed of pursuit and saccadic eye movements.



■ **Figure 8.10** Patient working with the Wayne Membrane Saccadic Fixator.



■ **Figure 8.11** Visual Stick-ups attached to Wayne Membrane Saccadic Fixator.

Equipment Needed

- Computer Orthoptics software and appropriate hardware^b
- Computer-Aided Vision Therapy software and appropriate hardware^a
- Eye patch

Description and Setup

A description of the many different software programs available for training saccades and pursuits would be too lengthy for this text. Be aware that the list of available software improves and expands regularly. Any clinician involved in vision therapy should stay abreast of these developments.

Afterimage Techniques

AFTERIMAGES

Objectives

The objectives of these procedures are to improve the accuracy of saccadic and pursuit eye movements by providing feedback about performance.

Equipment Needed

- Photographic flash device
- Eye patch

Description

Almost any photographic flash device can be used to create afterimages. The only modification necessary is to use black electrical tape to form a narrow slit on the flash device. To create the afterimage, occlude one of the patient's eyes and instruct the patient to fixate at the center of the vertical slit on the flash unit. Activate the flash unit and, after the flash, ask the patient to blink rapidly or flicker the lights in the room. These procedures are helpful initially to make the patient aware of the afterimage. Demonstrate to the patient that wherever he or she looks, he or she will see the afterimage follow. Explain that the afterimage is used to provide feedback about where he or she is aiming his or her eyes. The use of the afterimage can enhance almost any ocular motor technique. It is often used with the Hart chart saccadic technique and the automatic rotating device.

Computer Home Therapy Procedures

COMPUTER ORTHOPTICS

Home Therapy System

The Home Therapy System (HTS),^b described previously in Chapter 6, includes one saccadic and one pursuit technique. Like the HTS vergence program, the therapist or optometrist has the option to monitor the patient's performance at home and modify the program when necessary over the Internet. In addition, this company has developed two other home-based programs that are specifically designed to treat eye movement disorders. The first is called Perceptual Visual Tracking Program (PVT) and includes five computer procedures designed to improve saccadic accuracy and speed (Matching Targets, Moving Box, Moving Line, Hidden Targets, Saccadic Tracking). Another useful program from Computer Orthoptics is the ADRiNet Dynamic Reader.^b This program has three procedures that stress accurate and fast saccadic eye movements while reading text.

- **Moving Text Dynamic Reading:** The material to be read remains in the center of the screen and does not move down the page from top to bottom; therefore, saccadic eye movements are not required.
- **Standard Dynamic Reading:** The print moves left to right and top to bottom. The reading rate starts at a level that should be comfortable for the patient. It increases as the patient progresses.
- **Whole Line Dynamic Reading:** The material to be read does not move left to right but is presented as an entire line at a time. The reading material moves down the page one line at a time to the end of the passage.

A reading fluency test determines the starting words per minute (WPM) for the patient.

A major benefit of all of these home-based therapy programs is the ability to monitor the patient's compliance over the internet.

Computer-Aided Vision Therapy: Track and Read

Computer-Aided Vision Therapy has home therapy programs for binocular vision, eye movement, and visual information processing therapy. The program that is found useful for home-based vision therapy for eye movements is called Track and Read.

Study Questions

1. Describe a sequence that can be used with Hart chart saccades to gradually increase the level of difficulty of the task.
2. How can you increase the level of difficulty of the letter tracking procedure?

3. What are the advantages of using computer vision therapy techniques for oculomotor therapy?
4. Describe a procedure for combining both saccadic fixation and pursuit eye movements in one therapy technique.

SOURCES OF EQUIPMENT

- (a) Computer-Assisted Vision Therapy, from Bernell Corporation: 4016 N Home St, Mishawaka, IN 46545; 800-348-2225.
- (b) Computer Orthoptics: 6788 S. Kings Ranch Rd, Suite 4, Gold Canyon, AZ 85218; 800-346-4925 www.visiontherapysolutions.net.

SECTION



Management

Low AC/A Conditions: Convergence Insufficiency and Divergence Insufficiency

This chapter discusses the characteristics, diagnosis, and management of nonstrabismic binocular disorders associated with a low AC/A ratio. Although there are some significant differences among these conditions, they are grouped together based on the classification system described in Chapter 2. The unifying characteristic of the conditions described in this chapter is the low AC/A ratio. This similarity is important because it is the basis for the development of the management plan. Specifically, the AC/A ratio is the major factor that determines the sequence of management decisions in patients with heterophoria (Chapter 3). Consequently, certain general treatment strategies are shared by all binocular conditions associated with a low AC/A ratio. However, there are also important differences among these conditions. After a review of general principles that apply to all low AC/A disorders, each condition is described separately to highlight the differences in characteristics, diagnosis, and management.

The specific conditions discussed in this chapter are divergence insufficiency and various forms of convergence insufficiency (CI).

Overview of General Management Principles for Heterophoria Associated with Low Ac/A Ratio

Table 9.1 lists the various sequential management issues that we presented in Chapter 3. The specific sequence in which these factors should be considered is primarily dependent on the AC/A ratio. Thus, the magnitude of the AC/A ratio (low, normal, or high) establishes the treatment sequence. The direction of the phoria (exophoria, esophoria, or hyperphoria) determines certain particulars of treatment, such as whether prism base-out, base-in, up, or down should be prescribed or whether convergence or divergence should be stressed in the initial phases of vision therapy. For binocular vision disorders associated with a low AC/A ratio, the specific management sequences we suggest are listed in Tables 9.2 and 9.3.

A comparison of Tables 9.1, 9.2, and 9.3 reveals some similarities, but also several important differences in approach. The major difference that distinguishes low AC/A problems from conditions associated with high and normal AC/A ratios is the relative ineffectiveness of lenses in effecting a change in the size of the heterophoria. An example of this is Case 9.1.

Case 9.1

A 21-year-old man presents with a complaint of intermittent diplopia that is more bothersome when he looks at a distance. The problem has been present for several years. The refraction is +0.50 D OD and OS, the distance phoria is 10 esophoria, and the near phoria is ortho. The calculated AC/A ratio in this case is 2:1.

Prescribing for the ametropia in this case would have virtually no effect on the distance esophoria, reducing it from 10 esophoria to 9 esophoria. Of course, added plus lenses at distance for divergence insufficiency cannot even be considered because it would cause distance vision blur.

TABLE 9.1 SEQUENTIAL CONSIDERATIONS IN THE MANAGEMENT OF NONSTRABISMIC BINOCULAR ANOMALIES

Optical correction of ametropia	Vision therapy for amblyopia
Added lens power	Vision therapy for suppression
Horizontal prism	Vision therapy for sensory motor function
Vertical prism	Surgery
Occlusion for amblyopia	

TABLE 9.2 SEQUENTIAL CONSIDERATIONS IN THE MANAGEMENT OF CONVERGENCE INSUFFICIENCY

Optical correction of ametropia	Vision therapy for sensory motor function
Vertical prism	Horizontal prism
Occlusion for amblyopia	Added lens power
Vision therapy for amblyopia	Surgery
Vision therapy for suppression	

TABLE 9.3 SEQUENTIAL CONSIDERATIONS IN THE MANAGEMENT OF DIVERGENCE INSUFFICIENCY

Optical correction of ametropia	Vision therapy for suppression
Vertical prism	Vision therapy for sensory motor function
Horizontal prism	Added lens power
Occlusion for amblyopia	Surgery

Another example of the lack of effectiveness of lenses in low AC/A cases is illustrated in Case 9.2.

Case 9.2

A 14-year-old girl presents with complaints of eyestrain, blurred vision, and watery eyes after 10 minutes of reading. The near point of convergence is 20 cm with orthophoria at distance and 10 exophoria at near. The subjective is -2.00 D OD and OS. The AC/A ratio is 2:1 (interpupillary distance [IPD] = 60 mm).

Correction of ametropia or use of added lenses in this case would again have little effect on the magnitude of the deviation.

Therefore, the consideration of the use of added lenses is moved close to the bottom of the list in Tables 9.2 and 9.3. However, optical correction of ametropia still remains the first issue that a clinician should consider. As stated in Chapter 3, the first consideration for all patients with accommodative and nonstrabismic binocular anomalies is optical correction of ametropia. In low AC/A cases, although lenses have little effect on the size of the deviation, the presence of an uncorrected refractive error may create an imbalance between the two eyes. This imbalance may lead to sensory fusion disturbances, or create decreased fusional ability due to blurred retinal images.

As a general rule, when convergence insufficiency is associated with more than 0.5 D of anisometropia, a refractive correction should be prescribed. If convergence insufficiency is associated with myopia, management is not as simple. If a mild degree of myopia is present, the myopia may be secondary to the convergence

insufficiency. A cycloplegic refraction may help in the determination of whether an accommodative spasm is present. In such a case, the myopia may be secondary to the underlying binocular vision problem and should not be treated with a minus lens prescription. Rather, vision therapy should be prescribed and the refractive error monitored. This issue is covered in more detail later in this chapter. With moderate to high degrees of myopia, a prescription is indicated. Moderate degrees of astigmatism, particularly against-the-rule and oblique astigmatism, can contribute to discomfort during near work; 0.5 D or more of oblique or against-the-rule astigmatism and 1 D or more of with-the-rule astigmatism should be corrected.

With divergence insufficiency, the presence of hyperopia or anisometropia is significant. Although it is important to prescribe for ametropia in these cases, there is no need to have the patient wear the glasses for 4 to 6 weeks before prescribing other treatment since the effect on the size of the deviation is minimal.

When considering the final prescription for these patients, it is important to first determine whether a vertical deviation is present. London and Wick (1) have demonstrated that prescribing for even small amounts of vertical deviations can have a very positive effect on the horizontal deviation. We suggest prescribing for vertical deviations as small as 0.5 Δ and basing the prescription on fixation disparity assessment (Chapter 15).

A key difference between the sequential management of convergence insufficiency and divergence insufficiency is the differential effectiveness of horizontal prism for these two conditions. The use of prism is one of the early considerations for divergence insufficiency. Base-out prism prescriptions have been reported to be the most effective treatment strategy (2–4) for divergence insufficiency. For convergence insufficiency, however, prescribing base-in prism has a relatively low position in the sequential considerations for children (5), although base-in prism may be more useful with the presbyopic population (6). In a randomized clinical trial (5), the prescription of base-in prism reading glasses (based on Sheard's criterion) was no more effective than placebo reading glasses for the treatment of symptomatic convergence insufficiency in children. Nearly half of the children assigned to each of the two treatment groups reported a statistically significant decrease in symptoms, although neither group achieved a decrease in symptoms to a level considered clinically asymptomatic. In another study (6) 29 symptomatic convergence insufficiency subjects aged 45 to 68 years were assigned two pairs of progressive addition glasses in a randomized sequence, one with base-in prism and one with the same lens prescription but no prism (placebo). Subjects wore each pair of glasses for 3 weeks. The authors reported that the progressive addition glasses with base-in prism were found to be effective in alleviating symptoms of presbyopes with symptomatic convergence insufficiency.

Vision therapy is the primary treatment option for convergence insufficiency (7–12), whereas it has much less value in divergence insufficiency. Vision therapy is particularly challenging with divergence insufficiency because improvement of fusional divergence at distance is one of the more difficult goals to accomplish with vision therapy.

Although amblyopia is uncommon in nonstrabismic binocular vision anomalies, it will occur if the phoria is associated with a significant degree of anisometropia. In such cases, one of the early considerations should be treatment of amblyopia using occlusion and vision therapy. The use of occlusion and specific vision therapy procedures for the treatment of the amblyopia and any associated suppression always needs to be considered immediately after prescribing for the anisometropia and considering prism to compensate for a vertical phoria. In cases of convergence insufficiency or divergence insufficiency associated with anisometropia, we recommend part-time occlusion. Several (2 to 3) hours of occlusion using an opaque patch, along with active amblyopia therapy, are usually sufficient to resolve the amblyopia. Complete details about the evaluation and management of anisometropic amblyopia are provided in Chapter 17.

In almost all cases, however, amblyopia will not be present in either convergence or divergence insufficiency. Thus, after consideration of ametropia and prism, vision therapy is the next treatment issue. Vision therapy has been shown to be so effective for convergence insufficiency that it should always be presented as the treatment of choice for this condition.

The final sequential management consideration listed in Tables 9.2 and 9.3 is surgery. In Chapter 3, we discussed how infrequently such a recommendation would be necessary for convergence insufficiency. In addition, even if the nonsurgical approaches are ineffective, the research about the effectiveness of surgery for convergence insufficiency is equivocal (13–16). For divergence insufficiency, surgery is also unlikely to be necessary. Generally, a combination of nonsurgical approaches will be effective. However, when the magnitude of the distance deviation is large and all nonsurgical approaches have been unsuccessful in relieving the patient's symptoms, surgery may occasionally be helpful.

PROGNOSIS FOR TREATING BINOCULAR VISION DISORDERS ASSOCIATED WITH LOW AC/A RATIOS

Using the management approach suggested above, the prognosis for treating convergence insufficiency is excellent. Vision therapy is the primary treatment option for convergence insufficiency, and numerous studies have demonstrated its efficacy, with success rates between 73% and 95% (7,9–12,15–33). Virtually all recognized textbooks recommend vision therapy/orthoptics as the preferred treatment approach for convergence insufficiency (34–39). Vision therapy has also been shown to be effective for all age levels (7,10–12,29,31–33). Vision therapy should be effective in virtually all cases, as long as good motivation and compliance are present.

For divergence insufficiency (40), prism is the primary treatment modality, although the use of lenses, added lenses, and vision therapy may be helpful. Because prism is so important in the management of divergence insufficiency, the magnitude of the deviation is particularly critical. Most patients can be successfully treated if the degree of esophoria at distance is 15 Δ or less. As the distance deviation increases, the prognosis for complete relief of symptoms decreases. Although divergence insufficiency has the poorest prognosis for any of the nonstrabismic binocular vision anomalies described in this text, it is important to realize that even for this condition, the prognosis is good.

SUMMARY OF KEY POINTS IN TREATING PHORIA PATIENTS ASSOCIATED WITH LOW AC/A RATIOS

The important issue in the sequential management of low AC/A binocular vision problems is the de-emphasis of added lenses. Because of the low AC/A ratio, added lenses have minimal effect on the angle of deviation. For these problems, horizontal prism and vision therapy are the principal treatment alternatives. Horizontal prism is most effective for divergence insufficiency, and vision therapy is best for convergence insufficiency.

Convergence Insufficiency

BACKGROUND INFORMATION

Definition and Prevalence

Convergence insufficiency is a condition in which there is an exophoria at near, orthophoria or low exophoria at distance, a receded near point of convergence, reduced positive fusional vergence (PFV), and a low AC/A ratio. Of the various nonstrabismic binocular vision problems, convergence insufficiency is the most common and has received the most attention. The prevalence of convergence insufficiency has been reported to be about 3% to 5% of the population (41–45). Scheiman et al. (41) and Rouse et al. (42,45) studied the frequency of convergence insufficiency in schoolchildren in both clinical and school settings. These authors have been careful to clearly define convergence insufficiency. Scheiman et al. (41) defined convergence insufficiency as a condition with a receded near point of convergence, along with at least three additional low findings from the following categories: direct or indirect measures of PFV, exophoria greater at near than at distance, or a low AC/A ratio. They found a prevalence of 5.3% in a population of 1,650 children (6 to 18 years old). Rouse et al. (42,45) used the term *definite convergence insufficiency* to describe a patient with exophoria at near that is 4 Δ or greater in magnitude than the far phoria, a receded near point of convergence, and insufficient PFV. Using this specific definition, they found a frequency of 6% in children (8 to 12 years old) in a clinic setting (42) and 4.2% in children (9 to 12 years old) in a school screening setting (45). Porcar and Martinez-Palomera (46) did a similar study in a university setting. They defined convergence insufficiency as exophoria at near greater than 6 Δ , a low AC/A ratio, reduced PFV at near, and a receded near point of convergence. They found a prevalence of 7.7% in a population of 65 university students.

CHARACTERISTICS

Symptoms

Most symptoms are associated with reading or other close work. Common complaints include eyestrain and headaches after short periods of reading, blurred vision, diplopia, sleepiness, difficulty concentrating,

loss of comprehension over time, a pulling sensation, and movement of the print (12) (Table 9.4). Some patients with convergence insufficiency are asymptomatic. Cooper and Duckman (47) suggested that this absence of symptoms may be due to suppression, avoidance of near visual tasks, a high pain threshold, or occlusion of one eye when reading. Clinicians should always inquire about avoidance of reading or other near tasks if a patient with convergence insufficiency reports an absence of other symptoms. Avoidance is as important a reason for recommending therapy as any of the other symptoms associated with convergence insufficiency.

Although symptoms in convergence insufficiency are commonly reported in the literature, until recently there had been no standardized symptom survey for documenting the type and frequency of symptoms in this population. Borsting et al. (48) gathered validity-related evidence on child and parent versions of a convergence insufficiency symptom survey (Fig. 3.1). This questionnaire, the Convergence Insufficiency Symptom Survey (CISS), is the first standardized instrument that has been shown to be valid and reliable for measuring the type and frequency of symptoms before and after treatment for patients with convergence insufficiency (49–52). It can be used in clinical practice to compare symptoms before and after optometric intervention for patients with convergence insufficiency and other binocular vision and accommodative disorders.

The CISS allows a two-factor analysis of symptoms: first, whether the symptom is present, and second, how frequently it occurs. The questionnaire consists of 15 items. The patient chooses one of five possible answers (never, infrequently, sometimes, fairly often, always). Each answer is scored from 0 to 4, with 4 representing the highest frequency of symptom occurrence (i.e., always). The 15 items are summed to obtain the CISS score, with the lowest possible score being 0 (totally asymptomatic) and the highest possible score being 60 (most symptomatic). For children aged 9 to 17 years a symptom score of 16 or higher on the CISS has been found to differentiate those with symptomatic convergence insufficiency from those with normal binocular vision. For adults (18 and older) a symptom score of 21 or higher on the CISS has been found to be significant. Research using this survey has demonstrated that a score of less than 16 for children and less than 21 for adults or a change of 10 or more points is clinically significant.

TABLE 9.4 SYMPTOMS AND SIGNS OF CONVERGENCE INSUFFICIENCY

Symptoms	
These symptoms are generally related to the use of the eyes for reading or other near tasks:	
Eye strain	Difficulty concentrating on reading material
Headaches	Loss of comprehension over time
Blurred vision	A pulling sensation around the eyes
Double vision	Movement of the print
Sleepiness	
Signs	
Receded near point of convergence	
Greater exophoria at near than at distance	
Low AC/A ratio	
<i>Direct measures of positive fusional vergence (PFV)</i>	
Reduced smooth vergence	
Reduced step vergence	
Reduced vergence facility	
<i>Indirect measures of PFV</i>	
Low negative relative accommodation	
Difficulty with plus lenses during binocular accommodative facility testing	
Low finding with monocular estimation method retinoscopy	
<i>If accommodative excess is also present:</i>	
Difficulty with plus lenses during monocular accommodative facility testing	
<i>If accommodative insufficiency is also present:</i>	
Difficulty with minus lenses during monocular and binocular accommodative facility testing	
Low positive relative accommodation	
Low amplitude of accommodation	
Possible improvement in near point of convergence testing with plus lenses	

Another symptom questionnaire that could be used is the College of Optometrists in Vision Development Quality of Life Outcomes Assessment (COVD-QOL) described in Chapter 3 (53–57). Several authors have reported on the use of the COVD-QOL short form to evaluate symptoms before and after vision therapy (55,58,59) and found the assessment to be a valuable clinical tool.

Signs

See Table 9.4 for signs associated with convergence insufficiency.

Refractive Error

A clear trend has not been identified in the literature in regard to refractive error in convergence insufficiency.

Near Point of Convergence

A remote near point of convergence is considered the most consistent finding in convergence insufficiency (60). A survey conducted by Rouse, Hyman, and the CIRS group (60) determined that a receded near point of convergence was used in making the diagnosis of convergence insufficiency by about 94% of the optometrists surveyed; 35% of the doctors indicated that one criterion was sufficient to diagnose convergence insufficiency, and the most frequently used single diagnostic criterion was the near point of convergence.

Normative values for the near point of convergence in schoolchildren and young adults have been reported. Hayes et al. (61) studied 297 schoolchildren in kindergarten, third, and sixth grades using a standardized protocol. They recommended using a cutoff value of 6 to 10 cm for children. Maples and Hoenes (62) reported a similar value in children, with a cutoff value of 5 cm. Scheiman et al. (63) studied 175 young adults and suggested a cutoff value of 5 to 7 cm.

The near point of convergence test is traditionally performed by slowly moving a target toward the eyes until the patient reports diplopia or the examiner notices a break in fusion. Several modifications to this traditional approach have been suggested in the literature to make the test more sensitive. Wick (64) and Mohindra and Molinari (65) recommended that the near point of convergence test be repeated four to five times. Davis (66) claimed that asymptomatic patients manifest little change in the near point with repeated testing, whereas symptomatic patients have significantly less convergence with repeated testing. This recommendation is designed to improve the diagnostic sensitivity of the break of the near point of convergence test. Scheiman et al. (63) confirmed the value of repeating the near point of convergence test. They found a recession of the near point of convergence after repetition in both normal subjects and convergence insufficiency patients. In the subjects with normal binocular vision, however, the amount of recession was small—less than 1 cm. In the convergence insufficiency group, the amount of recession was 1.5 cm after five repetitions and about 4 cm after 10 repetitions. These findings suggest that repetition of the near point of convergence may yield useful clinical information, but the test would have to be performed about 10 times. Maples and Hoenes (62) also investigated the changes in the near point of convergence after repetition and found that the near point of convergence break and recovery do not change appreciably with multiple repetitions of the test.

Another criterion utilized for assessment of convergence ability is the recovery point, or the point at which an individual regains fusion after it has been lost during the push-up convergence testing. Capobianco (67) reported that a recovery point greatly different from the break indicates greater convergence problems. She also suggested that if one assesses the near point of convergence with a penlight, and then a penlight and red glass are held before the patient's right eye, the test becomes more sensitive. Several authors (64,65,68,69) have suggested that this procedure be part of the standard assessment of convergence amplitude. Scheiman et al. (63) found that in normal subjects, there was no significant difference in the near point of convergence when measured with an accommodative target, a penlight, or a penlight with red/green glasses. Subjects with convergence insufficiency, however, did show greater recession of both the break and recovery with the penlight and red/green glasses compared to the accommodative target. The mean break with an accommodative target was 9.3 cm; with a penlight and red/green glasses, the mean break was 14.8 cm. The recovery finding with the accommodative target was 12.2 cm, and with a penlight and red/green glasses it was 17.6 cm. For both the break and recovery, therefore, there was a difference of about 5.5 cm between the accommodative target and the penlight and red/green glasses. Statistically significant differences were not found for an

accommodative target compared to a penlight or a penlight compared to a penlight and red/green glasses. The use of a penlight and red/green glasses therefore does seem to have some additional diagnostic value in distinguishing convergence insufficiency patients from normal subjects.

Finally, Pickwell and Stephens (70) described another method of assessing convergence ability, which they termed *jump convergence*. In this procedure, the subject first fixates a target at 6 cm and then changes fixation to a target at 15 cm. Pickwell and Hampshire (71) reported that this jump convergence test appears to have more clinical significance and is a more sensitive way of determining the presence of convergence problems than the near point of convergence.

Characteristics of the Deviation

Patients with convergence insufficiency generally have greater exophoria at near, decreased PFV, and a receded near point of convergence.

Some authors have suggested that a 10 Δ difference from one distance to another is a useful guideline. This suggestion, however, has no firm research basis and should be used only as a guideline. Rather than depend on this guideline, we find it more useful to think about the difference one would expect based on the presence of a low AC/A ratio. Since an AC/A ratio of less than 3:1 is considered low, as little as an 8 Δ difference between distance and near would be sufficient to fit the diagnosis of convergence insufficiency.

Clinicians should also use their judgment and rely on other characteristics in addition to the magnitude of the angle at distance and near to reach a diagnosis. For instance, the near deviation may be an intermittent or constant strabismus versus a phoria at distance. This finding, along with a receded near point of convergence, would lead to a diagnosis of convergence insufficiency even if the difference in magnitude was less than 8 Δ . Thus, a comparison of the proportion of time the deviation is present, as well as the magnitude at distance and near, is an important part of the diagnostic process.

AC/A Ratio

A low AC/A ratio (less than 3:1) is generally considered to be present in convergence insufficiency. This is well accepted, based on the calculated AC/A, and is an important factor when treatment is considered.

ANALYSIS OF BINOCULAR AND ACCOMMODATIVE DATA

All direct tests of PFV will tend to be low in convergence insufficiency (Table 9.4). This includes step, smooth vergences, and jump vergences. In addition, tests that indirectly assess PFV (Table 9.4) will be low as well. Tests performed binocularly with plus lenses evaluate the patient's ability to relax accommodation and control binocular alignment using PFV. Two examples are the negative relative accommodation (NRA) and binocular accommodative facility (BAF) tests. A low finding with either of these tests may be due to an inability to relax accommodation or due to reduced PFV. The differential diagnosis is based on assessment of accommodation under monocular conditions. An easy and helpful technique is to simply cover one eye after the patient reports blur on the NRA test. If the blur continues, the problem is accommodative (accommodative excess). If the patient's vision clears, the problem is associated with binocular vision (PFV). Normal monocular accommodative ability on other tests suggests reduced PFV.

Another important indirect test is monocular estimation method (MEM) retinoscopy. It is not unusual to find an abnormal result on this test in convergence insufficiency. An MEM finding of less plus than expected suggests that the patient is using accommodative convergence to supplement inadequate PFV to maintain binocular vision.

In some instances, a secondary accommodative excess is present along with the convergence insufficiency. In such cases, in addition to the signs described above, the patient will perform poorly on monocular accommodative facility (MAF) with plus lenses. Covering one eye after the NRA test, as described above, is useful in this differential diagnosis. When an accommodative excess is present along with a convergence insufficiency, the accommodative problem is thought to be secondary to excessive use of accommodative convergence to supplement the inadequate PFV. This continual use of excessive accommodative effort may lead to a spasm of accommodation. In such cases, the patient may also report blurred distance vision. At first, this distance blur is transient. If the condition persists untreated, the distance blur may become permanent as myopia develops.

DIFFERENTIAL DIAGNOSIS

Convergence insufficiency is considered to be a benign condition with no serious consequences other than the visual symptoms listed in Table 9.4. It is relatively easy to differentiate from other binocular vision disorders associated with exophoria, such as basic exophoria (equal deviation at distance and at near) and divergence excess (greater exophoria at distance).

Richman and Cron (72) described a condition called *pseudoconvergence insufficiency* that can be confused with convergence insufficiency. Pseudoconvergence insufficiency is a condition in which the primary problem is accommodative insufficiency. The amplitude of accommodation and all other tests assessing the ability to stimulate accommodation are reduced. It is believed that this condition is basically an accommodative insufficiency with a secondary convergence insufficiency. The patient tends to accommodate as little as possible for any given demand. As a result, accommodative convergence is reduced, placing a greater demand on PFV. If a patient is already moderately exophoric with borderline PFV, this additional demand can simulate a convergence insufficiency. Case 9.3 is an example of pseudoconvergence insufficiency.

Case 9.3

Joseph is a 13-year-old who is complaining of eyestrain and blurred vision after 10 minutes of reading. He is healthy and is not taking any medication. He has been a patient in your practice for several years, and his most recent examination was 2 years ago. At that time, he had no complaints. The findings from the previous and current examinations are listed below:

Test	Previous Examination	Current Examination
Near point convergence	10 cm	20 cm
Amplitude of accommodation	15 D	6 D
Distance phoria	Orthophoria	Orthophoria
Near phoria	5 exophoria	11 exophoria
Calculated AC/A ratio	4:1	1.6:1
Base-out (near)	10/18/10	4/12/4
Vergence facility	12 cpm	6 cpm (slow with base-out)
NRA	+2.50	+2.50
PRA	-2.50	-1.75
BAF	12 cpm	4 cpm (fails -)
MEM retinoscopy	+0.25 OU	+1.00 OU
IPD	58 mm	58 mm

If this were the first time you examined this patient, the findings could easily be confused with true convergence insufficiency. The key findings for the differential diagnosis are the amplitude of accommodation and other tests that probe the ability to stimulate accommodation. In true convergence insufficiency, these findings are normal. If an accommodative anomaly exists, it tends to be an accommodative excess. Thus, if the accommodative amplitude is reduced, along with other probes of the ability to stimulate accommodation, pseudoconvergence insufficiency is the probable diagnosis. Because the patient accommodates as little as possible to identify the stimulus, the amount of near point exophoria increases and the measured PFV decreases. Clinically, repetition of the near point of convergence with +0.75 or +1.00 lenses may actually improve performance in cases of pseudoconvergence insufficiency. With the low plus lenses, the patient may accommodate more accurately, leading to improvement in the near point of convergence.

Convergence insufficiency can also be associated with serious underlying conditions. A condition called *convergence paralysis* is a supranuclear gaze disorder that must be ruled out. Patients with this condition can fully adduct their eyes during conjugate gaze movements, and the deviation is comitant. Convergence paralysis can occur secondary to ischemic infarction, demyelination, and flu or other viral infection (73). When secondary to flu, it can be transient or permanent. If convergence paralysis exists in isolation of accommodative or pupillary involvement or other evidence of central nervous system disease, it may be difficult to differentiate from a functional convergence insufficiency. The primary differential is the history. A recent onset of diplopia and asthenopia is suspicious. The history of a patient with convergence insufficiency is generally associated with long-standing chronic complaints.

A receded near point of convergence has also been reported secondary to Parkinson disease, Parinaud syndrome, and medial rectus weakness in multiple sclerosis and myasthenia gravis. One must therefore be cognizant of the differential diagnosis of convergence insufficiency and first rule out the more serious disorders that can cause convergence insufficiency. Table 9.5 lists the various conditions that must be considered in the differential diagnosis of convergence insufficiency.

Summary

A serious underlying etiology must be ruled out in all cases of convergence insufficiency. This differential diagnosis depends very much on the nature of the patient's symptoms. Typically, convergence insufficiency presents with long-standing chronic complaints and a negative health history. The history is also negative for any medication known to affect accommodation. The primary functional disorder that must be differentiated from true convergence insufficiency is pseudoconvergence insufficiency, which has an accommodative etiology. When managing a case of convergence insufficiency that is thought to have a functional basis, if symptoms and findings do not improve as expected, it is wise to reconsider the etiology of the condition.

Convergence paresis associated with serious underlying disease has an acute onset, and medical problems or neurologic symptoms are usually present.

TREATMENT

We recommend the management sequence listed in Table 9.2.

Lenses

In all cases of binocular, ocular motor, and accommodative dysfunction, the first management consideration is correction of any significant refractive error. With convergence insufficiency, it is important to prescribe glasses if a significant degree of myopia is present. When a low degree of myopia is present, it is possible that the myopia is secondary to the convergence insufficiency. The presence of accommodative excess would support such a conclusion. In such cases, we recommend not prescribing glasses for low degrees of myopia. Rather, vision therapy to remediate both the convergence insufficiency and the accommodative excess should be prescribed. As therapy progresses, the refractive error should be monitored. If a change in the myopia does not occur, glasses can be prescribed at the completion of therapy.

TABLE 9.5 DIFFERENTIAL DIAGNOSIS OF CONVERGENCE INSUFFICIENCY

Functional disorders to rule out	
Pseudoconvergence insufficiency	
Basic exophoria	
Divergence excess	
Serious underlying disease to rule out	
<i>Convergence paralysis secondary to:</i>	<i>Medial rectus weakness due to:</i>
Ischemic infarction	Multiple sclerosis
Demyelination	Myasthenia gravis
Flu or other viral infection	Previous strabismus surgery
Parkinson disease	
Parinaud syndrome	

The prevalence of hyperopia in convergence insufficiency does not appear to be any greater than in the general population. If hyperopia is present, however, it does create a management problem. Even though the AC/A ratio is low, if there is a significant degree of hyperopia, correction of the refractive error will lead to an increase in the amount of exophoria. This will create a greater demand on the already inadequate PFV and may exacerbate the patient's symptoms. In some cases, a borderline problem might become clinically significant or an exophoria at near may decompensate into an intermittent exotropia. Case 9.4 is an example of the effect of correction of hyperopia on a borderline convergence insufficiency.

Case 9.4

Robert, a 41-year-old accountant, presents with complaints of eyestrain, blurred vision, burning, and frontal headaches. These problems begin every afternoon during the workweek and have been occurring for the last 6 months. He has never worn glasses before. Testing reveals +2.50 OD and OS, orthophoria at distance, and 8 exophoria at near without correction. With correction, he is 6 exophoric at distance and about 15 exophoric at near.

Base-out ranges at near (without the correction): 8/16/8

Base-out ranges at near (with the correction): 4/10/4

Near point of convergence (without correction): 3 to 6 in.

Near point of convergence (with correction): 6 to 10 in.

In such cases, we must decide whether the patient's symptoms are secondary to the uncorrected refractive error, the convergence insufficiency, or both. Case 9.4 illustrates that the patient is uncomfortable when reading and needs a correction for the hyperopia. However, with this correction, the findings suggest a convergence insufficiency. Several treatment alternatives could be recommended for this patient:

- Prescribe the full prescription and instruct the patient to wear the glasses full time and return for a reevaluation after 4 to 6 weeks. If symptoms persist, vision therapy could then be recommended.
- Prescribe a partial prescription and instruct the patient to wear the glasses full time and return for a reevaluation after 4 to 6 weeks. If symptoms persist, vision therapy could then be recommended.
- Prescribe the full prescription and instruct the patient to wear the glasses full time and simultaneously begin vision therapy.
- Prescribe a partial prescription and simultaneously begin vision therapy. After vision therapy is complete, consider changing the prescription and increasing the amount of plus.

The best approach will depend upon the specifics of the situation and the clinician's management philosophy. In Case 9.4 we suggest that a partial prescription (+1.50 OD and OS) along with vision therapy would lead to the most rapid resolution of the patient's symptoms. Once the patient's PFV and near point of convergence improve, additional plus could be prescribed.

Prism

If a vertical deviation is present, we recommend that vertical prism be prescribed before vision therapy begins. The most effective method for determining the amount of vertical prism is the associated phoria, which can be measured with any fixation disparity device (Chapter 15).

In the vast majority of cases, the use of base-in relieving prism is not necessary in convergence insufficiency. Although the use of base-in prism intuitively makes sense, there is little research to support the efficacy of prescribing base-in prism for convergence insufficiency. In the only placebo-controlled, randomized clinical trial, Scheiman et al. (5) found that the prescription of base-in prism reading glasses (based on Sheard's criterion) was no more effective than placebo reading glasses for the treatment of symptomatic convergence insufficiency in children. There is evidence from one study that base-in prism reading glasses may be beneficial for presbyopic patients (6). Additional study of base-in prism reading glasses for the young adult population is needed.

In the meantime, base-in prism can be used in cases of convergence insufficiency in which vision therapy is unsuccessful or when a patient is unable to comply with a vision therapy recommendation, but its use as a primary treatment for convergence insufficiency cannot be supported in children, and there are little data to support its use in young adults. Because the remediation of the convergence insufficiency is so effective, office-based vision therapy should be the treatment of choice for convergence insufficiency for all age groups. Fixation disparity analysis, as described in Chapter 15, should be used to prescribe base-in prism for convergence insufficiency when it is necessary.

Vision Therapy

Home-based Vision Therapy and Pencil Push-up Treatment

Pencil push-up treatment (PPT) or home-based vision therapy is often recommended for convergence insufficiency. Scheiman et al. (74) completed a survey using a randomly selected national sample of 863 optometrists and 863 ophthalmologists. Surveys were mailed to optometrists and to ophthalmologists in the United States requesting the doctors to indicate which treatment or treatments they prescribed and which treatments they believed to be most effective for symptomatic convergence insufficiency. For optometrists, the most common treatment was PPT (36%), followed by home-based vision therapy (22%) and office-based vision therapy (16%). For the ophthalmologists, the most common treatment was PPT (50%), followed by home-based vision therapy (21%) and base-in prism (10%). A survey of 100 pediatric ophthalmologists yielded similar findings, with the most common treatment being PPT (53%), followed by more extensive home-based vision therapy (38%) (75).

Thus, many eye practitioners believe that PPT is an effective treatment procedure for convergence insufficiency, and it appears to be the most frequently assigned home-training procedure. The basic PPT technique is described in Duke-Elder and Wybar (34):

Exercises to improve the near point of convergence are carried out simply by the patient holding a target at arm's length and then gradually bringing it towards the eye, all the time maintaining bifoveal fixation. These exercises should be carried out several times each day for a few minutes.

Use of a target providing physiologic diplopia is generally recommended.

Although PPT is widely prescribed by clinicians, until recently there were no randomized clinical trials studying its effectiveness. Gallaway, Scheiman, and Malhotra (76) carried out a preliminary uncontrolled study to investigate the efficacy of PPT, as prescribed in practice, for the treatment of convergence insufficiency. Twenty-five subjects between 9 and 51 years of age with symptomatic convergence insufficiency were studied. All subjects completed a symptom questionnaire before treatment began. They were instructed to perform PPT at home for 15 minutes, 5 days a week. To monitor compliance, subjects were asked to fill out a daily treatment form. A follow-up was scheduled for 6 weeks. The initial testing was repeated at this follow-up visit. Only 12 subjects returned for the 6-week follow-up. Of these, only 4 were classified as normal (based on examination results) after treatment. All but one subject experienced some improvement in symptoms, although only one subject reported an elimination of symptoms. The low retention rate in this study is a significant concern and appears to be an inherent problem associated with this treatment. More recently, Kim and Chun (77) reported on a prospective study of 16 patients who were diagnosed with convergence insufficiency. The mean value of near point of convergence prior to home-based pencil push-ups (HBPP) therapy was 36.3 cm and after 12 weeks of therapy the near point of convergence had improved to 14.4 cm. They conclude that 12 weeks of HBPP appears to be an easy, cost-free and effective therapy for patients with symptomatic convergence insufficiency. However, serious study design issues (small sample size, no symptoms assessment, no randomization, lack of a placebo group, unmasked examiners) weaken this conclusion.

The Convergence Insufficiency Treatment Trial (CITT) investigator group completed three randomized clinical trials designed to study the effectiveness of various treatments for symptomatic convergence insufficiency in children 9 to 17 years old and adults 18 to 30 years old (10–12). In a small randomized clinical trial of 47 symptomatic children with convergence insufficiency, this group found that HBPP were no more effective than placebo therapy. Pencil push-ups did not significantly improve symptoms, near point of convergence, or PFV. Of the 11 children treated with pencil push-ups, none met the study criteria for “successful” or “improved” (10). In a similar study with young adults, the CITT investigator group found that HBPP did not lead to a statistically significant change in the near point of convergence or PFV, and only 20% of the

patients were asymptomatic at the end of treatment (11). In a large, multicenter, randomized clinical trial, the CITT investigator group studied 221 children with symptomatic convergence insufficiency and compared the effectiveness of four treatments. They found statistically significant improvements in symptoms, near point of convergence, and PFV in the office-based vision therapy treatment group. There were no statistically significant changes in the home-based PPT group (12).

Thus, although PPT is simple and inexpensive, there is a lack of scientific support for its efficacy, and most patients lose interest with the procedure and discontinue treatment. PPT is thus not a viable treatment option for convergence insufficiency.

The use of more extensive home-based vision therapy for convergence insufficiency, however, may be a viable option for patients who are unable to participate in an office-based vision therapy program. In recent years, software has been developed that allows patients to perform vision therapy techniques at home.

Techniques such as pencil push-ups, stereograms, loose prism, Brock string, Lifesaver cards, or Eccentric Circles have been traditionally prescribed for home-based vision therapy. To be used effectively, these procedures often require an experienced doctor or technician to interpret patients' responses and use that information to alter stimulus conditions in order to improve binocular response. Since the patient or parents may not have this experience, these procedures may not be effective when used exclusively at home. Also, with young children or with any patient who is not responding accurately for a variety of reasons, traditional techniques become difficult and unreliable to use. The child who "learns" the expected response and has a strong desire to please the parent may "give the right response" even though he or she is not achieving the desired objective. Where a trained therapist can detect this behavior, a parent might not be able to do so.

The Home Therapy System (HTS Vergence and Accommodation)^a computerized vision therapy program overcomes each of the problems listed above. Little interpretation is necessary, the computer always maintains an appropriate treatment level, and the parent does not need to supervise the child's therapy. This home-based vision therapy software primarily uses random dot stereograms as targets. Cooper and Feldman (78), Cooper and Citron (79), Cooper et al. (29), and Cooper (80) have demonstrated the effectiveness of random dot stereograms for improving visual function using computer-generated random dot stereograms that are very similar to the stimuli used in the HTS Vergence and Accommodation home-based computer software. However, these studies did not involve home-based therapy. The technique was studied in an office setting. Until recently there were limited studies on more extensive home-based vision therapy.

A few studies have investigated the effectiveness of home-based vision therapy (19,27,30,81). Most studies have been retrospective case reviews that have not had either a control group or masked examiners. Although this limits the value of the conclusions, these studies do suggest that home-based vision therapy may be successful and a useful treatment if office-based vision therapy cannot be implemented for financial or other reasons. Aziz et al. (12) reported on the effectiveness of home-based orthoptics for 65 exophores between the ages of 5 and 73 years (mean 11.9 years). The home therapy consisted of pencil push-ups, stereograms, and loose prism jumps. Patients were instructed to do these procedures 6 days per week, about 30 minutes per day. The authors do not report how often they followed these patients, but state that the treatment period ranged from 1 to 32.5 months (mean 8.2, SD 6.6). About 90% of the patients were asymptomatic at the end of treatment. The near point of convergence normalized in 85%, and 54.7% achieved normal PFV. These results are quite good and approach the success rates reported for office-based vision therapy. However, the lack of a control group and unmasked examiners may have resulted in overestimation of the success rate. Serna et al. (81) performed a retrospective study of 42 children with symptomatic convergence insufficiency and concluded that "home-based computer orthoptic exercises reduced symptoms and improved near point of convergence and fusional amplitudes" in children with convergence insufficiency. This conclusion is erroneous, and in fact no causative relationship between home-based computerized treatment and the reported outcomes can be made based on their data. Like all studies that are retrospective and uncontrolled, there is always concern that any observed treatment effect is attributable to bias. In this study, Serna and colleagues did not use either of the two most important methods of minimizing bias: there was no placebo control group with randomization of treatment assignment, nor were the study subjects and examiners masked to treatment. Furthermore, not all patients received only home-based computerized therapy. Of the 42 patients treated, 35 were also treated with push-up exercises, 13 received reading glasses or bifocals, and 5 wore base-in Fresnel prism. Because of these serious study design limitations, any causative relationship between the home-based computerized therapy and subjective and objective outcomes cannot be inferred. Although the methodological limitations of the study by Serna and colleagues prevent any conclusions being made regarding the effectiveness of home-based computerized treatment, these results, taken together with those from the CITT described below, support the need for

further investigation of home-based treatments with the objective of determining how their effectiveness can be improved when it is not possible to offer office-based vergence accommodative therapy to children with symptomatic convergence insufficiency.

In a randomized clinical trial performed by the CITT, office-based vergence/accommodative therapy was compared to placebo office-based therapy, HBPP, and home-based computer vergence/accommodative therapy plus pencil push-ups (12). This last group represents more intensive home therapy than simple pencil push-ups. The results showed that office-based vergence/accommodative therapy was more effective than home-based PPT or home-based computer vergence/accommodative therapy and PPT in improving both the symptoms and clinical signs associated with symptomatic convergence insufficiency. The two home-based treatments were no more effective in improving symptoms than office-based placebo therapy for improving symptoms. The posttreatment mean PFV findings were significantly better in the more intensive home-based therapy group than the PPT group alone. However, only about 35% of the home-based computer vergence/accommodative therapy and PPT patients achieved the criteria to be considered “successful” or “improved” after 12 weeks of treatment, compared with 73% in the office-based therapy group and 41% in the home-based PPT group (12).

OFFICE-BASED VISION THERAPY

Ideally we recommend office-based vision therapy program for convergence insufficiency. Such a program generally requires between 12 and 24 visits. The total number of therapy sessions depends on the severity of the condition, the age of the patient, and his or her motivation and compliance with home vision therapy procedures. Motivated adults can sometimes successfully complete vision therapy for convergence insufficiency in as few as 12 visits.

Specific Vision Therapy Program

All of the vision therapy techniques recommended below are described in detail in Chapters 6 to 8.

Phase 1

This first phase of therapy is designed to accomplish the objectives listed in Table 9.6 under Phase 1. Because vision therapy requires communication and cooperation between the therapist and patient, it is important to develop a working relationship with the patient during the first few sessions to ensure the success of the therapy. Some of the key issues that may need to be discussed or clarified are the nature of the vision problem being treated, why vision therapy is necessary, and the goals of vision therapy. Although these issues generally have been discussed before the beginning of vision therapy, misconceptions and misunderstandings can occur because many people have little previous knowledge of vision therapy. A short amount of time spent reiterating previous discussions about these topics can be very valuable.

TABLE 9.6 OBJECTIVES OF VISION THERAPY FOR CONVERGENCE INSUFFICIENCY

Phase 1
<ul style="list-style-type: none"> • Develop a working relationship with the patient • Develop an awareness of the various feedback mechanisms that will be used throughout therapy • Develop voluntary convergence • Normalize positive fusional vergence (PFV) amplitudes (smooth or tonic vergence demand) • Normalize accommodative amplitude and ability to stimulate and relax accommodation
Phase 2
<ul style="list-style-type: none"> • Normalize negative fusional vergence (NFV) amplitudes (smooth or tonic vergence demand) • Normalize PFV facility (jump or phasic vergence demand) • Normalize NFV facility (jump or phasic vergence demand)
Phase 3
<ul style="list-style-type: none"> • Develop ability to change from a convergence to a divergence demand • Integrate vergence procedures with changes in accommodative demand • Integrate vergence procedures with versions and saccades

TABLE 9.7 FEEDBACK CUES USED IN VISION THERAPY

Diplopia	Small in, large out (SILO) response
Blur	Float
Suppression	Localization
Luster	Parallax
Kinesthetic awareness	

It is equally important in this first phase to make the patient aware of the various feedback mechanisms that will be used throughout therapy. If the patient develops a good understanding of the nine feedback cues listed in Table 9.7, therapy will progress more rapidly. These feedback cues are discussed in detail in Chapter 5.

The first goal of the therapy itself is to teach the concept and feeling of converging. The patient should be able to voluntarily converge and diverge to any distance from 5 cm (2 in.) to 6 m (20 ft). Once the patient can voluntarily initiate a controlled convergence movement, the other goals of the vision therapy program become much easier to accomplish. Three commonly used procedures to accomplish this first objective are the Brock string, bug on string, and the red/green Barrel Card.

Convergence insufficiency patients generally have very limited base-out to blur, break, and recovery findings. Therefore, another objective of the first phase of vision therapy is to normalize PFV amplitudes. The initial goal is to reestablish a normal vergence range for smooth- or tonic-type vergence demand. A smooth vergence demand is easier for the patient to accomplish in the early part of a vision therapy program. It allows the patient to begin the procedure with accommodation and convergence at the same plane. A convergence demand can then be slowly introduced, requiring the patient to hold accommodation at 40 cm and move the convergence plane closer. It is important, however, to move to the next phase involving jump vergence as soon as possible. This tends to shorten the time course of therapy.

Another advantage of beginning with smooth vergence procedures is that, in some cases, the introduction of any convergence demand is enough to cause suppression or diplopia. Smooth vergence techniques provide a starting point for therapy with such patients. If the patient is unable to fuse any convergence demand, the procedure can begin with a divergence demand. For example, a variable tranaglyph can be set at 10 base-in and then gradually reduced to zero. This approach at least allows the patient to get started and experience some success, and the change from 10 base-in to zero can be viewed as convergence therapy, relative to the starting point. Speed is of little importance initially. Rather, we simply want the patient to be able to maintain fusion as the convergence demand is slowly increased.

Equipments that can be used to accomplish these objectives are the variable tranaglyphs, variable vectograms, and the Variable Prismatic Stereoscope from Bernell. These three devices can be used to create a smooth, gradual increase in convergence demand.

In many cases of convergence insufficiency in presbyopes, an accommodative problem is also present. If so, the final objective of the first phase of therapy is to normalize accommodative amplitude and the ability to stimulate and relax accommodation. If accommodative function is normal, however, there is generally no need to spend much time working with the accommodative system. Accommodative techniques can be found in Chapters 7 and 8. Lens sorting, loose lens rock, and Hart chart procedures are commonly used in this first phase of therapy.

Endpoint. Phase 1 of therapy ends when the patient can:

- Demonstrate voluntary convergence
- Fuse to about 30 base-out with a tranaglyph or other comparable technique
- Complete 12 cpm of accommodative facility with +2.00/−2.00 lenses using a 20/30 target.

A sample vision therapy program for Phase 1 is summarized in Table 9.8. This program includes several techniques that can be used by the patient at home to supplement the in-office therapy.

Phase 2

This second phase of therapy is designed to accomplish the objectives listed in Table 9.6 under Phase 2. Once smooth PFV is normalized, phasic or jump vergence demand should be emphasized. Variable tranaglyphs

TABLE 9.8 SAMPLE VISION THERAPY PROGRAM FOR CONVERGENCE INSUFFICIENCY

Phase 1
<p><i>Sessions 1 and 2</i></p> <p>IN-OFFICE</p> <ul style="list-style-type: none"> • Discuss nature of vision problem, goals of vision therapy, various feedback cues, importance of practice • Brock string • Lens sorting • Loose lens rock (begin with plus if accommodative excess, with minus if accommodative insufficiency) • Tranaglyphs or vectograms: base-out • Begin with a peripheral target such as tranaglyph 515 or the Quoit vectogram • Computer Orthoptics Random Dot program: base-out
<p>HOME THERAPY</p> <ul style="list-style-type: none"> • Brock string • HTS Vergence and Accommodation programs
<p><i>Sessions 3 and 4</i></p> <p>IN-OFFICE</p> <ul style="list-style-type: none"> • Bug on string • Loose lens rock • Tranaglyphs or vectograms: base-out • Use targets with more central demand (Clown, Bunny tranaglyphs; Clown, Topper vectograms) • Computer Orthoptics Random Dot program: base-out
<p>HOME THERAPY</p> <ul style="list-style-type: none"> • Brock string • HTS Vergence and Accommodation programs • Loose lens rock
<p><i>Sessions 5 through 8</i></p> <p>IN-OFFICE</p> <ul style="list-style-type: none"> • Barrel Card • Voluntary convergence • Loose lens rock • Tranaglyphs or vectograms: base-out • Use even more detailed targets, such as tranaglyph Sports Slide and Faces targets and the Spirangle vectogram • Computer Orthoptics Random Dot program: base-out
<p>HOME THERAPY</p> <ul style="list-style-type: none"> • HTS Vergence and Accommodation programs
Phase 2
<p><i>Sessions 9 and 10</i></p> <p>IN-OFFICE</p> <ul style="list-style-type: none"> • Tranaglyphs or vectograms with modifications to create jump vergence demand: base-out • Nonvariable tranaglyphs • Tranaglyph 515 or the Quoit vectogram: base-in • Binocular accommodative therapy techniques: use any of the binocular techniques listed above with \pm lenses
<p>HOME THERAPY</p> <ul style="list-style-type: none"> • HTS Vergence and Accommodation programs
<p><i>Sessions 11 and 12</i></p> <p>IN-OFFICE</p> <ul style="list-style-type: none"> • Tranaglyphs or vectograms with modifications to create jump vergence demand: base-out • Aperture Rule: base-out • More central tranaglyphs or the vectograms: base-in • Binocular accommodative therapy techniques: use any of the binocular techniques listed above with \pm lenses
<p>HOME THERAPY</p> <ul style="list-style-type: none"> • HTS Vergence and Accommodation programs
<p><i>Sessions 13 through 16</i></p> <p>IN-OFFICE</p> <ul style="list-style-type: none"> • Aperture Rule: base-out • Eccentric Circles or Free Space Fusion Cards • Computer Orthoptics Random Dot Vergence program: both base-in and base-out

(Continued)

TABLE 9.8 CONTINUED

<ul style="list-style-type: none"> • Aperture Rule: base-in • Tranaglyphs or vectograms with modifications to create jump vergence demand: base-in • Binocular accommodative therapy techniques: use any of the binocular techniques listed above with \pm lenses
HOME THERAPY <ul style="list-style-type: none"> • HTS Vergence and Accommodation programs • Eccentric Circles or Free Space Fusion Cards
Phase 3
<i>Sessions 17 through 20</i>
IN-OFFICE <ul style="list-style-type: none"> • Tranaglyphs or vectograms with Polaroid or red/green flippers • Eccentric Circles or Free Space Fusion Cards • Computer Orthoptics Random Dot Vergence program: step–jump vergence
HOME THERAPY <ul style="list-style-type: none"> • HTS Vergence and Accommodation programs • Eccentric Circles or Free Space Fusion Cards: base-out
<i>Sessions 21 and 22</i>
IN-OFFICE <ul style="list-style-type: none"> • Tranaglyphs or vectograms with Polaroid or red/green flippers • Eccentric Circles or Free Space Fusion Cards • Lifesaver cards • Computer Orthoptics Random Dot Vergence program: jump–jump vergence
HOME THERAPY <ul style="list-style-type: none"> • HTS Vergence and Accommodation programs • Eccentric Circles or Free Space Fusion Cards: base-in
<i>Sessions 23 and 24</i>
IN-OFFICE THERAPY <ul style="list-style-type: none"> • Tranaglyphs or vectograms with Polaroid or red/green flippers • Eccentric Circles or Free Space Fusion Cards with rotation and versions • Lifesaver cards with rotation and versions • Computer Orthoptics Vergence program with rotation
HOME THERAPY <ul style="list-style-type: none"> • HTS Vergence and Accommodation programs • Eccentric Circles or Free Space Fusion Cards: base-in/base-out

and vectograms can still be used. However, the specific modifications to create a step vergence demand (described in Chapter 6) must be implemented. These include the following:

- Changing fixation from the target to another point in space
- Covering and uncovering one eye
- Loose prism or flip prism
- Flip lenses to create a step vergence change in vergence demand
- Two different tranaglyphs set up in a dual Polachrome illuminated trainer
- Polaroid or red/green flippers

Other valuable techniques at this stage are the nonvariable tranaglyphs, the Aperture Rule, Eccentric Circles, Free Space Fusion cards, Lifesaver cards, and the Computer Orthoptics Jump Vergence program.

In contrast to Phase 1, in which speed was not a factor, during this second phase of therapy the emphasis should be on the qualitative aspects (speed, accuracy) of fusion rather than the quantitative (magnitude) aspects. It is important to increase the speed of the fusional vergence response and the quality of the recovery of fusion.

A second objective of this phase of therapy is to begin working with negative fusional vergence (NFV) amplitudes. It is not unusual to find a reduction occurring in NFV in convergence insufficiency patients when the entire vision therapy program stresses only convergence techniques. Once the patient begins to demonstrate normal smooth PFV, it is important to also implement therapy with smooth negative vergence

demand. The same techniques used in Phase 1 to work with PFV are repeated for NFV. Finally, during the end of this phase of therapy, incorporate NFV facility-type techniques using the same procedures as listed above for jump vergence demand for PFV.

Endpoint. The endpoint of Phase 2 is reached when the patient can:

- Fuse card 12 using convergence and card 6 using divergence with the Aperture Rule
- Fuse the Eccentric Circles or Free Space Fusion Cards using convergence (12 cm separation) and divergence (6 cm separation).

A sample vision therapy program for Phase 2 is summarized in Table 9.8. This program includes several techniques that can be used by the patient at home to supplement the in-office therapy.

Phase 3

This third phase of therapy is designed to accomplish the objectives listed in Table 9.6 under Phase 3. Until this point, the patient has either worked separately with convergence techniques or divergence techniques. Now the objective is to develop the patient's ability to change from a convergence to a divergence demand and to integrate vergence procedures with versions. Several excellent procedures are available to help accomplish these objectives. Vectograms with Polaroid flippers or tranaglyphs with red/green flippers can be used. Each time the flippers are changed, the demand switches from divergence to convergence. The transparent Keystone Eccentric Circles or transparent Bernell Free Space Fusion Cards are excellent, inexpensive methods for achieving these objectives. The patient has already learned, by this time, to fuse these cards with a divergence or convergence demand separately. Now the patient is taught to switch from convergence and then back to divergence. As this skill improves, speed or the number of cycles per minute is emphasized.

The final objective of therapy is to integrate vergence procedures with versions and saccades. Under normal seeing conditions, patients are constantly trying to maintain accurate vergence while changing fixation from one location to another. It is therefore important to combine vergence therapy with versions and saccades. Techniques such as the Brock string with rotation and Eccentric Circles or Lifesaver cards with rotation or lateral movements and saccades can be used to accomplish this goal. The Computer Orthoptics program that combines horizontal vergence with rotation is also useful for this objective.

Endpoint. Phase 3 ends when the patient can maintain clear single binocular vision with the Eccentric Circle cards held together, while slowly rotating the cards during both convergence and divergence training.

Because the objectives of vision therapy are to eliminate the patient's symptoms and normalize binocular and accommodative findings, a reevaluation should be performed about halfway through the therapy program and again at the end of therapy. A reference point for determining when to perform the first reevaluation is when the patient can begin working with jump vergence techniques, such as the Aperture Rule. During these evaluations, the clinician should refer to the original complaints and determine whether the patient is now comfortable. All tests of binocular and accommodative function should be repeated and compared to the initial findings as well as the expected findings.

When all vision therapy objectives have been reached and the vision therapy program is completed, we recommend the home vision therapy maintenance program outlined in Table 9.9. For the first 3 months following completion of vision therapy, the patient works with the HTS Vergence and Accommodation programs and Eccentric Circles or Free Space Fusion Cards three times per week, 10 to 15 minutes each session.

TABLE 9.9 **VISION THERAPY MAINTENANCE PROGRAM**

1. Three months following completion of vision therapy, work with HTS Vergence and Accommodation programs and the Eccentric Circles or Free Space Fusion Cards three times a week, 10 to 15 minutes each session. Reevaluation in 3 months.
2. For the next 6 months, the patient is asked to work with the same procedures, one session each week for 10 to 15 minutes. Reevaluation in 6 months.
3. Patient to try the Eccentric Circles or Free Space cards the first day of each month to monitor his or her visual systems. If the patient can still perform the task as expected, he or she need not do any therapy that month. If the patient feels that there has been some deterioration, he or she works with the technique until the expected level of performance is reached. Annual routine vision care.

The patient is reevaluated after 3 months; if all findings are still normal and the patient is comfortable, the amount of home therapy can be decreased. For the next 6 months, the patient is asked to work with the same procedures, one session each week, for 5 to 10 minutes. Another reevaluation is scheduled in 6 months. If all findings are normal and the patient is still asymptomatic, we advise patients to practice HTS Vergence and Accommodation and the Eccentric Circles or Free Space cards on the first day of each month to monitor their visual systems. If they can still perform the tasks as expected, they need not do any therapy that month. If they feel that there has been some deterioration, they work with the techniques until they reach the expected level of performance. We then advise patients to return on an annual basis for routine vision care.

Summary of Vision Therapy for Convergence Insufficiency

The sample vision therapy program described above and outlined in Table 9.8 represents one approach that will lead to successful elimination of a patient's symptoms and normalization of optometric data. The number of sessions is approximate and will vary from one patient to another. Remember that it is often not necessary to work with every procedure suggested in this chapter. The objective is to achieve a successful result as quickly as possible. If it becomes apparent that a recommended procedure is easy for the patient, go on to the next technique. In our experience, motivated adults generally can complete a vision therapy program in about half the time necessary for children.

Another variable is the use of home therapy techniques to supplement the activities used for in-office therapy. Home therapy can be useful with a highly motivated adult patient. It can also work when the patient is a motivated compliant child with a parent who has the capability to function as the home therapist. In some cases, however, the parent may not interact well with the child in this role, and home therapy will not be helpful.

Appendix I provides a variety of instructional sheets for vision therapy that can be used for home therapy. Computer software is now available that allows the clinician to generate these home therapy sheets and customize the instructions for specific patients.^b

Using the approach suggested above should lead to the achievement of the excellent success rates reported in the literature for convergence insufficiency.

Surgery

The use of lenses, prism, and vision therapy in the treatment of convergence insufficiency is so successful that surgery is virtually never necessary.

CASE STUDIES

The following case studies (Cases 9.5–9.8) are representative of the types of convergence insufficiency patients that clinicians will encounter in practice.

Case 9.5 Convergence Insufficiency Associated with a Secondary Accommodative Excess

History

Timmy, an 11-year-old boy in sixth grade, presented with complaints of eyestrain, burning, and watery eyes associated with reading. These problems began shortly after the beginning of the school year. He felt that he could read for about 15 minutes before experiencing discomfort. Timmy also complained that after working on a reading assignment for 15 minutes, the writing on the chalkboard was blurry for several minutes before clearing up. All of these problems seemed worse toward the end of the day. His medical history was negative, and he was not taking any medication. This was Timmy's first eye examination, other than periodic school vision screenings. He has never been told that a problem exists.

Examination Results

Visual Acuity (VA) (distance, uncorrected):	OD: 20/20 –2 OS: 20/20 –2
VA (near, uncorrected):	OD: 20/20 OS: 20/20
Near point of convergence	
Accommodative target:	10 cm
Penlight:	25 cm
Cover test (distance):	Orthophoria
Cover test (near):	10 exophoria
Subjective:	OD: –0.25, 20/20 OS: plano –0.25 × 90, 20/20
Cycloplegic refraction:	+0.50, 20/20 +0.50, 20/20
Distance lateral phoria:	Orthophoria
Base-in vergence (distance):	X/9/4
Base-out vergence (distance):	10/18/10
Vertical associated phoria (distance):	No vertical deviation
Near lateral phoria:	9 exophoria
–1.00 gradient:	7 exophoria
Gradient AC/A ratio:	2:1
Calculated AC/A ratio:	2:1
Base-in vergence (near):	12/22/10
Base-out vergence (near):	4/6/1
Vergence facility:	3 cpm (slow with base-out)
Vertical associated phoria (near):	No vertical deviation
NRA:	+1.50
PRA:	–2.50
Accommodative amplitude (push-up):	OD: 13 D; OS: 13 D
MAF:	OD: 0 cpm, fails +; OS: 0 cpm, fails +
BAF:	0 cpm, fails +
MEM retinoscopy:	OD: plano; OS: plano

Pupils were normal, all external and internal health tests were negative, the deviation was comitant, and color vision testing revealed normal function.

Case Analysis

The patient's symptoms seem to be related to the use of his eyes. The onset was at the beginning of the school year, and symptoms occurred shortly after the commencement of reading. Because of the high degree of exophoria at near, the analysis should begin with the data in the PFV group. The near point of convergence was receded, and both the direct (base-out at near and vergence facility) and indirect findings (NRA, BAF, and MEM retinoscopy) were low. In addition, the AC/A ratio was low, confirming a diagnosis of convergence insufficiency.

The other interesting factor in this case is the complaint of blur when looking at the chalkboard. Distance VA was slightly reduced, and subjective findings indicated a low degree of myopia in the right eye with a small degree of against-the-rule astigmatism in the left eye. However, cycloplegic refraction indicated low hyperopia. Thus, when all of the data that probe the patient's ability to relax accommodation are analyzed, it becomes clear that an accommodative excess problem is also present.

The NRA and MEM retinoscopy were lower than expected, and the patient was unable to clear plus with both BAF and MAF testing.

The diagnosis in this case, therefore, is convergence insufficiency with a secondary accommodative excess. The assumption is that because of the high exophoria, reduced PFV, and receded near point of convergence, the patient uses accommodative convergence to help maintain alignment. This excessive use of accommodation can lead to an accommodative spasm or accommodative excess.

Management

Even though there was a slight decrease in distance VA, the ametropia was not corrected because of the presence of accommodative excess. Vertical prism was not necessary because no vertical deviation was present, and horizontal prism was deferred until the results of vision therapy were known. Added lenses were not recommended because of the low AC/A ratio. A program of vision therapy was prescribed, and eighteen 45-minute in-office visits were necessary. The sequence suggested in Table 9.8 was followed. The patient was seen twice a week. After 9 weeks, the patient reported elimination of all of his initial complaints and was able to read comfortably as long as desired. A reevaluation at this point revealed the following findings:

Near point of convergence:	5 cm
Base-out at near:	16/32/18
NRA:	+2.50
Vergence facility:	18 cpm
MAF:	12 cpm
BAF:	10 cpm
Subjective:	OD: +0.25, 20/20 OS: +0.25, 20/20

We followed the maintenance procedures recommended in Table 9.9 and reevaluated the patient after 3 months and again after 9 months. After the second follow-up at 9 months, we recommended that Timmy continue to check his binocular vision once per month using the Eccentric Circles, and return for routine annual vision care.

This case is representative of the most common type of convergence insufficiency case. Lenses, prism, and added lenses typically have little value, and vision therapy is very effective in eliminating symptoms and restoring normal findings.

Case 9.6 Convergence Insufficiency Associated with Hyperopia

History

John, a 19-year-old freshman in college, presented with complaints of headaches, eyestrain, and blurred vision after 10 to 15 minutes of studying. He also complained of general eye discomfort in the evening and blurred vision when driving, particularly at night. Although he had problems reading throughout high school, they were never bothersome enough for him to see an eye doctor. He did remember wearing reading glasses when he was in elementary school. He could not recall if they helped him or not. He was last examined about 4 years ago. There was no other significant vision history. Medical history was negative.

Examination Results

VA (distance, uncorrected):	OD: 20/20 OS: 20/20
VA (near, uncorrected):	OD: 20/20 OS: 20/20
Near point of convergence	
Accommodative target with subjective:	25 cm
Penlight with subjective:	30 cm
Cover test (distance, uncorrected):	2 esophoria
Cover test (near, uncorrected):	6 exophoria
Subjective:	OD: +1.75, 20/20 OS: +1.75, 20/20
Distance lateral phoria:	Orthophoria
Base-in vergence (distance):	X/8/4
Base-out vergence (distance):	X/16/10
Vertical associated phoria (distance):	No vertical deviation
Near lateral phoria:	10 exophoria
-1.00 gradient:	7 exophoria
Gradient AC/A ratio:	3:1
Calculated AC/A ratio:	2:1
Base-in vergence (near):	12/19/11
Base-out vergence (near):	4/8/2
Vergence facility:	0 cpm (fails base-out)
Vertical associated phoria (near):	No vertical deviation
NRA:	+2.50
PRA:	-2.50
Accommodative amplitude (push-up):	OD: 12 D; OS: 12 D
MAF:	OD: 9 cpm; OS: 9 cpm
BAF:	2 cpm, slow with +2.00
MEM retinoscopy:	+0.25 OD and OS

Pupils were normal, all external and internal health tests were negative, the deviation was comitant, and color vision testing revealed normal function.

Case Analysis

The high exophoria at near with correction is the entry point into analysis and suggests looking at the data in the PFV group. These data indicate problems in both the direct measures of PFV (base-out vergence and vergence facility at near) and indirect measures of PFV (near point of convergence, and BAF with +2.00 lenses). A convergence insufficiency is clearly present. A complicating factor in this case, however, is the presence of a moderate degree of hyperopia.

Management

In this type of case, the clinician must make management decisions about the following issues:

- Are the patient's symptoms secondary to the uncorrected hyperopia, the convergence insufficiency, or both?
- Should we prescribe for the hyperopia, even though it will make the exophoria larger and place a greater demand on the already inadequate PFV?

- If we just treat the convergence insufficiency, would the patient still be uncomfortable because of the uncorrected hyperopia?

Because of the significant degree of hyperopia in this case, lenses were prescribed. However, because of the convergence insufficiency, only a partial prescription was given. The initial prescription was +1.00 OD and OS. These glasses were prescribed for full-time wear because the patient had general complaints of asthenopia and blurred vision when driving. Prism and added lenses were not used in this case because of the absence of any vertical deviation and the low AC/A ratio. The patient did experience some immediate relief with the glasses and was able to read for about 30 minutes without discomfort, felt more comfortable at the end of the day, and reported clearer vision when driving.

The vision therapy program recommended to treat the convergence insufficiency lasted 12 visits (the sequence outlined in Table 9.8 was followed). John came in once a week for in-office vision therapy and was given home therapy procedures to practice between visits.

Some of the procedures used for home therapy included HTS Vergence and Accommodation, the Brock string, Eccentric Circles, Lifesaver cards, and plus/minus flippers. A reevaluation at the end of vision therapy revealed the following findings:

Near point of convergence:	5 cm
Base-out at near:	18/36/24
NRA:	+2.50
Vergence facility:	15 cpm
MAF:	15 cpm
BAF:	15 cpm
Subjective:	OD: +1.75, 20/20 OS: +1.75, 20/20

After 12 weeks of vision therapy, John felt he could study without discomfort for several hours while wearing his glasses. We changed his prescription to +1.50 OU, and John continued to wear the prescription for full-time wear and adhered to the maintenance program of vision therapy recommended in Table 9.9.

Case 9.7 Convergence Insufficiency Associated with Presbyopia

History

Charles, a 78-year-old man working as a tool-and-die cutter, complained of intermittent double vision that was interfering with his work. He reported that this had bothered him for several years and he had already been examined by three previous doctors. One doctor changed his glasses and added prism, another said nothing was wrong, and the third suggested that he do pencil push-up exercises. Charles did not feel that any of these recommendations improved his symptoms. His health was excellent, and he was not taking any medication.

Examination Results

Current prescription:

OD: +1.25 – 1.00 ×7; 90, +2.25 add
OS: +1.00 – 0.75 ×7; 90, +2.25 add

The prescription from the doctor who prescribed prism was identical to the above prescription, with the addition of 2 base-in OD and OS.

VA (distance, corrected):	OD: 20/20 OS: 20/20
VA (near, corrected):	OD: 20/20 OS: 20/20
Near point of convergence	
Penlight:	40 cm
Cover test (distance):	2 exophoria
Cover test (near):	14 exophoria
Subjective:	OD: +1.25 – 1.00 ×7; 90, +2.25 add OS: +1.00 – 0.75 ×7; 90, +2.25 add
Distance lateral phoria:	1 exophoria
Base-in vergence (distance):	X/6/2
Base-out vergence (distance):	X/16/8
Vertical associated phoria (distance):	No vertical deviation
<i>All near testing through +2.25 add</i>	
Near lateral phoria:	10 exophoria
Calculated AC/A ratio:	2:1
Base-in vergence (near):	X/22/12
Base-out vergence (near):	X/8/–4
Vergence facility	2 cpm (slow base-out)
Vertical associated phoria (near):	No vertical deviation
NRA:	+0.75
PRA:	–0.75
Accommodative amplitude (push-up):	OD: 0.50 D; OS: 0.50 D

Pupils were normal, all external and internal health tests were negative, the deviation was comitant, and color vision testing revealed normal function.

Case Analysis

Because of the high exophoria at near, analysis of the PFV data is the logical starting point in this case. Both the direct findings (base-out and vergence facility at near) and the indirect findings (near point of convergence and NRA) are low. The high exophoria, receded near point of convergence, and reduced PFV indicate the presence of a convergence insufficiency problem. The interesting aspect of this case is the combination of convergence insufficiency with presbyopia.

Management

A vision therapy program was prescribed for Charles. Twelve in-office therapy visits were necessary to eliminate his symptoms and complete the treatment (the therapy sequence recommended in Table 9.8 was followed, with the exception of accommodative therapy). At the end of therapy, the near point of convergence was 5 to 7 cm and PFV at near was X/36/28. Charles continued to work with the Eccentric Circles, doing both convergence and divergence therapy three times a week. An examination 2 years later revealed that he was still comfortable, and his binocular findings remained essentially the same.

It is not unusual for convergence insufficiency to be associated with presbyopia. Convergence insufficiency is the most common binocular vision problem in presbyopia and is often responsible for asthenopia, diplopia, and other symptoms. Unfortunately, problems like these are sometimes ignored

or left untreated in this population because of a misconception that vision therapy is not effective in adults. Several authors (19–21), however, have reported excellent success treating convergence insufficiency in presbyopia. Presbyopes with convergence insufficiency should therefore be managed in the same way as prepresbyopes. Such patients are generally very motivated and are among the easiest patients to treat using vision therapy.

Case 9.8 Pseudoconvergence Insufficiency

History

Jennifer, a 10-year-old girl in the fifth grade, presented with complaints of blurred vision and eyestrain after reading for 5 to 10 minutes. She was unsure when these problems began, but she thought it bothered her in the fourth grade as well. She had never had an eye examination, and her health status was normal.

Examination Results

VA (distance, uncorrected):	OD: 20/20 OS: 20/20
VA (near, uncorrected):	OD: 20/20 OS: 20/20
Near point of convergence	
Accommodative target:	20 cm
Penlight:	20 cm
Cover test (distance):	Orthophoria
Cover test (near):	8 exophoria
Subjective:	OD: +0.50, 20/20 OS: +0.50, 20/20
Distance lateral phoria:	1 base-in
Base-in vergence (distance):	X/7/4
Base-out vergence (distance):	X/20/10
Near lateral phoria:	7 base-in
–1.00 gradient:	3 base-in
Gradient AC/A ratio:	4:1
Calculated AC/A ratio:	3.6:1
Base-in vergence (near):	6/18/10
Base-out vergence (near):	4/12/8
Vergence facility:	9 cpm (slow with base-out)
NRA:	+2.50
PRA:	–1.00
Accommodative amplitude (push-up):	OD: 8 D; OS: 8 D
MAF:	OD: 2 cpm, slow with –2.00 OS: 2 cpm, slow with –2.00
BAF:	2 cpm, difficulties with –2.00, no problem with +2.00
MEM retinoscopy:	+1.25 OD and OS

Pupils were normal, all external and internal health tests were negative, the deviation was comitant, and color vision testing revealed normal function.

Case Analysis

Because of the exophoria at near inspection of the PFV data is the first step in case analysis for this patient. Although the direct measures of PFV are low in this case (base-out vergence and vergence facility) the indirect findings are either normal (NRA BAF with +2.00) or high (MEM). Thus although the exophoria at near receded near point of convergence and reduced exophoria suggest a diagnosis of convergence insufficiency, another problem coexists. A closer look at the data indicates that all of the tests that assess the patient's ability to stimulate accommodation are also abnormal.

The results of MAF, the amplitude of accommodation, the PRA, and MEM retinoscopy suggest a diagnosis of accommodative insufficiency.

Management

When convergence insufficiency is associated with accommodative insufficiency it is important to think of the possibility of pseudoconvergence insufficiency. A patient experiencing difficulty accommodating may underaccommodate leading to a greater degree of exophoria and possibly a receded near point of convergence. Sometimes repeating the cover test and near point of convergence with plus lenses will actually lead to a decrease in the exophoria and an improved near point of convergence. Such a scenario would confirm a diagnosis of pseudoconvergence insufficiency. In many cases however such improvement with plus lenses does not occur. Even when plus does not immediately improve the binocular findings a pseudoconvergence insufficiency may be present.

In this case low plus did not have a positive effect on the near point of convergence. Nevertheless we treated the accommodative insufficiency along with the convergence problem. We prescribed +0.75 OU for reading along with a program of vision therapy (Table 9.8). After eighteen 45-minute in-office visits Jennifer was comfortable and all findings were normal. She continued to use the reading glasses and followed our standard vision therapy maintenance schedule.

SUMMARY AND CONCLUSIONS

Convergence insufficiency is the most common form of binocular vision disorder that clinicians will encounter. It is present in all age groups, including the presbyopic population. Research has shown that the procedures described in Cases 9.5–9.8 will almost always be effective for this condition and work equally well for all age groups.

Divergence Insufficiency

BACKGROUND INFORMATION

The term *divergence insufficiency* was first used by Duane (82). He described divergence insufficiency as a condition in which there is an esophoria of 2 to 8 degrees at distance and slight esophoria at near, normal versions, and reduced divergence at distance. Of the various nonstrabismic binocular vision problems, divergence insufficiency is the least common and has received the least attention. Although divergence insufficiency is uncommon, it does cause significant symptoms that may be alleviated if the condition is properly diagnosed. Divergence insufficiency also can be confused with other vision anomalies that have very serious etiologies.

CHARACTERISTICS

Table 9.10 lists the signs and symptoms of divergence insufficiency.

TABLE 9.10 SIGNS AND SYMPTOMS OF DIVERGENCE INSUFFICIENCY

Signs	Symptoms
Esophoria greater at distance than at near	Long-standing
Frequency of esodeviation worse at distance than at near	Intermittent diplopia at distance
Low AC/A ratio (calculated method)	Diplopia worsens if tired
Decreased negative fusional vergence at distance	Headaches
No significant refractive error	Eyestrain
Comitant deviation	Nausea
Single vision by recession	Dizziness Train and car sickness Panoramic headaches Blurred vision Difficulty focusing from far to near Sensitivity to light

Signs

Magnitude of the Deviation

Patients with divergence insufficiency have greater esophoria at distance than near, decreased NFV, and a comitant deviation. The distinguishing characteristic is the larger deviation at distance, which can be a phoria, an intermittent esotropia, or a constant esotropia. Duane (82), in his original description, suggested that 2 to 8 degrees of esophoria at distance and a slight esophoria at near was characteristic of the anomaly. He did not report a more specific difference between the distance and near deviations. Prangen and Koch (2), Oaks (3), and Burian (4) repeated the statement that the amount of esodeviation must be larger at distance than at near, without stating a specific magnitude. In describing their sample of 16 cases of divergence insufficiency, Moore, Harbison, and Stockbridge (83) stated that the amount of esodeviation at distance ranged from 8 to 30 Δ , with an average of 16 Δ . At near, the deviation was always less eso, with the difference ranging from 4 to 18 Δ .

Other authors have suggested that a 10 Δ difference from one distance to another is a useful guideline. This suggestion, however, has no firm research basis and should be used only as a guideline. Rather than depend on this guideline, we find it more useful to think about the difference one would expect based on the presence of a low AC/A ratio. Since an AC/A ratio of less than 3:1 is considered low, as little as an 8 D difference between distance and near would be sufficient to fit the diagnosis of divergence insufficiency.

Clinicians therefore must use their judgment and generally rely on other characteristics, in addition to the magnitude of the angle at distance and near, to reach a diagnosis. These additional characteristics are described below.

Proportion of Time the Deviation Occurs

An important characteristic is the proportion of time the deviation occurs at distance compared to at near. Anytime that an intermittent strabismus is present, it is important to categorize the proportion of time the deviation is present. For example, two patients might both present with an intermittent esotropia at distance. Although they have the identical condition at first glance, they may actually be very different because of differences in the amount of time the deviation is present. One may have an intermittent esotropia present 95% of the time, whereas the other may have a deviation present only 5% of the time. The dramatic difference in frequency of the deviation would lead to a different treatment plan.

This characteristic should also be considered when analyzing the distance and near deviations. A divergence insufficiency patient may have an esodeviation only slightly greater at distance than at near, yet the deviation may be an intermittent esotropia at distance and an esophoria at near. Thus, a significant difference in the proportion of time the deviation is present can be just as significant as a difference in magnitude between distance and near.

AC/A Ratio

A low AC/A ratio is present in divergence insufficiency (82). This is generally well accepted, based on the calculated AC/A, and is an important consideration when treatment is considered.

Fusional Vergence Amplitudes and Facility

All direct measures of NFV at distance will be low in divergence insufficiency, regardless of whether NFV is measured using smooth, step, or jump vergence techniques. Unlike the assessment of binocular vision at near, there are no standardized tests to indirectly assess NFV at distance.

Refractive Error

A clear trend has not been identified in the literature in regard to refractive error in divergence insufficiency. The prevalence of hyperopia does not appear to be any greater in divergence insufficiency than in the general population. This is an important clinical characteristic. The presence of uncorrected hyperopia would be a possible etiologic factor for esophoria at distance. The ease of eliminating hyperopia as a cause, using spectacle correction, makes it a desirable characteristic from a management viewpoint. Unfortunately, hyperopia is rarely associated with divergence insufficiency.

Comitancy

An important feature of divergence insufficiency is the comitant nature of the deviation (3,4,82–84). This means that versions are normal in all positions of gaze, and there is no difference in the magnitude of the phoria or strabismus when measured in different positions of gaze or with either eye fixating. Comitancy is a key finding that distinguishes divergence insufficiency from more serious conditions, such as sixth nerve palsy.

Symptoms

The most frequent symptom associated with divergence insufficiency is intermittent diplopia (3,4,82–84). The diplopia is most evident at distance. An important characteristic of this symptom is that the onset is not sudden. The patient usually reports that the diplopia has been a problem for a long time and has not changed in nature. The diplopia has been reported to decrease or disappear entirely after rest. Other reported symptoms include headaches, ocular fatigue, nausea, dizziness, train and car sickness, panoramic headaches, blurred vision, difficulty focusing from far to near, and sensitivity to light (40).

Differential Diagnosis

Divergence insufficiency is considered to be a benign condition with no serious consequences other than the visual symptoms listed in Table 9.10. However, it resembles several other conditions, and a careful differential diagnosis is important. These conditions include convergence excess, basic esophoria, divergence paralysis, and sixth nerve palsy, all of which can present with an esodeviation at distance. The underlying cause of the last two conditions can often be life threatening. One must therefore be cognizant of the differential diagnosis of divergence insufficiency and first rule out the more serious disorders, such as divergence paralysis and sixth nerve palsy, that can mimic divergence insufficiency. Table 9.11 lists the various conditions that must be considered in the differential diagnosis of divergence insufficiency.

TABLE 9.11 DIFFERENTIAL DIAGNOSIS OF DIVERGENCE INSUFFICIENCY

Functional Disorders to Rule Out	Serious Underlying Disease to Rule Out
Convergence excess	Sixth nerve palsy
Basic esophoria	Divergence paralysis

Convergence Excess and Basic Esophoria

Of the four conditions that must be ruled out, convergence excess and basic esodeviations are easily excluded because neither presents with greater eso at distance than at near or with frequency of eso worse at distance than at near. Convergence excess is a condition in which there is greater eso at near than at distance, and basic eso presents with approximately equal deviations at distance and near.

Sixth Nerve Palsy

Both unilateral and bilateral sixth nerve palsy more closely resemble divergence insufficiency, except that, in these conditions, a noncomitant deviation is present. A variety of clinical techniques, such as measurement of the deviation in the cardinal positions of gaze, the red glass test, and the Hess-Lancaster screen, can be used to determine comitancy.

Divergence Paralysis

The most difficult task for the clinician will be differentiating divergence insufficiency from divergence paralysis.

Signs and Symptoms. Table 9.12 lists the signs and symptoms of divergence paralysis. The most important characteristic is the *sudden* development of diplopia with marked esotropia at distance. The amount of diplopia at distance and the magnitude of the deviation decrease as the object of regard is brought toward the patient, until, at a certain distance, there is binocular vision. Duane (82) also reported that divergence paralysis, like divergence insufficiency, is a comitant deviation. Another symptom occasionally associated with divergence paralysis is headaches. The key difference between the headaches in divergence insufficiency and divergence paralysis is the sudden onset of the symptom in the latter condition.

Occasionally, but not always, ophthalmoscopy reveals papilledema in patients with divergence paralysis. An “A” pattern may be present with greater esodeviation in up-gaze and a decrease in down-gaze.

Is Divergence Paralysis a Distinct Entity? Considerable controversy exists concerning the nature of divergence paralysis, and some authors question the validity of divergence paralysis as a diagnostic entity. Most authors (85–88) have described divergence paralysis as a condition consisting of the characteristics described above. However, Jampolsky (89) stated that the clinical signs and symptoms of so-called divergence paralysis are consistent with the diagnosis of a mild or moderate degree of sixth nerve paresis. It is quite possible that a mild bilateral sixth nerve palsy could resemble a divergence paralysis. Careful evaluation of comitancy should be part of the differential diagnosis of divergence paralysis. In addition, one should look carefully for endpoint nystagmus, which would tend to support a diagnosis of bilateral sixth nerve palsy.

Etiology of Divergence Paralysis. Divergence paralysis has been observed in a variety of conditions affecting the central nervous system. It has been seen in chorea, encephalitis, lues, multiple sclerosis, head trauma, cerebral hemorrhage, increased intracranial pressure, brain tumor, and vascular lesions of the brainstem.

TABLE 9.12 SIGNS AND SYMPTOMS OF DIVERGENCE PARALYSIS

Signs	Symptoms
Esophoria greater at distance than at near	Recent onset of intermittent diplopia at distance
Frequency of esodeviation worse at distance than at near	Recent onset of headaches
Low AC/A ratio (calculated method)	Recent onset of eyestrain
Decreased negative fusional vergence at distance	
No significant refractive error	
Comitant deviation	
Papilledema may be present	
“A” pattern esodeviation may be present	

Summary

Divergence insufficiency must be differentiated from divergence paralysis, as well as from sixth nerve paresis, convergence excess, and basic esophoria (Table 9.11). This differential diagnosis depends very much on the nature of the patient's symptoms. Typically, divergence insufficiency presents with a long history of intermittent diplopia that is most noticeable during distance viewing. In divergence paralysis and sixth nerve palsy, the diplopia is also worse for distance, but is sudden in onset. Although in both divergence insufficiency and divergence paralysis the diplopia is essentially the same in all positions of gaze, in sixth nerve palsy the deviation is noncomitant. In bilateral or unilateral sixth nerve palsy, endpoint nystagmus may be present. Divergence insufficiency, of course, can be distinguished from convergence excess, in which the esodeviation is larger at near than at distance and the symptoms are also more significant at near. Divergence insufficiency can also be differentiated from basic esophoria, in which the magnitude of the deviation is equal at distance and near. Other distinguishing features include the following:

- Divergence insufficiency worsens with fatigue, but divergence paralysis and sixth nerve palsy are stable in their manifestations. Thus, in divergence insufficiency, the diplopia becomes worse when the patient is tired.
- The diplopia noted by patients with divergence insufficiency is generally less than that in divergence paralysis or sixth nerve palsy.
- The range of single vision, as measured with a penlight, is large in divergence insufficiency and small in divergence paralysis.
- Papilledema is sometimes associated with divergence paralysis and sixth nerve palsy.
- In divergence paralysis or sixth nerve palsy, the patient may have other associated signs or symptoms, such as dizziness, lethargy, vomiting, irritability, gait disturbance, and distal paresthesia.
- In sixth nerve palsy, the deviation is noncomitant, and endpoint nystagmus may be present.

The differential diagnosis is critical because, as stated previously, the causes of the various conditions under consideration vary from insignificant to life threatening. Divergence insufficiency is a benign isolated phenomenon, whereas divergence paralysis and sixth nerve palsy may be associated with brainstem pathology and vascular disorders. Acute neurologic oculomotor palsies suggest a serious condition. About one-third of such patients do not survive 5 years (90). All patients suspected of having either divergence paralysis or sixth nerve palsy require immediate and careful neurologic study.

TREATMENT

We recommend the management sequence outlined in Table 9.3 (after neurologic problems have been ruled out).

Lenses

In all cases of binocular and accommodative dysfunction, the first management consideration is correction of any significant refractive error. In the case of divergence insufficiency, however, correction of refractive error generally has little beneficial effect on reduction of the angle of deviation. As stated previously, the prevalence of hyperopia in divergence insufficiency does not appear to be any greater than in the general population. In addition, divergence insufficiency is usually accompanied by a low calculated AC/A ratio. Both of these factors significantly decrease the likelihood of lenses being effective in the treatment of the condition. If hyperopia is present, however, one should certainly prescribe maximum plus to decrease the deviation as much as possible.

Prism

If a vertical deviation is present, vertical prism should be prescribed. For divergence insufficiency, horizontal prism is generally the most important treatment option. In the vast majority of cases, the use of horizontal relieving prism is necessary and represents the first and most effective treatment approach for divergence insufficiency.

Determination of the magnitude can be accomplished by several methods. One can use techniques that assess binocular status under dissociated conditions, such as the von Graefe phoria and vergence analysis using Sheard's criterion. A more desirable alternative is the use of fixation disparity analysis. Most authorities

now consider fixation disparity analysis to be the method of choice because it evaluates binocularity under associated, and presumably more natural, conditions (64,91). In general, the minimum prism needed to eliminate the patient's symptoms should be prescribed. The prism prescription indicated by fixation disparity has generally been shown to be less than that revealed by other methods.

The associated phoria, as measured by the Mallett unit and the American Optical vectographic slide, tends to overestimate the amount of prism necessary (64) and is therefore not the preferred method for determination of horizontal prism. Rather, the Wesson card may be used to generate a forced vergence fixation disparity curve. This approach permits actual measurement of the fixation disparity, along with the associated phoria, curve type, and slope of the curve. Of these four findings, it is the slope of the curve that provides the main information for prescribing prism. Guidelines for generating such curves and procedures for prescribing prism based on this information are described in detail in Chapter 15. However, the Wesson card is designed only for near testing. Many of the new computerized visual acuity devices include a distance fixation disparity target that can be used for evaluating fixation disparity at distance. These instruments along with the American Optical vectographic slide can be used to measure the associated phoria at distance.

Because divergence insufficiency usually produces symptoms only at distance, a correction can be prescribed for distance-related tasks only or for full-time wear. Often divergence insufficiency patients can tolerate this additional base-out at near because PFV is usually adequate. If a patient is unable to tolerate the base-out prism for near work, vision therapy to expand PFV can be prescribed.

Vision Therapy

If the prescription of prism is not successful in eliminating the patient's symptoms, vision therapy is indicated. Although there are no specific data available on the effectiveness of vision therapy in cases of divergence insufficiency, there is sufficient information with other types of esodeviations to indicate that vision therapy should be effective in the management of the esodeviation (92,93).

Generally the following guidelines are appropriate:

- Begin vision therapy at near where the patient can succeed, and gradually move toward greater distances.
- At any particular distance, begin with peripheral fusion targets and proceed to the use of central targets.
- Begin therapy with third-degree stimuli and proceed to second- and then first-degree stimuli.

The overall goals are to increase the NFV amplitude at distance and to improve vergence facility, permitting the patient to make rapid changes in vergence and accommodation with comfort and without diplopia.

Specific Vision Therapy Program

Phase 1

This first phase of therapy is designed to accomplish the objectives listed in Table 9.13 under Phase 1. The first goals are to teach the concept and feeling of diverging and to begin working with NFV at near. Although

TABLE 9.13 OBJECTIVES OF VISION THERAPY FOR DIVERGENCE INSUFFICIENCY

Phase 1

- Develop a working relationship with the patient
- Develop an awareness of the various feedback mechanisms that will be used throughout therapy
- Develop feeling of diverging
- Normalize negative fusional vergence (NFV) amplitudes at near (smooth or tonic vergence demand)
- Normalize accommodative amplitude and ability to stimulate and relax accommodation

Phase 2

- Normalize positive fusional vergence (PFV) amplitudes (smooth or tonic vergence demand)
- Normalize NFV facility at near (jump or phasic vergence demand)
- Normalize PFV facility (jump or phasic vergence demand)

Phase 3

- Normalize NFV amplitudes at intermediate and far distances
- Normalize NFV facility at intermediate and far distances

the ultimate goal with divergence insufficiency is to improve NFV at distance, it is much easier to begin therapy at near. Procedures that can be used to accomplish these first objectives are the Brock string, bug on string, variable tranaglyphs, and vectograms.

Endpoint. Phase 1 of therapy ends when the patient can:

- Fuse to about 15 base-in at near with a tranaglyph or other comparable technique
- Complete 12 cpm of accommodative facility with +2.00/−2.00 lenses using a 20/30 target.

A sample vision therapy program for Phase 1 is summarized in Table 9.14.

TABLE 9.14 SAMPLE VISION THERAPY PROGRAM FOR DIVERGENCE INSUFFICIENCY

Phase 1
<p><i>Sessions 1 and 2</i> IN-OFFICE</p> <ul style="list-style-type: none"> • Discuss nature of vision problem, goals of vision therapy, various feedback cues, importance of practice • Brock string • Tranaglyphs or vectograms: base-in <ul style="list-style-type: none"> • Begin with a peripheral target such as tranaglyph 515 or the Quoit vectogram • Computer Orthoptics Random Dot program: base-in
<p>HOME THERAPY</p> <ul style="list-style-type: none"> • HTS Vergence and Accommodation programs • Brock string
<p><i>Sessions 3 and 4</i> IN-OFFICE</p> <ul style="list-style-type: none"> • Bug on string • Tranaglyphs or vectograms: base-in <ul style="list-style-type: none"> • Use targets with more central demand (Clown, Bunny tranaglyphs; Clown, Topper vectograms) • Computer Orthoptics Random Dot program: base-in
<p><i>Sessions 5 through 8</i> IN-OFFICE</p> <ul style="list-style-type: none"> • Bug on string • Tranaglyphs or vectograms: base-in <ul style="list-style-type: none"> • Use even more detailed targets such as tranaglyph Sports Slide and Faces targets and the Spirangle vectogram) • Computer Orthoptics Random Dot program: base-in
<p>HOME THERAPY</p> <ul style="list-style-type: none"> • HTS Vergence and Accommodation programs
Phase 2
<p><i>Sessions 9 and 10</i> IN-OFFICE</p> <ul style="list-style-type: none"> • Tranaglyphs or vectograms with modifications to create jump vergence demand: base-in • Nonvariable tranaglyphs • Tranaglyph 515 or the Quoit vectogram: base-out • Binocular accommodative therapy techniques: use any of the binocular techniques listed above with \pm lenses
<p>HOME THERAPY</p> <ul style="list-style-type: none"> • HTS Vergence and Accommodation programs
<p><i>Sessions 11 and 12</i> IN-OFFICE</p> <ul style="list-style-type: none"> • Tranaglyphs or vectograms with modifications to create jump vergence demand: base-in • Aperture Rule: base-in • More central tranaglyphs or the vectograms: base-out • Binocular accommodative therapy techniques: use any of the binocular techniques listed above with \pm lenses
<p>HOME THERAPY</p> <ul style="list-style-type: none"> • HTS Vergence and Accommodation programs

(Continued)

TABLE 9.14 CONTINUED

<p>Sessions 13 through 16</p> <p>IN-OFFICE</p> <ul style="list-style-type: none"> • Aperture Rule: base-in • Eccentric Circles or Free Space Fusion Cards: base-in • Computer Orthoptics Random Dot Vergence program: both base-in and base-out • Aperture Rule: base-out • Tranaglyphs or vectograms with modifications to create jump vergence demand: base-out • Binocular accommodative therapy techniques: use any of the binocular techniques listed above with \pm lenses
<p>HOME THERAPY</p> <ul style="list-style-type: none"> • HTS Vergence and Accommodation programs • Eccentric Circles: base-in
<p>Phase 3</p> <p>Sessions 17 through 20</p> <p>IN-OFFICE</p> <ul style="list-style-type: none"> • Tranaglyphs or vectograms at 1 m • Eccentric Circles or Free Space Fusion Cards: base-in at 1 m • Computer Orthoptics Random Dot Vergence program: step-jump vergence at 1 m
<p>HOME THERAPY</p> <ul style="list-style-type: none"> • HTS Vergence and Accommodation programs • Large Eccentric Circles at 1 m
<p>Sessions 20 through 24</p> <p>IN-OFFICE</p> <ul style="list-style-type: none"> • Tranaglyphs or vectograms projected with overhead projector • Large Eccentric Circles at distance
<p>HOME THERAPY</p> <ul style="list-style-type: none"> • HTS Vergence and Accommodation programs • Large Eccentric Circles at distance

Phase 2

The second phase of therapy is designed to accomplish the objectives listed in Table 9.13 under Phase 2. Once smooth NFV is normalized at near, phasic or jump vergence demand should be emphasized. Variable tranaglyphs and vectograms can still be used. However, the specific modifications to create a step vergence demand (described in Chapter 6) must be implemented.

Other valuable techniques at this stage are nonvariable tranaglyphs, the Aperture Rule, Eccentric Circles, Free Space Fusion cards, Lifesaver cards, and the Computer Orthoptics Jump Vergence program.

In contrast to Phase 1—in which speed was not a factor—during this second phase of therapy the emphasis should be on the qualitative aspects of fusion rather than magnitude. It is important to increase the speed of the fusional vergence response and the quality of the recovery of fusion. A second objective of this phase of therapy is to begin working with PFV amplitudes and facility.

Endpoint. The endpoint of phase 2 is reached when the patient can:

- Fuse card 12 using convergence and card 6 using divergence with the Aperture Rule
- Fuse the Eccentric Circles or Free Space Fusion cards using convergence (12 cm separation) and divergence (6 cm separation).

A sample vision therapy program for Phase 2 is summarized in Table 9.14.

Phase 3

After achieving the objectives of Phases 1 and 2, the goal is to begin moving the training distance from near to far. This can be accomplished in several steps. For example, after working with techniques such as the tranaglyphs, vectograms, and Eccentric Circles at 40 cm, the same procedures can be repeated at 1 m. Once success is achieved at this distance, other targets must be used as the distance is increased. The tranaglyphs and vectograms can also be projected on an overhead projector, or large eccentric circles printed on 8.5×11 in.

paper can be used. Another technique that can be used for training NFV at distance is the use of loose prism with appropriate targets containing suppression controls. Samples of such targets are illustrated in Chapter 6 (Figs. 6.33 and 6.34).

Vision therapy may also be necessary when base-out prism is prescribed for divergence insufficiency. Occasionally this prism is successful in relieving the patient's symptoms at distance, but creates discomfort at near when the prism is worn for full-time wear. One option is to prescribe two pairs of glasses, using prism only in the distance glasses. Another option is vision therapy to expand PFV at near to allow the patient to function comfortably with the additional convergence demand. A vision therapy program similar to that described earlier in this chapter for convergence insufficiency would be appropriate.

A reevaluation should be performed about halfway through the therapy program and again at the end of therapy. Refer to the original complaints and determine whether the patient is now comfortable. All tests of binocular and accommodative function should be repeated and compared to the initial findings as well as the expected findings.

When all vision therapy objectives have been reached and the vision therapy program is completed, we recommend the home vision therapy maintenance program outlined in Table 9.9.

Summary of Vision Therapy for Divergence Insufficiency

In contrast to convergence insufficiency, which is the easiest heterophoric binocular vision disorder to treat with vision therapy, divergence insufficiency is the most difficult. If the use of lenses and base-out prism is not totally effective in eliminating the patient's symptoms, the therapy program outlined above should be attempted.

Surgery

Optometric treatment of divergence insufficiency involves the judicious application of lenses, prism, and vision therapy. Fortunately, only in very extreme cases is a surgical consultation necessary. Prangen and Koch (2) stated that divergence insufficiency patients appear to be poor surgical risks. Dunnington (94) recommended surgery only for the more resistant types of this condition. Burian (4) believed that bilateral lateral rectus resection is the procedure of choice, but only after prism therapy has been attempted.

CASE STUDIES

The following case studies (Cases 9.9 and 9.10) are representative of the types of divergence insufficiency patients that clinicians will encounter in practice.

Case 9.9

History

Suzanne, a 16-year-old girl in the 11th grade, presented with a complaint of occasional double vision. The double vision was particularly bothersome when she had to take notes from the board in school and when driving. Her last eye examination was about 2 years ago, and no problem was found. Her mother remembers, however, that about 4 years ago, Suzanne was also complaining of double vision. At that time, the doctor suggested that there was a vision problem, but it was not serious enough to treat.

Suzanne was in good health and was not taking any medication. She was doing well in school, had a normal appetite, and her sleep patterns were normal.

Examination Results

VA (distance, uncorrected):	OD: 20/20
	OS: 20/20
VA (near, uncorrected):	OD: 20/20
	OS: 20/20

Near point of convergence	
Accommodative target:	6 cm
Penlight:	6 cm
Cover test (distance):	12 esophoria
Cover test (near):	2 exophoria
Subjective:	OD: +1.00, 20/20 OS: +1.00, 20/20
Distance lateral phoria:	12 esophoria
Base-in vergence (distance):	X/2/−4
Base-out vergence (distance):	12/28/18
Vertical associated phoria (distance):	No vertical deviation
Near lateral phoria:	Orthophoria
−1.00 gradient:	2 esophoria
Gradient AC/A ratio:	2:1
Calculated AC/A ratio:	1.2:1
Base-in vergence (near):	X/16/12
Base-out vergence (near):	12/26/12
Vertical associated phoria (near):	No vertical deviation
NBA:	+2.50
PRA:	−2.50
Accommodative amplitude (push-up):	OD: 12 D; OS: 12 D
MAF:	OD: 9 cpm; OS: 9 cpm
BAF:	8 cpm
MEM retinoscopy:	+0.50 OD and OS

Pupils were normal, all external and internal health tests were negative, the deviation was comitant, and color vision testing revealed normal function.

Case Analysis

All of the near point data are normal in this case. However, there is a significant degree of esophoria at distance, and the NFV at distance is reduced. The most likely diagnosis is divergence insufficiency. However, in such cases, it is important to think about the differential diagnosis listed in Table 9.11. The history suggests that this is not an acute problem. Suzanne complained of diplopia at least 4 years ago. It is likely that she is bothered more now because of the need to take more notes from the board at school and the fact that she is beginning to drive. The health history is negative, and she is eating and sleeping well. Her school performance has not shown any signs of deterioration. Thus, Suzanne is a teenager who appears to be thriving and doing well in all areas, except for the occasional complaint of diplopia. This history suggests divergence insufficiency, and the comitant nature of the deviation precludes a sixth nerve paresis. Thus, a diagnosis of divergence insufficiency is most likely.

Management

Because the lenses reduced the deviation slightly, they were prescribed to correct the hyperopia, even though the AC/A ratio is low. In addition, base-out prism was incorporated into her glasses. The amount of prism was determined based on the associated phoria measured at distance using the American Optical fixation disparity target. The associated phoria with this device was 6 base-out. The final prescription was

OD: +1.00 with 3 base-out

OS: +1.00 with 3 base-out.

Suzanne was asked to wear these glasses for school and driving for 4 weeks and was scheduled for a reevaluation. At the reevaluation, she reported elimination of her symptoms with the new glasses. The cover test with her glasses was 3 esophoria at distance and 6 exophoria at near. Base-in vergence at distance was X/7/3.

Suzanne was told to continue to wear the glasses in the same manner and to return in 1 year, or sooner if she experienced any additional problems. This is a very typical case of divergence insufficiency. Glasses with low plus and base-out prism were effective without the need for vision therapy.

Case 9.10

History

Greg, a 22-year-old accountant, presented with a complaint of intermittent double vision and eyestrain. The double vision only bothered him when driving or when engaged in other tasks at a distance, such as watching movies. At the end of the day, he often experienced eyestrain that he described as a general feeling of pulling around his eyes. He had complained for years about these problems and had been given glasses in the past. The glasses relieved, but did not entirely eliminate, the problems. In fact, the most recent glasses he received a year ago made it a little less comfortable when he read. He sometimes experienced eyestrain even when reading with the newer glasses. His medical history was negative, and he was not taking any medication.

Examination Results

Current prescription	OD: plano with 5 base-out OS: plano with 5 base-out
VA	
Distance, uncorrected:	OD: 20/20; OS: 20/20
Distance, corrected:	OD: 20/20; OS: 20/20
Near, uncorrected:	OD: 20/20; OS: 20/20
Near, corrected:	OD: 20/20; OS: 20/20
Near point of convergence	
Accommodative target:	5 cm
Penlight:	5 cm
Cover test (distance, uncorrected):	15 esophoria
Cover test (near, uncorrected):	Orthophoria
Cover test (near, corrected):	10 exophoria
Subjective:	OD: plano, 20/20 OS: plano, 20/20
Distance lateral phoria:	15 esophoria
Base-in vergence (distance):	X/2/−4
Base-out vergence (distance):	10/14/8
Vertical associated phoria (distance):	No vertical deviation
Near lateral phoria:	Orthophoria
−1.00 gradient:	2 esophoria
Gradient AC/A ratio:	2:1
Base-in vergence (near):	12/18/9

Base-out vergence (near):	10/14/10
Vertical associated phoria (near):	No vertical deviation
NRA:	+2.25
PRA:	-2.50
Accommodative amplitude (push-up):	OD: 10 D; OS: 10 D
MAF:	OD: 9 cpm; OS: 9 cpm
BAF:	7 cpm
MEM retinoscopy:	+0.50 OD and OS

Pupils were normal, all external and internal health tests were negative, the deviation was comitant, and color vision testing revealed normal function.

Case Analysis

The long-standing history of diplopia and asthenopia, along with the high esophoria at distance with a low AC/A ratio, clearly establishes a diagnosis of divergence insufficiency. This patient had already been treated with prism in the past, and although these glasses had helped, they had not totally eliminated his symptoms. The challenge in this case is the management rather than the diagnosis.

Management

Two problems had to be addressed in this case. The first problem was that even with his current prescription (10 base-out prism), the patient reported that he still had some diplopia and discomfort. The second issue was that with his glasses on, the patient had an additional problem of asthenopia when reading. Analysis of his near data, with his prescription, reveals the reason for this problem. The cover test at near through his prescription was 10 exophoria. The PFV at near without the glasses was 10/14/10. With the 10 base-out prism, the PFV measurement would be reduced about 10 Δ . Thus, with glasses on, he had a high degree of exophoria with reduced PFV ranges at near.

The use of additional prism was not indicated in this case. The associated phoria determined with fixation disparity testing confirmed that 8 to 10 base-out was an appropriate amount of prism. Vision therapy was prescribed to solve both problems described above. The first goal was to improve PFV at near, and the second was to improve NFV at distance. This vision therapy program lasted about 3 months with 14 in-office visits. We followed the vision therapy sequence outlined in Table 9.14.

After vision therapy, the patient was able to wear the prism glasses more comfortably during reading tasks, and he no longer had complaints about distance-related tasks. The cover test through his prescription was 4 esophoria at distance and 10 exophoria at near. The PFV at near with the glasses was 18/28/24, and the NFV at distance was X/7/5.

Summary and Conclusions

Divergence insufficiency represents a disorder of considerable clinical significance, even though it is the least prevalent binocular vision problem. Patients with greater esodeviation at distance than at near, a comitant deviation, and diplopia present a challenging diagnostic puzzle for the clinician. Divergence insufficiency, a benign condition, must be differentiated from divergence paralysis and sixth nerve palsy, which often have underlying etiologies of a serious nature. Knowledge of the characteristic signs and symptoms of these disorders is therefore important.

A diagnosis of either divergence paralysis or sixth nerve palsy would necessitate a referral for a neurologic examination. Once a tentative diagnosis of divergence insufficiency is reached, the condition is generally managed by a combination of prism, lenses, and vision therapy.

Study Questions

1. Why are added lenses not a very effective treatment approach for low AC/A conditions?
2. Why is prism considered to be a more important treatment tool for divergence insufficiency than for convergence insufficiency?
3. Describe two modifications to the traditional near point of convergence test that can be used to detect subtler cases of convergence insufficiency.
4. What are the key findings that would differentiate classic convergence insufficiency from convergence insufficiency associated with accommodative excess and pseudoconvergence insufficiency?
5. Outline a three-phase vision therapy program for convergence insufficiency and indicate the key objectives for each phase of therapy.
6. Describe the recommendations you would make after a patient completes vision therapy for convergence insufficiency. What would the clinical care be like for the next 3 to 12 months?

SOURCES OF EQUIPMENT

- (a) Computer Orthoptics: 6788 Kings Ranch Rd, Ste 4, Gold Canyon, AZ 85218; 800-346-4925; www.visiontherapysolutions.net.
 (b) Available from Bruce Wick, O.D., Ph.D., 13615 Bellaire Blvd, Houston, TX 77083.

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High AC/A Conditions: Convergence Excess and Divergence Excess

This chapter discusses the characteristics, diagnosis, and management of nonstrabismic binocular disorders associated with a high AC/A ratio. As described previously, the AC/A ratio is the major factor that determines the sequence of management decisions in patients with heterophoria (Chapter 3). Consequently, certain general treatment strategies are shared by all binocular conditions associated with a high AC/A ratio. However, there are also important differences among patients with high AC/A ratios who have convergence excess and those who have divergence excess. After a review of the general principles that apply to all high AC/A disorders, each condition is described separately to highlight the differences in characteristics, diagnosis, and management.

The specific conditions that are discussed in this chapter are the various forms of convergence excess and divergence excess.

Overview of General Management Principles for Heterophoria Associated with High AC/A Ratio

For binocular vision disorders associated with a high AC/A ratio, the specific management sequences are listed in Tables 10.1 and 10.2. The major difference that distinguishes high AC/A problems from conditions associated with low and normal AC/A ratios is the relative effectiveness of added lenses in effecting a change in the size of the heterophoria. An example of this is the patient with convergence excess described in Case 10.1.

Case 10.1

A 10-year-old boy presented with complaints of eyestrain, blurred vision, and inability to concentrate when reading after 10 minutes. These problems had been bothering him since the beginning of the school year. The refraction was +1.00 D OD and OS, the distance phoria was 4 esophoria, and the near phoria was 20 esophoria (interpupillary diameter [IPD] = 58 mm). The calculated AC/A ratio in this case is 8:1. Near point testing through the subjective revealed the following:

Negative relative accommodation (NRA):	+2.50
Positive relative accommodation (PRA):	−1.00
Near lateral phoria (NLP):	3 esophoria
Base-in (near):	4/10/4
Base-out (near):	16/26/16
Vergence facility:	0 cpm, diplopia with base-in
Monocular estimation method (MEM):	+1.25 OD and OS
Binocular accommodative facility (BAF):	Diplopia with −2.00, 0 cpm
Monocular accommodative facility (MAF):	12 cpm

Because the AC/A ratio is high, it is important to prescribe for the ametropia in this case. Prescribing +1.00 will reduce the near phoria to about 2 esophoria. Analysis of the near point data indicates that all of the direct and indirect measures of NFV are low. The use of added plus lenses in this case is indicated and will eliminate the remaining esophoria, balance the NRA/PRA relationship, and normalize the MEM and base-in findings. The near point analysis in this case suggests that a +0.75 to a +1.00 add is appropriate.

Another example of the effectiveness of added lenses in high AC/A cases is illustrated in Case 10.2.

Case 10.2

A 4-year-old girl was brought for an examination because her parents had noticed that her right eye was drifting out toward the end of the day and when she was tired. They had noticed it for the last year and felt that the proportion of time that the eye turned was increasing. The refraction was +0.25 OD and OS. The cover test at distance was an intermittent 25 Δ, right exotropia (deviates 10% of the time). At near, the cover test was 5 exophoria. The calculated AC/A ratio is 13:1.

The ametropia is insignificant in this case, but the use of added lenses can be helpful in the treatment of this patient. Because of the high AC/A ratio, glasses can be prescribed to help control the deviation. The use of -1.50 OU would significantly reduce the angle at distance. Because it could also lead to a high degree of esophoria at near, investigation of the use of a bifocal is also appropriate. In this case, the use of -1.50 with a +1.00 add OU is a valuable optical management technique because of the high AC/A ratio. If this child were older, vision therapy would probably be adequate to treat the divergence excess. In preschool children who may be difficult to treat using vision therapy, added lenses are an important temporary treatment option.

TABLE 10.1 SEQUENTIAL CONSIDERATIONS IN THE MANAGEMENT OF CONVERGENCE EXCESS

Optical correction of ametropia	Vision therapy for amblyopia
Added lens power	Vision therapy for suppression
Vertical prism	Vision therapy for sensory motor function
Horizontal prism	Surgery
Occlusion for amblyopia	

TABLE 10.2 SEQUENTIAL CONSIDERATIONS IN THE MANAGEMENT OF DIVERGENCE EXCESS

Optical correction of ametropia	Vision therapy for suppression
Vertical prism	Vision therapy for sensory motor function
Added minus lens power	Horizontal prism
Occlusion for amblyopia	Surgery
Vision therapy for amblyopia	

Optical correction of ametropia still remains the first issue that should be considered. However, as evidenced by Case 10.2, the consideration of added lenses is close to the top of the list in Table 10.1. In high AC/A cases, correction of the refractive error may be helpful for two reasons. The first is that the presence of an uncorrected refractive error may create an imbalance between the two eyes, leading to sensory fusion disturbances, or may create decreased fusional ability due to blurred retinal images. The second reason is that, because of the high AC/A, correction of the ametropia may have a beneficial effect on the magnitude of the deviation.

When considering the final prescription for these patients, it is important to first determine whether a vertical deviation is present. As discussed in previous chapters, correction of even small amounts of vertical deviations can have a positive effect on the horizontal deviation. We suggest prescribing for vertical deviations as small as 0.5Δ (Chapter 14).

A key difference between the sequential management of convergence excess and divergence excess is that esophores are more likely to benefit from horizontal prism than exophores. The use of base-out prism is an early management consideration in convergence excess, but the use of base-in is near the bottom of the list for divergence excess (Tables 10.1 and 10.2). Because of the effectiveness of added lenses, prism is rarely necessary for convergence excess associated with normal tonic vergence (orthophoria at distance). An example of the value of base-out prism in the treatment of convergence excess, however, is illustrated in Case 10.3.

Case 10.3

A 21-year-old woman presented with a chief complaint of intermittent diplopia when driving and when reading. The diplopia was worse when reading, and she also complained of eyestrain when reading for more than 15 minutes. Although she had always had these problems, they seemed worse since she started a new job in which she worked at a desk 8 hours a day doing paperwork. The cycloplegic refraction revealed plano OD and OS. The cover test was 8 esophoria at distance and 16 esophoria at near. The calculated AC/A ratio is 9.4:1 (IPD = 62 mm).

This is a case of convergence excess with high tonic vergence or a moderate degree of esophoria at distance. Because there is no refractive error, the use of lenses in a distance prescription is not an option. The patient does have a high AC/A ratio, and the near deviation can be decreased easily using added lenses. However, a prescription such as plano with a +1.50 add would only eliminate the patient's near complaints. She would still experience diplopia when driving. The use of base-out prism is an important option in this type of case. The magnitude of the prism should be determined based on fixation disparity assessment (Chapter 15). A final prescription in this case might be as follows:

OD: plano, 2 base-out

OS: plano, 2 base-out

+1.00 add

Thus, in cases of convergence excess associated with high tonic vergence, horizontal prism is an important consideration. When convergence excess is associated with a normal or low tonic vergence, prism is generally not necessary.

Although amblyopia is uncommon in nonstrabismic binocular vision anomalies, it can occur if the phoria is associated with a significant degree of anisometropia. Although anisometropic amblyopia is typically shallow (about 20/60 to 20/80), one of the early considerations should be treatment of amblyopia using occlusion and vision therapy. The use of occlusion and specific vision therapy procedures for the treatment of the amblyopia, and any associated suppression, always needs to be considered immediately after prescribing for the anisometropia and considering prism to compensate for a vertical phoria. In cases of convergence excess or divergence excess associated with anisometropia, we recommend part-time occlusion. Several (2 to 4) hours of occlusion using an opaque patch along with active amblyopia therapy is usually sufficient to resolve the amblyopia. Details regarding the evaluation and management of anisometropic amblyopia are

provided in Chapter 17. In almost all cases, however, amblyopia will not be present in either convergence or divergence excess. Thus, after consideration of ametropia, added lenses, and prism, vision therapy is the next treatment issue.

In many cases of convergence excess, the use of added lenses and prism will be sufficient to successfully treat the patient. If negative fusional vergence (NFV) is severely reduced, or the magnitude of the esophoria is very large, or if the patient remains uncomfortable even after wearing the glasses, vision therapy should be recommended. In contrast, vision therapy is the primary treatment option for divergence excess. In general, vision therapy is more effective for divergence excess, whereas base-out prism and added plus lenses tend to be more effective for convergence excess.

The final sequential management consideration listed in Tables 10.1 and 10.2 is surgery. Convergence excess can almost always be successfully managed with a combination of nonsurgical methods. Divergence excess may at times present with a very large magnitude exotropia at distance. When the size of the deviation is greater than 30 to 35 Δ , surgery is sometimes necessary to supplement other nonsurgical approaches.

PROGNOSIS FOR BINOCULAR VISION DISORDERS ASSOCIATED WITH HIGH AC/A RATIOS

The prognosis for successful treatment of convergence excess is excellent. In many cases the use of lenses, added lenses, and prism will be sufficient. If the patient is still symptomatic after these other interventions, vision therapy can be used and will generally lead to success. It would be rare, therefore, to be unable to successfully treat a patient with convergence excess. Failures with these patients are almost always associated with refusal to wear glasses or poor compliance with vision therapy.

The treatment of convergence excess with vision therapy has received some attention in the literature. In a record review of 12 patients with convergence excess who underwent vision therapy, Shorter and Hatch (1) found that 8 (66%) of 12 patients reported improved symptoms, and 5 (62.5%) of the 8 patients with complete data showed increased NFV. The changes were not statistically significant, however. Grisham et al. (2) and Wick (3) each reported a case of convergence excess that showed increased NFV and reduced symptoms after vision therapy. Ficcara et al. (4) performed a retrospective review of 31 patients (mean age 15.9 years) with convergence excess. The mean number of vision therapy visits was 19.4. There was a significant reduction in symptoms and significant improvement in NFV and positive relative accommodation (PRA). The authors found that the most important factor in determining success was the magnitude of the near phoria prior to vision therapy. Gallaway and Scheiman (5) also performed a retrospective analysis of 83 consecutive patients treated with vision therapy for convergence excess. In contrast to the study by Ficcara et al. (4), which took place at an optometry school clinic, this study consisted of private practice patients. Thus, the testing was standardized within a practice, and two clinicians performed all the measurements. Statistically significant changes were found in direct and indirect measures of NFV, and 84% of patients reported total elimination of symptoms. Vision therapy does appear to be a viable alternative for patients with convergence excess.

In contrast to the success of added lenses with convergence excess, divergence excess responds best to vision therapy. Many studies have evaluated the efficacy of vision therapy for divergence excess. Goldrich (6) reported on the success of vision therapy in a sample of 28 divergence excess patients. He developed criteria for excellent, good, fair, and poor outcomes. To be placed in the excellent category, a patient had to be free from asthenopia, have a phoria at all times, and have normal binocular findings. Placement in the good category meant that the patient was also free from asthenopia and had a phoria at all times, but could have deficiencies on some binocular test findings. A fair result meant that an intermittent strabismus was occasionally observed on cover testing, and a poor result suggested that little improvement had occurred. Twenty patients (71.4%) achieved an excellent rating, and 3 patients (10.7%) had a good rating. Thus, in 82.1% of the patients, vision therapy was successful in eliminating the intermittent strabismus and asthenopia. For the subjects in the excellent category, the mean number of therapy visits was 20.2 sessions, and for the good category, 28.3 sessions. Only 1 patient was rated poor after treatment.

Pickwell (7) reported on the results of vision therapy on 14 divergence excess patients; 10 patients achieved a satisfactory level, 2 patients showed measurable improvement, and 2 others discontinued therapy before completion. Daum (8) did a retrospective study of 18 divergence excess patients. The duration of treatment was unusually short, only 5.2 weeks, which raises questions about the meaning of his treatment results. However, he did suggest several interesting points relative to prognosis. He found that success was significantly better in subjects who had lower angles of deviation and no vertical deviation.

Other authors who have studied the effectiveness of vision therapy for intermittent exotropia did not differentiate divergence excess from other types of intermittent exotropia. Although this makes the results more difficult to analyze, the results still have relevance for understanding the effectiveness of vision therapy for divergence excess. Divergence excess is the most common type of intermittent exotropia for which surgery is likely to be recommended. As a result, it is reasonable to suggest that many of the patients reported in the following studies had divergence excess strabismus.

In a study of 37 exotropes, Sanfilippo and Clahane (9) found an excellent result in 64.5%, a good result in 9.7%, and a fair result in 22.6%. Only 1 patient (or 3.2%) had a poor result. The authors considered 64.5% to be “cured,” and 32.3% to have immediate improvement in status. They also provided useful data about various factors that influenced the effectiveness of treatment. Amblyopia, a constant deviation, noncomitancy, and a vertical component were negative factors.

Cooper and Leyman (10) reported on a retrospective study of 182 intermittent exotropes treated with orthoptics alone. They found a good result in 58.7% and a fair result in 38.4%. Only 5.6% of their sample failed to make significant progress with orthoptics.

Coffey et al. (11) reviewed 59 studies of intermittent exotropia treatment and compiled pooled success rates. They calculated the following pooled success rates: 28% for over minus therapy, 28% for prism therapy, 37% for occlusion, 46% for surgery, and 59% for vision therapy. Cooper and Medow (12) also reviewed the literature and concluded that divergence excess in patients younger than 6 years should be treated cautiously so as to reduce or eliminate the possibility of developing amblyopia or permanent loss of stereopsis. They suggested various nonsurgical intervention approaches such as patching, minus lens therapy, and home-based antisuppression treatment initially. Only if the deviation persists or increases should surgical intervention be considered. They suggested that in children older than 6 years, vision therapy is the treatment of choice unless the deviation is large ($>35 \Delta$).

Thus, the literature supports the effectiveness of vision therapy in the treatment of divergence excess and, when compared to the cure rates for surgery described later in this chapter, suggests that vision therapy should be the first treatment option. It is important to keep in mind some of the negative prognostic factors suggested by the studies described above. Negative factors include a large angle of deviation ($>35 \Delta$), a large vertical component, and a noncomitancy.

SUMMARY OF KEY POINTS IN TREATING PHORIA PATIENTS ASSOCIATED WITH HIGH AC/A

The primary determinant of the management sequence of high AC/A binocular vision problems is the effectiveness of added lenses. Because of the high AC/A ratio, added lenses have a significant effect on the angle of deviation and are therefore an important early treatment consideration. When esophoria is present at distance and correction of hyperopia is not sufficient to decrease the phoria to a manageable level, base-out prism is sometimes useful. At times, the use of lenses, added lenses, and prism will not be enough to restore comfort, and vision therapy is necessary.

Convergence Excess

Convergence excess is a condition in which there is an esophoria at near, orthophoria or low to moderate esophoria at distance, reduced NFV, and a high AC/A ratio. Of the various nonstrabismic binocular vision problems seen in clinical practice, convergence excess is one of the most common. Hokoda (13) found a prevalence rate of 5.9% in a population of symptomatic individuals seeking vision care. In contrast, 4.2% were found to have convergence insufficiency. Scheiman et al. (14) also found a higher prevalence of convergence excess than convergence insufficiency. They performed a prospective study on 1,650 children between the ages of 6 and 18 years and found a prevalence of 8.2%. In a university population, Porcar and Martinez-Palmera (15) found a 1.5% prevalence of convergence excess.

CHARACTERISTICS

Symptoms

Most symptoms are associated with reading or other close work. Common complaints include eyestrain and headaches after short periods of reading, blurred vision, diplopia, sleepiness, difficulty concentrating, and loss of comprehension over time (Table 10.3). Some patients with convergence excess are asymptomatic. This

TABLE 10.3 **SIGNS AND SYMPTOMS OF CONVERGENCE EXCESS**

Signs	Symptoms
Esophoria greater at near than at distance	Eyestrain associated with reading
Frequency of esodeviation worse at near than at distance	Headaches associated with reading
High AC/A ratio (calculated method)	Inability to attend and concentrate when reading
Moderate degree of hyperopia	Problems with reading comprehension
Comitant deviation	Occasional double vision
Direct tests of negative fusional vergence	Blurred vision
Reduced smooth negative fusional vergence (NFV) at near	
Reduced jump NFV at near	
Indirect tests of negative fusional vergence	
Low positive relative accommodation	
Fails -2.00 on binocular accommodative facility testing	
High monocular estimation method retinoscopy finding	

may be due to suppression, avoidance of near visual tasks, a high pain threshold, or occlusion of one eye when reading. Clinicians should always inquire about avoidance of reading or other near tasks if a patient with convergence excess reports an absence of other symptoms. Avoidance is often as important a reason for recommending therapy as any of the other symptoms associated with convergence excess.

Signs

Signs of convergence excess are listed in Table 10.3.

Refractive Error

Convergence excess may be associated with hyperopia. This is a desirable characteristic. Because of the high AC/A ratio, correction of the hyperopia will lead to a decrease in the magnitude of the esophoria at near and at distance. As we stated earlier, one of the primary reasons for a lack of success in the treatment of convergence excess is the patient's refusal to wear glasses. Although this is very rare, there is another treatment alternative that can be considered in such cases.

When all efforts to have the patient wear eyeglasses or contact lenses fail, pharmacologic treatment is a last resort that can be attempted. Because of the side effects and complications associated with these drugs, this approach should only be used when the patient is either very symptomatic or the deviation is intermittent and the proportion of time the eye deviates is significant and is increasing. Pharmacologic treatment involves the use of echothiophate iodide (Phospholine Iodide) drops or diisopropyl fluorophosphate (DFP) ointment. Both are anticholinesterase agents that cause miosis and ciliary spasm. This reduces or eliminates the need for accommodative effort and thereby leads to less accommodative convergence and reduced esophoria.

Echothiophate iodide solution comes in concentrations of 0.03%, 0.06%, 0.125%, and 0.25%. We recommend using 0.03% echothiophate iodide solution once a day (at night) for 1 week. The use of Tylenol for the first week helps reduce the headaches associated with the ciliary spasm, which occur initially. After the first week, increase the concentration to 0.06%, and reevaluate the patient's status in 2 weeks. Side effects and complications associated with the use of echothiophate iodide include headaches, reversible iris cysts, cataracts, and a greater risk of retinal detachment. Concurrent use of 2.5% phenylephrine has been shown to minimize the formation of iris cysts.

DEP ointment is also an anticholinesterase that can be used to treat convergence excess. A 0.25-in. strip of 0.025% ointment is applied every night. Tylenol should be used the first week or two to reduce the headaches associated with ciliary spasm. Side effects are similar to those described for echothiophate iodide.

When either drug is used, monthly reevaluations should be scheduled to monitor the patient for any side effects or complications and to assess the effect of the treatment. If symptoms have decreased or the proportion of time the deviation occurs is significantly reduced, the treatment can be continued with monthly reevaluation.

Characteristics of the Deviation

Patients with convergence excess generally have greater esophoria at near, a high AC/A ratio, and decreased NFV.

Some authors have suggested that a 10 Δ difference from one distance to another is a useful guideline. Rather than depend on this guideline, we find it more useful to think about the difference one would expect based on the presence of a high AC/A ratio. Since an AC/A ratio of greater than 7:1 is considered high, as little as a 3 Δ difference between distance and near would be sufficient to fit the diagnosis of convergence excess.

Clinicians should use their judgment and generally rely on the other characteristics, in addition to the magnitude of the angle at distance and near, to reach a diagnosis. For instance, the near deviation may be an intermittent or constant strabismus versus a phoria at distance. This finding would also suggest a diagnosis of convergence excess. Thus, a comparison of the proportion of time the deviation is present, as well as the magnitude at distance and near, is an important part of the diagnostic process.

AC/A Ratio

A high AC/A ratio (= 7:1) is always present in convergence excess. This is well accepted, based on the calculated AC/A, and is an important factor when treatment is considered.

ANALYSIS OF BINOCULAR AND ACCOMMODATIVE DATA

All direct tests of NFV tend to be low in convergence excess (Table 10.3). This includes step, smooth, and jump vergences. In addition, all tests that indirectly assess NFV (Table 10.3) will be low as well. Tests performed binocularly with minus lenses evaluate the patient's ability to stimulate accommodation and control binocular alignment using NFV. Two examples are PRA and binocular accommodative facility (BAF) testing with minus lenses. A characteristic finding in convergence excess is a report of diplopia, rather than blur, as the endpoint on PRA and BAF testing. In fact, it is important to specifically ask about diplopia when performing these tests on a patient suspected of having convergence excess.

A low finding on either PRA or BAF testing may be due to an inability to stimulate accommodation or to reduce NFV. The differential diagnosis is based on assessment of accommodation under monocular conditions. An easy and helpful technique is to simply cover one eye after the patient reports blur on the PRA test. If the blur continues, the problem is usually accommodative (accommodative insufficiency or ill-sustained accommodation). If the patient's vision clears, the problem is associated with binocular vision (NFV). Normal monocular accommodative ability on other tests suggests reduced NFV.

Another important indirect test of NFV is monocular estimate method (MEM) retinoscopy. It is not unusual to find an abnormal result on this test in convergence excess. An MEM finding of greater plus than expected suggests that the patient is using as little accommodation as possible to decrease the use of accommodative convergence. This reduces the amount of esophoria and the demand on NFV.

In some instances of convergence excess, a low to moderate degree of esophoria is present at distance as well. This is due to a moderate to high degree of tonic vergence. In such cases, in addition to the low NFV at near, the distance findings will be low as well.

DIFFERENTIAL DIAGNOSIS

It is important to rule out serious underlying etiologies in all cases of convergence excess. Differential diagnosis (Table 10.4) depends very much on the nature of the patient's symptoms. Typically, convergence excess presents with long-standing chronic complaints. The health history is negative, and the patient is not taking any medication known to affect accommodation. Convergence excess associated with serious underlying disease has an acute onset, and medical problems or neurologic symptoms are usually present. The primary functional disorders that must be differentiated from true convergence excess are basic esophoria, divergence insufficiency, and esophoria at near secondary to accommodative anomalies.

Convergence excess is considered to be a benign condition, with no serious consequences other than the visual symptoms listed in Table 10.3. It is relatively easy to differentiate from other binocular vision disorders associated with esophoria, such as basic esophoria (equal deviation at distance and at near) and divergence insufficiency (greater esophoria at distance). Convergence excess must also be differentiated from esophoria at near secondary to an accommodative anomaly, requiring a careful analysis of all accommodative and binocular vision data. Cases 2.1 to 2.4 in Chapter 2 are examples of the analytical process the clinician must follow.

TABLE 10.4 DIFFERENTIAL DIAGNOSIS OF CONVERGENCE EXCESS**Functional disorders to rule out**

Basic esophoria
 Divergence insufficiency
 Accommodative disorders

Serious underlying disease to rule out

Spasm of accommodation/convergence due to local inflammation such as scleritis, iritis, uveitis
 Spasm of accommodation/convergence due to sympathetic paralysis or syphilis
 Spasm of accommodation/convergence due to drugs, including:
 Eserine
 Pilocarpine
 Excessive doses of vitamin B₁
 Sulfonamides

Convergence excess or esophoria at near can also be associated with more serious underlying conditions. A condition called spasm of accommodation or convergence can occur, and one resulting clinical finding may be esophoria at near. Accommodative spasm can be functional, but it may also be caused by more serious underlying disease. Some of the more common causes include local inflammation and central nervous system lesions. Ocular inflammation such as scleritis, iritis, and uveitis can cause unioocular accommodative spasm and esophoria. This suggests that slit lamp evaluation is an important test in the differential diagnosis of convergence excess.

Central nervous system disorders such as sympathetic paralysis and syphilis may also lead to accommodative spasm and esophoria. In addition, a variety of drugs may produce bilateral accommodative spasm and esophoria. Some of the more common drugs that can produce these effects include eserine, pilocarpine, excessive doses of vitamin B₁, and sulfonamides.

When managing a case of convergence excess that is thought to have a functional basis, if symptoms and findings do not improve as expected, it is wise to reconsider the etiology of the condition.

TREATMENT

We recommend following the management sequence listed in Table 10.1.

Lenses

In all cases of binocular and accommodative dysfunction, the first management consideration is correction of any significant refractive error. With convergence excess, it is important to prescribe maximum plus if a significant degree of hyperopia is present (+0.50 or greater). When dealing with convergence excess associated with high tonic vergence, a cycloplegic examination should be performed before determining the prescription.

Added Lenses

Because of the high AC/A ratio, the use of added plus lenses at near is highly effective in cases of convergence excess. Chapter 3 discussed the important clinical data that are used to determine whether additional plus should be prescribed. Although the AC/A ratio is the key finding, it is important to consider all of the data listed in Table 10.5.

How Much Additional Plus Should Be Prescribed?

When prescribing added plus lenses, the objective is to determine the lowest amount of plus that will eliminate the patient's symptoms and normalize optometric data. A variety of methods have been suggested for calculating the amount of additional plus to prescribe for patients with convergence excess. Some of the more popular methods are analysis of the NRA/PRA relationship, MEM retinoscopy or other near point retinoscopy,

TABLE 10.5 CONSIDERATIONS FOR PRESCRIBING ADDED PLUS LENSES

Test	Consider the Use of Added Plus	Added Plus Not Indicated
AC/A ratio	High	Low
Refractive error	Hyperopia	Myopia
Near phoria	Esophoria	Exophoria
Negative relative accommodation (NRA)/positive relative accommodation (PRA)	Low PRA	Low NRA
Base-out at near	Normal to high	Low
Monocular estimation method retinoscopy	High	Low
Amplitude of accommodation	Low	Normal
Accommodative facility testing	Fails –	Fails +

use of the AC/A ratio, and fixation disparity analysis. We advocate the use of a group of findings rather than relying on any one test. As discussed in Chapter 2, reliance on any one test may be misleading at times. The optometric data listed in Table 10.5 can be used to determine the amount of plus to prescribe.

An example of this is Case 10.1, described earlier in this chapter. After prescribing +1.00 to correct the hyperopia, this patient was still 3 esophoric at near, with a low PRA, reduced base-in at near, an MEM finding of +1.25, and diplopia with minus lenses during BAF testing. Both the NRA/PRA (NRA, +2.50; PRA, –1.00) relationship and MEM retinoscopy suggest a prescription of an additional +0.75 to +1.00 for near. In addition, the AC/A ratio suggests that the near phoria should be about 3 exophoria with this prescription.

Prism

If a vertical deviation is present, we recommend that vertical prism be prescribed. The most effective method for determining the amount of vertical prism is the associated phoria, which can be measured with any fixation disparity device (Chapter 15).

Because of the high AC/A ratio, the use of lenses is so effective that horizontal prism is rarely necessary except for convergence excess associated with high tonic vergence (moderate to high esophoria at distance). When a moderate to high degree of esophoria is present at distance, base-out prism should be considered. The decision to prescribe base-out prism should be based on the presence or absence of distance-related symptoms. If a prism prescription is being considered, fixation disparity testing is the most effective method for determining the amount of horizontal prism (Chapter 15).

Vision Therapy

If NFV is severely reduced, if the magnitude of the esophoria is very large, or if the patient remains uncomfortable even after wearing the glasses, vision therapy should be recommended. A vision therapy program for convergence excess generally requires 12 to 24 office visits. If refractive correction and added lenses are used, the number of sessions may be less. The total number of therapy sessions also depends on the age of the patient and his or her motivation and compliance.

Specific Vision Therapy Program

All of the vision therapy techniques recommended below are described in detail in Chapters 6 to 8.

Phase 1

This first phase of therapy is designed to accomplish the objectives listed in Table 10.6 under Phase 1. As discussed in Chapter 9, vision therapy requires communication and cooperation between the therapist and patient, and it is important to develop a working relationship with the patient during the first few sessions.

TABLE 10.6 OBJECTIVES OF VISION THERAPY FOR CONVERGENCE EXCESS**Phase 1**

- Develop a working relationship with the patient
- Develop an awareness of the various feedback mechanisms that will be used throughout therapy
- Develop voluntary convergence/divergence
- Normalize negative fusional vergence (NFV) amplitudes (smooth or tonic vergence demand)
- Normalize accommodative amplitude and ability to stimulate and relax accommodation

Phase 2

- Normalize positive fusional vergence (PFV) amplitudes (smooth or tonic vergence demand)
- Normalize NFV facility (jump or phasic vergence demand)
- Normalize PFV facility (jump or phasic vergence demand)

Phase 3

- Develop ability to change from a convergence to a divergence demand
- Integrate vergence procedures with changes in accommodative demand
- Integrate vergence procedures with versions

The first goal of the therapy is to teach the concept and feeling of diverging and the ability to accurately diverge. The patient should be able to voluntarily converge and diverge to any distance from 5 cm (2 in.) to 6 m (20 ft). Commonly used procedures to accomplish this first objective are the Brock string and bug on string.

Convergence excess patients generally have very limited base-in blur, break, and recovery findings. Therefore, another objective of the first phase of vision therapy is to normalize NFV amplitudes. The initial goal is to reestablish a normal vergence range for smooth- or tonic-type vergence demand. A smooth vergence demand is easier for the patient to accomplish in the early part of a vision therapy program. Such a demand allows the patient to begin the procedure with accommodation and convergence at the same plane. A divergence demand can then be slowly introduced, which requires the patient to hold accommodation at 40 cm and move the convergence plane further away.

Another advantage of beginning with smooth vergence procedures is that, in some cases, the introduction of any divergence is enough to cause suppression or diplopia. Smooth vergence techniques provide a starting point for therapy with such patients. If the patient is unable to fuse any divergence demand, the procedure can begin with a convergence demand. For example, a variable tranaglyph can be set at 10 base-out and then gradually reduced to zero. This approach at least allows the patient to get started and experience some success. The change from 10 base-out to zero can be viewed as divergence therapy relative to the starting point. Speed is of little importance initially. Rather, we just want the patient to be able to maintain fusion as the divergence demand is slowly increased. Equipment that can be used to create a smooth, gradual increase in divergence demand includes the variable tranaglyphs, variable vectograms, and the Variable Prismatic Stereoscope.

In some cases of convergence excess in presbyopes, an accommodative problem may also be present. If so, the final objective of the first phase of therapy is to normalize accommodative amplitude and the ability to stimulate and relax accommodation. If, however, accommodative function is normal, there is generally no need to spend much time working with the accommodative system. Accommodative techniques can be found in Chapter 7. Lens sorting, loose lens rock, and Hart chart procedures are commonly used in this first phase of therapy.

Endpoint. Phase 1 of therapy ends when the patient can:

- Accurately diverge using the Brock string to 3 m (10 ft)
- Fuse to about 15 base-in at 40 cm using a tranaglyph or other divergence technique
- Complete 12 cpm of MAF with +2.00/−2.00 lenses using a 20/30 target.

A sample vision therapy program for phase 1 is summarized in Table 10.7.

Phase 2

This second phase of therapy is designed to accomplish the objectives listed in Table 10.6 under Phase 2. Once smooth NFV is normalized, phasic or jump vergence demand should be emphasized. Variable

TABLE 10.7 SAMPLE VISION THERAPY PROGRAM FOR CONVERGENCE EXCESS**Phase 1***Sessions 1 and 2*

IN-OFFICE

- Discuss nature of vision problem, goals of vision therapy, various feedback cues, importance of practice
- Brock string; concentrate on developing feeling of diverging
- Lens sorting
- Loose lens rock (begin with plus if accommodative excess, with minus if accommodative insufficiency)
- Tranaglyphs or vectograms: divergence
 - Begin with a peripheral target such as tranaglyph 515 or the Quoit vectogram
- Computer Orthoptics Random Dot program: divergence

HOME THERAPY

- HTS Vergence and Accommodation programs
- Brock string

Sessions 3 and 4

IN-OFFICE

- Bug on string, concentrate on feeling of diverging
- Loose lens rock
- Tranaglyphs or vectograms: divergence
 - Use targets with more central demand (Clown, Bunny tranaglyphs; Clown, Topper vectograms)
- Computer Orthoptics Random Dot program: divergence

HOME THERAPY

- Loose lens rock
- HTS Vergence and Accommodation programs

Sessions 5 through 8

IN-OFFICE

- Loose lens rock
- Tranaglyphs or vectograms: divergence
 - Use even more detailed targets such as tranaglyph Sports Slide and Faces targets and the Spirangle vectogram
- Computer Orthoptics Random Dot program: divergence

HOME THERAPY

- HTS Vergence and Accommodation programs

Phase 2*Sessions 9 and 10*

IN-OFFICE

- Tranaglyphs or vectograms with modifications to create jump vergence demand: divergence
- Nonvariable tranaglyphs
- Tranaglyph 515 or the Quoit vectogram: convergence
- Binocular accommodative therapy techniques: use any of the binocular techniques listed above with \pm lenses

HOME THERAPY

- HTS Vergence and Accommodation programs

Sessions 11 and 12

IN-OFFICE

- Tranaglyphs or vectograms with modifications to create jump vergence demand: divergence
- Aperture Rule: divergence
- More central tranaglyphs with loose prism jumps
- Binocular accommodative therapy techniques: use any of the binocular techniques listed above with \pm lenses

HOME THERAPY

- HTS Vergence and Accommodation programs

Sessions 13 through 16

IN-OFFICE

- Aperture Rule: divergence
- Eccentric Circles or Free Space Fusion cards: divergence
- Computer Orthoptics Random Dot Vergence program: both divergence and convergence
- Aperture Rule: convergence
- Tranaglyphs or vectograms with modifications to create jump vergence demand: convergence
- Binocular accommodative therapy techniques: use any of the binocular techniques listed above with \pm lenses

(Continued)

TABLE 10.7 CONTINUED

HOME THERAPY <ul style="list-style-type: none"> • HTS Vergence and Accommodation programs • Eccentric Circles or Free Space Fusion cards: divergence
Phase 3
<i>Sessions 17 through 20</i>
IN-OFFICE <ul style="list-style-type: none"> • Tranaglyphs or vectograms with Polaroid or red/green flippers • Eccentric Circles or Free Space Fusion cards • Computer Orthoptics Random Dot Vergence program: step–jump vergence
HOME THERAPY <ul style="list-style-type: none"> • HTS Vergence and Accommodation programs • Eccentric Circles or Free Space Fusion cards: divergence
<i>Sessions 21 and 22</i>
IN-OFFICE <ul style="list-style-type: none"> • Tranaglyphs or vectograms with Polaroid or red/green flippers • Eccentric Circles or Free Space Fusion cards • Lifesaver cards • Computer Orthoptics Random Dot Vergence program: jump–jump vergence
HOME THERAPY <ul style="list-style-type: none"> • HTS Vergence and Accommodation programs • Eccentric Circles or Free Space Fusion cards: convergence and divergence
<i>Sessions 23 and 24</i>
IN-OFFICE <ul style="list-style-type: none"> • Tranaglyphs or vectograms with Polaroid or red/green flippers • Eccentric Circles or Free Space Fusion cards with rotation and versions • Lifesaver cards with rotation and versions • Computer Orthoptics Vergence program with rotation
HOME THERAPY <ul style="list-style-type: none"> • HTS Vergence and Accommodation programs • Eccentric Circles or Free Space Fusion cards: divergence and convergence

tranaglyphs and vectograms can still be used. However, the specific modifications to create a step vergence demand (described in Chapter 6) must be implemented. These include the following:

- Changing fixation from the target to another point in space
- Covering and uncovering one eye
- Loose prism or flip prism
- Flip lenses to create a step change in accommodative demand, requiring a compensatory vergence change to maintain fusion
- Two different tranaglyphs set up in a dual Polachrome illuminated trainer
- Polaroid or red/green flippers

Other valuable techniques at this stage are the nonvariable tranaglyphs, the Aperture Rule, Eccentric Circles, Free Space Fusion cards, Lifesaver cards, and the Computer Orthoptics Jump Vergence program.

In contrast to phase 1, in which speed was not a factor, during this second phase of therapy the emphasis should be on the qualitative aspects of fusion rather than magnitude. It is important to increase the speed of the fusional vergence response and the quality of the recovery of fusion.

A second objective of this phase of therapy is to begin working with positive fusional vergence (PFV) amplitudes. The same techniques used in phase 1 to work with NFV are repeated for PFV. Finally, during the end of this phase of therapy, begin to incorporate PFV facility-type techniques, using the same procedures listed above for jump vergence demand for NFV.

Endpoint. The endpoint of phase 2 is reached when the patient can:

- Fuse card 12 using convergence and card 6 using divergence with the Aperture Rule
- Fuse the Eccentric Circles or Free Space Fusion cards using convergence (12 cm separation) and divergence (6 cm separation)

A sample vision therapy program for phase 2 is summarized in Table 10.7.

Phase 3

This third phase of therapy is designed to accomplish the objectives listed in Table 10.6 under Phase 3. Until this point, the patient has either worked in the convergence or divergence directions separately. Now the objective is to develop the patient's ability to change from a convergence to a divergence demand and to integrate vergence procedures with versions and saccades. Several excellent procedures are available to help accomplish these objectives. Vectograms with Polaroid flippers or tranaglyphs with red/green flippers can be used. Each time the flippers are changed, the demand switches from divergence to convergence. Transparent Keystone Eccentric Circles or transparent Bernell Free Space Fusion cards are excellent, inexpensive methods for achieving this objective. By this time, the patient has already learned to fuse these cards using divergence or convergence. Now the patient is taught to switch from divergence and then back to convergence. As this skill improves, speed or the number of cycles per minute is emphasized.

The final objective of therapy is to integrate vergence procedures with versions and saccades. Under normal seeing conditions, patients are constantly trying to maintain vergence while changing fixation from one location to another. We feel that it is therefore important to combine vergence therapy with versions and saccades. Techniques such as the Brock string with rotation, Eccentric Circles and Free Space Fusion cards with rotation and/or lateral movements, and the Lifesaver cards with rotation can be used to accomplish this goal. The Computer Orthoptics program that combines horizontal vergence with rotation is also useful for this objective.

Endpoint. The endpoint for this phase of therapy is reached when the patient is able to maintain clear single binocular vision with the Eccentric Circles or Free Space Fusion cards together, while slowly rotating the cards.

Because the objectives of vision therapy are to eliminate the patient's symptoms and normalize binocular and accommodative findings, a reevaluation should be performed about 6 weeks into the therapy program and again at the end of therapy. Refer to the original complaints and determine whether the patient is now comfortable. All tests of binocular and accommodative function should be repeated and compared to the initial findings as well as the expected findings.

When all vision therapy objectives have been reached and the vision therapy program is completed, we recommend the home vision therapy maintenance program outlined in Table 9.10 and described in Chapter 9.

Summary of Vision Therapy for Convergence Excess

The phases and objectives outlined above and in Tables 10.6 and 10.7 represent one approach that will lead to successful elimination of a patient's symptoms and normalization of optometric data. The number of sessions is approximate and will vary from one patient to another. In our experience, adults generally can complete a vision therapy program in about half the time necessary for children. Another variable is the use of home therapy techniques to supplement the activities used for in-office therapy. Home therapy can be useful with a highly motivated adult patient. It may also be effective when the patient is a motivated compliant child with a parent who has the capability to function as the home therapist. In some cases, however, the parent may not interact well with the child in this role, and home therapy will not be helpful. Appendix I provides a variety of instructional sheets for vision therapy that can be used for home therapy. Using the approach suggested above should lead to the achievement of the very high success rates reported in the literature for convergence excess.

Surgery

The use of lenses, prism, and vision therapy in the treatment of convergence excess is so successful that surgery is seldom necessary.

CASE STUDIES

The following case studies (Cases 10.4–10.6) are representative of the types of convergence excess patients that clinicians will encounter in practice.

Case 10.4

History

Jessica, a 10-year-old fifth grader, presented with complaints of eyestrain and blurry vision after 15 to 20 minutes of reading. She said that these problems began this school year when the teachers began giving more homework. She never had an eye examination. Her medical history was negative, and she was not taking any medication.

Examination Results

VA (distance, uncorrected):	OD: 20/20 OS: 20/20
VA (near, uncorrected):	OD: 20/20 OS: 20/20
Near point of convergence	
Accommodative target:	5 cm
Penlight:	5 cm
Cover test (distance):	Orthophoria
Cover test (near):	10 esophoria
Subjective:	OD: plano, 20/20 OS: plano, 20/20
Distance lateral phoria:	Orthophoria
Base-in vergence (distance):	X/7/4
Base-out vergence (distance):	12/24/15
Near lateral phoria:	10 esophoria
-1.00 gradient:	18 esophoria
Gradient AC/A ratio:	8:1
Calculated AC/A ratio:	10:1
Base-in vergence (near):	X/4/-4
Base-out vergence (near):	14/30/18
Vergence facility:	0 cpm, diplopia with base-in
NRA:	+2.50
PRA:	Diplopia with -0.25
Accommodative amplitude (push-up):	OD: 15 D; OS: 15 D
MAF:	OD: 12 cpm; OS: 12 cpm
BAF:	Diplopia with -2.00
MEM retinoscopy:	+1.50 OD and OS

Pupils were normal, all external and internal health tests were negative, the deviation was comitant, and color vision testing revealed normal function.

Case Analysis

Based on the large esophoria at near, the best way to approach this case is to analyze the NFV group data. For this patient, all of the direct and indirect findings that probe NFV are abnormal. The direct findings (NFV at near, and vergence facility) are severely reduced. In addition, the indirect tests (PRA, BAF, and MEM retinoscopy) all suggest an esophoria/low NFV problem.

The distance phoria is ortho, and the calculated and gradient AC/A ratios are both high. This set of findings clearly suggests a diagnosis of convergence excess with normal tonic vergence.

Management

Because there was no refractive error, our initial approach in this case was to prescribe added lenses just for near. To determine the amount of plus to prescribe, we analyzed several key findings, including the AC/A ratio, NRA/PRA relationship, fusional vergence findings, and MEM retinoscopy. In this case, the NRA/PRA relationship suggested an add of about +1.25, as did MEM retinoscopy. The AC/A ratio showed that an add of +1.25 would reduce the near phoria to about ortho and increase the NFV ranges at near by about 10 Δ. We therefore prescribed +1.25 OD and OS for all near work.

A decision that clinicians must make when prescribing added plus lenses is whether to recommend single vision lenses or bifocals. We generally recommend a bifocal prescription for elementary schoolchildren so that they do not have to remove their glasses when looking at the teacher or the chalkboard. In our experience, young children wearing single vision glasses often lose, break, or scratch their glasses because of the continual need to remove the glasses.

As children become more mature and able to care properly for their glasses, a single vision prescription becomes a viable option. For older children (adolescent) and adults, we outline the advantages and disadvantages of single vision and bifocal lenses and allow the patient to help with the final decision. However, most patients find that a properly prescribed bifocal is the most satisfactory alternative.

Although a bifocal is our first recommendation for elementary schoolchildren, we do sometimes encounter resistance from parents about the idea of a bifocal for a child. When this occurs, it is best to review and demonstrate the benefits of a bifocal, and, if the parent is still uneasy, prescribe a single vision prescription. We ask the parent to carefully monitor the child's compliance with the wearing instructions and the child's ability to care for the glasses. The parent always has the option to switch to a bifocal at a later date and will often be more accepting of this suggestion after he or she personally experiences the problems associated with a single vision prescription.

In this case, a follow-up visit after 6 weeks revealed that Jessica was doing well with the glasses, and she reported a complete relief of symptoms. We therefore did not have to recommend any additional treatment.

Case 10.5

History

Marilyn, a 16-year-old high-school junior, complained of an inability to read comfortably for more than 10 minutes. When she read for longer periods of time, she felt a pulling sensation that would soon develop into a headache over her eyes. She experienced difficulty with comprehension and sometimes fell asleep when reading. Her last eye examination was about 1 year ago, when she had complained of similar symptoms. The doctor prescribed reading glasses, which did help. However, even with glasses, Marilyn continued to feel uncomfortable when reading. Her health history was negative.

Examination Results

VA (distance, uncorrected):	OD: 20/20
	OS: 20/20
VA (near, uncorrected):	OD: 20/20
	OS: 20/20
Near point of convergence	
Accommodative target:	5 cm
Penlight:	5 cm

Cover test (distance):	Orthophoria
Cover test (near):	15 esophoria
Subjective:	OD: plano, -0.25×180 , 20/20 OS: plano, 20/20
Distance lateral phoria:	1 exophoria
Base-in vergence (distance):	X/8/5
Base-out vergence (distance):	X/20/10
Near lateral phoria:	16 esophoria
-1.00 gradient:	25 esophoria
Gradient AC/A ratio:	9:1
Calculated AC/A ratio:	12.5:1
Base-in vergence (near):	X/2/-2
Base-out vergence (near):	10/16/6
Vergence facility:	0 cpm, diplopia with base-in
NRA:	+2.50
PRA:	Diplopia at plano
Accommodative amplitude (push-up):	OD: 13 D; OS: 13 D
MAF:	OD: 10 cpm; OS: 11 cpm
BAF:	Diplopia with -2.00
MEM retinoscopy:	+1.50

Pupils were normal, all external and internal health tests were negative, the deviation was comitant, and color vision testing revealed normal function.

Her current near prescription was OD +1.75 and OS +1.75.

Case Analysis

The analysis is very similar to that of Case 10.4. Because of the presence of the esophoria, analysis should begin with inspection of all NFV data. We reached a diagnosis of convergence excess with normal tonic vergence, based on the high AC/A and the low NFV findings on both direct and indirect measures. Both the MEM finding and the NRA/PRA relationship suggested a near prescription of about +1.25.

Management

The interesting thing about this case was that Marilyn was already wearing a near prescription of +1.75 OD and OS. This was essentially the prescription that we would have given, based on our analysis. She reported a decrease in symptoms with her glasses, but was still not happy with her reading comfort. We therefore recommended that she continue to wear her glasses and begin a program of vision therapy.

The vision therapy program lasted 20 visits, and we followed the sequence recommended in Table 10.7. She came in twice a week and was given home vision therapy techniques to practice for about 10 minutes, 5 days a week. A reevaluation at the end of therapy revealed the following findings (all through plano):

Near lateral phoria:	14 esophoria
Base-in (near):	12/16/12
Base-out (near):	22/32/24
Vergence facility:	9 cpm
NRA:	+2.50
PRA:	-1.25
MEM:	+1.00 OD and OS

Marilyn continued to wear her reading prescription and reported that she was able to read with comfort for as long as she desired. We recommended the maintenance schedule outlined in Table 9.10.

Case 10.6

History

Paul, a 6-year-old first grader, was brought for an evaluation by his mother because she noticed that he often rubbed his eyes and occasionally covered one eye when he read.

These problems began after the first month of first grade. His mother had a history of surgery for crossed eyes when she was 3 years old. She said that when Paul was younger, she occasionally noticed his eyes crossing, but it seemed to stop. Paul had never had an eye examination before. His health history was negative.

Examination Results

IPD:	54 mm
VA (distance, uncorrected):	OD: 20/20 OS: 20/20
VA (near, uncorrected):	OD: 20/20 OS: 20/20
Near point of convergence	
Accommodative target:	5 cm
Penlight:	5 cm
Cover test (distance):	15 Δ esophoria
Cover test (near):	22 Δ , intermittent (deviates with prolonged cover), alternating esotropia
Cover test (near with +2.00):	6 esophoria
Subjective:	OD: +1.00, 20/20 OS: +1.00, 20/20
Cycloplegic:	OD: +1.50, 20/20 OS: +1.50, 20/20
Base-in vergence (distance):	X/2/0
Base-out vergence (distance):	X/14/10
Associated phoria measured with the AO vectographic target:	3 base-out
Gradient AC/A ratio:	8:1
Calculated AC/A ratio:	8.8:1
Base-in vergence (near):	X/1/−4
Base-out vergence (near):	X/28/16
Vergence facility:	0 cpm, diplopia with base-in
NRA:	+2.50
PRA:	Diplopia with plano
Accommodative amplitude (push-up):	OD: 15 D; OS: 15 D
MAF:	OD: 6 cpm; OS: 6 cpm
BAF:	Diplopia with −2.00
MEM retinoscopy:	+1.75

Pupils were normal, all external and internal health tests were negative, the deviation was comitant, and color vision testing revealed normal function.

Case Analysis

In this case, there is a large amount of eso at both distance and at near. The near deviation, however, is significantly larger than the distance heterophoria. NFV findings, both direct and indirect, are significantly reduced. The AC/A ratio is high, using both the gradient and calculated methods. Based on this information, we reached a diagnosis of convergence excess with high tonic vergence.

Management

Because of the high tonic vergence, it was important to prescribe maximum plus to correct the hyperopia. Through +1.00, however, the distance phoria was still 7 esophoria. With +1.00, cover testing at near revealed about a 12 to 14 Δ esophoria. Analyzing the NRA/PRA relationship and MEM retinoscopy showed that an add of about +1.25 to +1.50 was indicated. With the add, the near deviation decreased to about 2 esophoria.

If we had prescribed

OD: +1.00

OS: +1.00 with a +1.50 add

the patient would have been left with about 7 esophoria at distance and 2 esophoria at near. We felt that the residual deviation at distance was too large, and therefore prescribed base-out prism based on the associated phoria measurement. Because we were prescribing base-out prism, we also reduced the near add to +1.00.

The final prescription was as follows:

OD: +1.00, 1.5 base-out, +1.00 add

OS: +1.00, 1.5 base-out, +1.00 add

Paul adapted to the glasses well, and a reevaluation 4 weeks later revealed that he was no longer showing any of the initial behaviors that had prompted the evaluation.

SUMMARY

Convergence excess is one of the more common binocular vision disorders. Because of the high AC/A ratio, lenses and added lenses are very effective and, in many cases, may be sufficient in the treatment of convergence excess. In cases of convergence excess associated with high tonic vergence, base-out prism may be required. When the magnitude of the esophoria is large and the NFV very reduced, vision therapy may also be necessary.

Divergence Excess

BACKGROUND INFORMATION

Divergence excess is a condition in which there is a greater amount of exophoria at distance than at near (16). Other important basic characteristics include a tendency for the deviation to be intermittent and vary with attention (17), an absence of amblyopia, and normal stereopsis at near (18).

Several studies have investigated the prevalence of divergence excess in the strabismic population. In a population of 1,000 consecutive exotropes, Bair (19) found 7.5% were of the divergence excess type. In

a similar-type study, Pickwell (7) found that 7% of 250 strabismics were diagnosed as having divergence excess. In a more recent study, Wick et al. (18) found a higher prevalence of divergence excess. They reported that 24% of intermittent exotropes had a divergence excess pattern.

CHARACTERISTICS

Table 10.8 lists the signs and symptoms of divergence excess.

Signs

Magnitude of the Deviation

Patients with divergence excess have greater exophoria at distance than at near. In a sample of 76 divergence excess patients, Bair (19) found that the average deviation at distance was 29 Δ and at near 13 Δ . The deviation in divergence excess is always a comitant deviation. This means that the deviation is the same in all positions of gaze. The distinguishing characteristic is the larger deviation at distance, which can either be a phoria, an intermittent exotropia, or a constant exotropia. Some authors have suggested that a 10 to 15 Δ difference from one distance to another is a useful guideline. This suggestion, however, should be used only as a guideline. As discussed previously, clinicians should use their judgment and generally rely on the other characteristics, in addition to the magnitude of the angle at distance and near, to reach a diagnosis. These additional characteristics are described below.

A vertical deviation has been reported to be present in as many as 50% of divergence excess patients (20). Dunlap and Gaffney (20) have suggested that this vertical component may be due to overaction of the inferior oblique muscle. Unless the vertical deviation can be demonstrated under fused conditions, it is usually not clinically significant and does not require specific treatment.

Proportion of Time the Deviation Occurs

An important characteristic is the proportion of time that the deviation occurs at distance compared to at near. Divergence excess often presents with an intermittent exotropia at distance, since the average magnitude of the deviation at distance is about 30 Δ . Cooper (17) notes that there seem to be several triggering mechanisms for this intermittent deviation. The intermittent deviation tends to manifest during distance tasks and with inattention, fatigue, illness, or daydreaming. Because the cover test procedure is performed when attention is high, it may sometimes be difficult for the clinician to detect an intermittent strabismus in the office setting, despite reports from the parent of an eye turn. Cooper suggests that, in such cases, the parents' observations are more likely to be correct than the clinician's cover test. It is important to use the Intermittent Exotropia Clinic Control Scale described in Chapter 1 (Table 1.3) to describe the control of the intermittent exotropia.

This characteristic of proportion of time of occurrence should also be considered when analyzing the distance and near deviations. A divergence excess patient may have an exodeviation only slightly greater at distance than at near, yet the deviation may be an intermittent exotropia at distance and an exophoria at near. Thus, a significant difference in the proportion of time the deviation occurs can be just as significant as a difference in magnitude between distance and near.

TABLE 10.8 SIGNS AND SYMPTOMS OF DIVERGENCE EXCESS

Signs	Symptoms
Exophoria greater at distance than at near	Concern about cosmesis
Frequency of exodeviation worse at distance than at near	Closes one eye in bright lights or at the beach
High AC/A ratio (calculated method)	
Essentially normal positive fusional vergence at distance and near	
No significant refractive error	
Comitant deviation	

AC/A Ratio

The idea that a high AC/A ratio is present in divergence excess has been based on the fact that the exodeviation is greater at distance than at near. For example, based on the average deviation of 29 Δ at distance and 9 Δ at near reported by Bair (19), the average calculated AC/A ratio would be 14.0:1. Studies that have determined the AC/A ratio using fixation disparity (12) or gradient methods, however, reported much lower mean AC/A ratios. Ogle, Martens, and Dyer (21) found the mean stimulus AC/A ratio using a fixation disparity method to be 3.0:1, and von Noorden (22) found the mean stimulus gradient AC/A ratio to range from 3.3:1 to 9.0:1.

In a more recent study, Cooper, Ciuffreda, and Kruger (23) studied a small sample of divergence excess patients and used an infrared optometer to objectively assess the accommodative response. Using this method, they were able to measure both the stimulus and response AC/A ratios. They found high stimulus AC/A ratios using the distance and near cover test results (10.4:1). The objective assessment, however, revealed response AC/A ratios ranging from 3.6:1 to 4.9:1, with a mean of 4.2:1.

These results suggest that the commonly accepted idea that the AC/A ratio is high in divergence excess may not be true. This is an important finding because it directly affects our understanding of the basic nature of divergence excess. It is commonly suggested that the difference in the size of the angle of deviation at near and distance can be attributed primarily to the high AC/A ratio associated with divergence excess. The normal AC/A ratio demonstrated by Cooper, Ciuffreda, and Kruger (23), along with other studies using gradient methods, challenges this concept. The authors believe that the high calculated AC/A ratios found in divergence excess are contaminated by fusional convergence aftereffects and proximal convergence. The fusional convergence aftereffect refers to a transient change in the fusion-free position of the eyes following a short period of sustained vergence. A commonly experienced example of this phenomenon is the relative increase in esophoria found after measurement of PFV ranges.

This idea may help to explain the clinical findings in the condition called *simulated divergence excess*. In this condition, the near deviation approaches the magnitude of the distance deviation after 30 to 45 minutes of occlusion. This change in the near deviation is consistent with a gradual loss of the fusion convergence aftereffect. Under fused conditions, the patient is constantly using convergence to overcome the large near exodeviation. When the near deviation is measured using the cover test procedure, the full magnitude is not revealed because of fusional convergence aftereffects. After a period of occlusion, however, the fusional aftereffect wears off and the full magnitude of the deviation becomes evident.

In some cases of divergence excess, even after long periods of occlusion, the near deviation remains significantly less than the distance deviation. This is referred to as *true divergence excess*. Even in these cases, however, the gradient AC/A tends to be normal. In such cases, neither the high AC/A concept nor fusional convergence aftereffects can explain the smaller angle at near. Cooper, Ciuffreda, and Kruger (23) suggest that proximal convergence effects account for the findings in true divergence excess.

In divergence excess, it is therefore important to evaluate both the calculated and gradient AC/A ratios. If both are high, then the sequential management approach suggested for high AC/A ratios would be applicable. If the gradient AC/A is not high, however, the use of added lenses will probably not be as effective a treatment strategy. Rather, the management approach suggested in Chapter 11 for binocular conditions associated with normal AC/A ratios would be applicable.

CA/C Ratio

Although the CA/C ratio is still not commonly assessed in the clinical situation, it will probably become an important factor in analysis of optometric data in the future. In divergence excess and other cases of high exophoria at distance, the CA/C ratio may play a key role when determining appropriate management. For example, when the divergence excess patient converges to fuse at distance, there will usually be excess accommodation due to convergence accommodation. For the divergence excess patient who is unable to inhibit this extra accommodation, small amounts of added minus lens power may help to maintain clear single binocular vision (Chapter 14).

Fusion Vergence Amplitudes and Facility

An interesting aspect of divergence excess is that, in spite of the large exophoria, the PFVs are usually normal (17,24,25). When targets such as the Bernell vectograms are used to measure fusional vergence, both the

convergence and divergence ranges are similar to those found in normal subjects (17). This is an important finding and suggests that it may be inappropriate to view divergence excess as simply a problem of a high phoria and low compensating fusional vergence. Although this model is useful to explain some binocular vision conditions such as convergence insufficiency and convergence excess, divergence excess may have a different etiology.

Refractive Error

Wick et al. (18) found a higher prevalence of myopia and anisometropia in divergence excess than in the normal population in a study.

Sensory Adaptations

Even though intermittent exotropia is common in divergence excess, these patients rarely complain of diplopia. To avoid diplopia, divergence excess patients must either suppress or experience anomalous correspondence, or a combination of the two. Some authors have reported that suppression occurs when the deviation is manifest (18). Cooper and Feldman (25) found harmonious anomalous correspondence when the divergence excess patient is strabismic at distance. Wick et al. (18) found that about 25% of divergence excess patients display a combination of both anomalous correspondence and suppression when the deviation manifests. They also found that when the deviation is constant at distance, 55% of these patients have anomalous correspondence. Because anomalous correspondence is often present in divergence excess when the deviation manifests, it is important to consider this issue when designing a therapy program. For example, one of the initial objectives of vision therapy for divergence excess is to make the patient aware of diplopia when the eyes deviate. This therapy approach would only be appropriate if the patient had normal correspondence. It is therefore important to perform specific testing for anomalous correspondence when evaluating a patient with divergence excess.

We recommend using the Hering-Bielschowsky afterimage test for the assessment of anomalous correspondence in divergence excess patients. To perform this test, the left eye is occluded while the patient fixates a target on an electronic strobe flasher. The clinician flashes the electronic strobe, creating a horizontal afterimage on the right eye. The right eye is then occluded and a vertical afterimage is created on the left eye. The patient fixates a small target on a blank wall and reports the relationship between the vertical and horizontal afterimages. It is important for the patient to be dissociated for this part of the test. A response of a “perfect cross” indicates normal retinal correspondence. A misalignment of the afterimages is an anomalous retinal correspondence response.

Symptoms

The most common patient complaint is about cosmetic appearance. Generally parents bring their child in for an examination because they have noticed that the child’s eye turns out at times. Subjective symptoms are rare in divergence excess. Because of the presence of suppression or anomalous correspondence or both, diplopia is unusual, although it is occasionally reported. Reports of asthenopia, so characteristic of other binocular and accommodative anomalies, are less common with divergence excess patients. Other than cosmesis, the only reported symptoms associated with divergence excess are photophobia and squinting or covering an eye in bright sunlight.

DIFFERENTIAL DIAGNOSIS

Functional Disorders to Rule Out

- Basic exophoria
- Simulated divergence excess
- Convergence insufficiency

Divergence excess must be differentiated from other exodeviations, such as convergence insufficiency and basic exophoria. The differences between convergence insufficiency and divergence excess are so great that this differentiation is very clear. There has been much discussion in the literature, however, regarding the differentiation of true divergence excess from simulated divergence excess or basic exophoria. It is important to

understand that distinguishing true from simulated divergence excess is primarily a surgical concern because some clinicians recommend a different surgical procedure for the two conditions (22,26). Burian and Spivey (26) recommend recession of both lateral rectus muscles in cases of true divergence excess, and resection of the medial rectus, combined with recession of the lateral rectus of the same eye, for simulated divergence excess. Von Noorden (22) studied 91 divergence excess patients and compared the success rates for simulated and true divergence excess based on the type of surgery performed. He found that surgical results can be improved when a differentiation between simulated and true divergence excess is made preoperatively and the proper surgical procedure is selected accordingly. This finding, however, is by no means universal. Wickens (27) reported that in her sample of 50 patients with divergence excess, the type of surgery performed made little difference in the results for simulated or true divergence excess.

The primary value of this differential diagnosis, therefore, is for the surgical treatment of divergence excess. There has been no similar demonstration of clinical significance relative to the optometric management of divergence excess. Kran and Duckman (28) speculated that clinicians should vary their treatment approach for the two conditions. There is no research support, however, for their hypothesis. Pickwell (7) studied this issue and found that true and simulated divergence excess do not respond differently to vision therapy. Vision therapy is the primary treatment approach for either condition, and the specific treatment does not vary significantly for either diagnosis. The only significant difference would be the potential value of added lenses in true divergence excess. However, it is important to remember that Cooper, Ciuffreda, and Kruger (23) found normal AC/A ratios even in the two patients they examined who demonstrated true divergence excess.

Thus, there has been little research to demonstrate the clinical significance of differentiating true from simulated divergence excess. Even for surgical intervention, the importance of this differentiation has not been unequivocally demonstrated. Nevertheless, since the terminology does exist and it may become necessary at times to communicate with other professionals about this issue, it does deserve some discussion.

True divergence excess is the condition defined in the beginning of this section, in which there is a greater amount of exophoria at distance than at near, the AC/A is high (when the distance deviation is compared to the near deviation), there is an absence of amblyopia, and stereopsis is normal at near. Simulated divergence excess presents with similar characteristics; however, with additional testing, it becomes apparent that the magnitude of the phoria at near is approximately equal to that at distance.

The two specific tests that have been suggested are the occlusion test and the +3.00 OU test. If after either test is performed the angle of deviation at near equals the angle of deviation at distance (within 10 Δ), the condition is called simulated divergence excess. Burian and Franceschetti (29) recommend 30 to 45 minutes of occlusion. After this amount of occlusion, it is important not to allow the patient to regain binocular vision before performing the cover test. Thus, one eye is covered while the patch is removed, and then the alternate cover test is performed to measure the angle of deviation.

The +3.00 D test (29) is performed by assessing the near angle through the subjective and again through a +3.00 add. If the distance and near results are within 10 Δ of each other, the patient has a simulated divergence excess.

Summary

Strabismus surgeons stress the importance of differentiating true from simulated divergence excess because the surgical treatment differs for the two conditions. A similar need to differentiate the two conditions has not been demonstrated relative to vision therapy. Although some authors have suggested that vision therapy treatment programs should be different for true versus simulated divergence excess, there have been no clinical studies to determine whether this is necessary. In our experience, the vision therapy program outlined below works well with both conditions, and it is therefore not necessary to differentiate true from simulated divergence excess.

TREATMENT

We recommend the sequential management sequence listed in Table 10.2.

Lenses

With divergence excess, it is important to prescribe for any significant refractive error. If a high AC/A ratio is present, prescription for any myopic refractive error would have a beneficial effect on the angle of deviation at distance. Unless a moderate to high degree of hyperopia is present, it is usually best not to prescribe because

of the increase in the size of the angle that would be expected to occur. As we have suggested previously, it is important to prescribe glasses for significant degrees of anisometropia.

Prism

If a vertical deviation is present, we recommend that vertical prism be prescribed. The most effective method for determining the amount of vertical prism is the associated phoria, which can be measured with any fixation disparity device. It is not unusual to find a vertical deviation with divergence excess when the patient is strabismic. However, under fused conditions, the vertical deviation is generally not present. Use of vertical prism, therefore, is not usually necessary in cases of divergence excess.

Because vision therapy is so highly successful with divergence excess, horizontal prism is almost never necessary.

Added Minus Lenses at Distance

Added minus lenses are sometimes helpful in the treatment of divergence excess as one part of the overall treatment plan. There are a number of situations in which added lenses may be of value. As explained earlier, if the CA/C ratio is high, the patient may be unable to inhibit accommodation at distance; small amounts of added minus lenses may help the patient maintain clear single binocular vision (Chapter 16).

The use of added minus lenses can also be considered as a device to help the patient during active vision therapy. When used for this purpose, large amounts of minus can be prescribed. For a large-angle exophoria or exotropia, it would not be unusual to prescribe 6 or 7 D of additional minus as a training lens. To determine the prescription, the clinician would find the least amount of minus that allows the patient to fuse. The power of the lenses would gradually be reduced as therapy progresses and the patient's ability to fuse improves. These lenses would only be used during active vision therapy.

Added minus lenses should also be considered for preschool children with divergence excess, particularly if the child is too young for in-office vision therapy and if the deviation is intermittent and appears to be deteriorating into a constant exotropia at distance. In such cases, the lenses may help to temporarily reduce the angle of deviation and are generally used for full-time wear. The objective is to reduce the proportion of time that the intermittent exotropia occurs. When prescribed for this purpose, smaller amounts of minus (i.e., 1.00 to 2.00 D) are used. In these cases, the AC/A ratio is not the critical factor in determining the amount of minus to prescribe. The objective of the added minus is to create a stimulus to convergence. Once this is accomplished, the patient is able to maintain fusion using fusional vergence. Because the use of added minus lenses for full-time wear creates an additional accommodative demand at near, this approach is generally useful in preschool children only. If this approach is used for older children, a bifocal is generally required to allow comfortable vision when reading. Table 10.9 lists the findings that should be considered and provides guidelines for prescribing added minus lenses.

Vision Therapy

At least three different vision therapy treatment strategies for divergence excess have been proposed. The first approach, popular in the orthoptic literature, strongly emphasizes the development of diplopia awareness,

TABLE 10.9 CONSIDERATIONS FOR PRESCRIBING ADDED MINUS LENSES

Test	Consider the Use of Added Minus	Added Minus Not Indicated
AC/A ratio	High	Low
CA/C ratio	High	Low
Phoria	Exophoria	Esophoria
Base-in at near	Normal to high	Low
Amplitude of accommodation	Normal	Low
Accommodative facility testing	Fails +	Fails –
Age	Younger than 6 years	9 years or older

utilizing occlusion to eliminate suppression (4,30). This strategy is based on the concept that the patient who becomes aware of when the strabismus manifests will be able to regain fusion. The initial step in this approach is constant occlusion for as long as 2 months. After about a month of occlusion, diplopia awareness procedures are prescribed. Techniques are designed to work on both pathologic diplopia (diplopia occurring while the patient is strabismic) and physiologic diplopia (diplopia occurring while the patient is fused).

As we stated previously, when working with pathologic diplopia, it is important to keep in mind that the patient may have anomalous correspondence. If anomalous correspondence is present, modifications must be made in the therapy approach. Specifically, antisuppression techniques based on the appreciation of pathologic diplopia would have to be avoided, although those based on physiologic diplopia could still be performed.

Some orthoptists limit therapy to just working with diplopia awareness (30). Others suggest working on fusional vergence as well (4). The major emphasis, however, is the occlusion and antisuppression techniques.

A second approach, based on the findings of Brock and popularized by Flax and Selenow (31), differs significantly and specifically avoids techniques for becoming aware of pathologic diplopia. Instead, Flax and Selenow emphasize the importance of carefully selecting therapy conditions that promote binocular vision. The objective is to begin therapy under optimal conditions and to gradually move to stimulus conditions that tend to trigger the intermittent strabismus. Divergence excess patients achieve binocularity most easily when viewing detailed stereopsis (third-degree fusion) targets at near. The Flax and Selenow approach therefore emphasizes the use of detailed third-degree targets initially, with a sequential introduction of second- and, finally, first-degree fusion targets. This sequence begins at near point and then is repeated at intermediate distances and finally at a distance of about 6 m (20 ft). At the end of therapy, the patient works with first-degree fusion targets at 6 m. These are the conditions under which divergence excess tends to manifest. The objective of this therapy strategy is to teach the patient to maintain binocularity in the absence of cues that promote binocular vision.

Flax and Selenow believe that diplopia awareness develops as a natural consequence of this training approach and does not have to be specifically addressed. They argue that avoidance of diplopia is not the mechanism used by normal individuals to maintain binocular vision and it should therefore not be the mechanism we stress in vision therapy to help the divergence excess patient regain normal binocular vision. Instead, the authors suggest that, as the divergence excess patient regains normal binocular vision, he or she develops a "postural awareness" or a kinesthetic feeling of binocular vision.

A third approach, recommended by Cooper and Leyman (10), is a combination of the two approaches described above. They suggest beginning therapy with diplopia awareness procedures and then following the sequence of therapy recommended by Flax and Selenow. Cooper feels that it is helpful to initially develop diplopia awareness because it enables the patient to regain fusion when the deviation occurs and shortens the length of therapy. Because the overall objective of vision therapy should be to eliminate symptoms and restore normal binocular vision as quickly as possible, we recommend following the approach suggested by Cooper and Leyman. Although the Flax and Selenow approach can be effective in treating divergence excess, we have also found that an emphasis on diplopia awareness early in the treatment program tends to shorten the length of therapy.

It is important to be flexible, however, because about 30% to 35% of divergence excess patients with normal correspondence are never able to develop diplopia awareness, although they can still achieve success.

Specific Vision Therapy Program

The vision therapy program we describe below is primarily designed for divergence excess patients who are exophoric or for those who have normal correspondence when the deviation manifests. If a constant strabismus is present at distance or the deviation is present most of the time, anomalous correspondence may be present. If so, the program described below must be altered. The main modification would be to eliminate all antisuppression techniques based on pathologic diplopia.

Vision therapy for divergence excess generally requires between 24 and 36 visits. The total number of therapy sessions depends on the severity of the condition, the age of the patient, and his or her motivation and compliance with home vision therapy procedures.

The vision therapy program for divergence excess is longer than that for most other accommodative and nonstrabismic conditions because of the need to begin therapy at near and move to distance and the need to work on diplopia awareness. However, other than the antisuppression procedures performed early in therapy, the treatment program is quite similar initially because many of the early treatment objectives are similar to those associated with other binocular conditions. Even though divergence excess is primarily a far point problem, the initial objectives are to normalize accommodation and fusional vergence skills at near.

As these abilities improve, the training distance is gradually increased, and the sequence of moving from third- to second- to first-degree targets is repeated at intermediate distances and finally at long distances.

Phase 1

This first phase of therapy is designed to accomplish the objectives listed in Table 10.10 under Phase 1. As we have recommended with all therapy, during the first few visits it is important to develop a working relationship with the patient and to establish an awareness of the various feedback mechanisms that will be used throughout therapy (Table 9.8).

A priority of phase 1 should be antisuppression therapy. Many procedures can be used to accomplish this objective. We described several of the more popular ones in Chapters 6 to 8. These include the Brock string, TV trainer, red/green glasses and penlight, vertical prism dissociation method, mirror superimposition, and cheirosopic tracings. Of course, all binocular vision therapy procedures indirectly train antisuppression because all binocular techniques contain antisuppression cues.

It is important to remember that there are different objectives of antisuppression therapy. One objective is to create diplopia awareness while the deviation is manifest (pathologic diplopia). This type of antisuppression therapy is only appropriate if normal correspondence is present when the eye deviates. If anomalous correspondence is present, only antisuppression therapy based on physiologic diplopia should be used. Effective techniques for pathologic diplopia training include red/green glasses and penlight, vertical prism dissociation method, and mirror superimposition. A second objective is to create diplopia awareness while the deviation is latent (physiologic diplopia). These techniques can be used even if the patient has anomalous correspondence when the deviation is manifest. The Brock string and Barrel convergence card are examples of procedures used to achieve this goal. The final objective of antisuppression therapy is to eliminate central and peripheral suppression while the patient is fusing. Techniques such as the TV trainer, mirror superimposition, cheirosopic tracings, vectograms, tranaglyphs, the Aperture Rule, and almost all binocular techniques can be used for this purpose.

TABLE 10.10 OBJECTIVES OF VISION THERAPY FOR DIVERGENCE EXCESS

<p>Phase 1</p> <ul style="list-style-type: none"> • Develop a working relationship with the patient • Develop an awareness of the various feedback mechanisms that will be used throughout therapy • Begin therapy using detailed third-degree targets at near, working with both positive and negative fusional vergence amplitudes • Develop diplopia awareness <ul style="list-style-type: none"> • If normal correspondence is present, use both pathologic and physiologic diplopia • If anomalous correspondence is present, only use physiologic diplopia • Remember that 30% to 35% of patients with normal correspondence will not achieve diplopia awareness • Normalize accommodative amplitude and ability to stimulate and relax accommodation
<p>Phase 2</p> <ul style="list-style-type: none"> • Continue therapy using second- and first-degree targets at near, working with both positive and negative fusional vergence • Concentrate on developing negative and positive fusional vergence facility (jump or phasic vergence demand)
<p>Phase 3</p> <ul style="list-style-type: none"> • Continue therapy using third-, second-, and first-degree targets at intermediate distances, working with both positive and negative fusional vergence • Concentrate on developing negative and positive fusional vergence facility (jump or phasic vergence demand) at intermediate distances • Develop ability to change from a convergence to a divergence demand • Integrate vergence procedures with changes in accommodative demand
<p>Phase 4</p> <ul style="list-style-type: none"> • Continue therapy using third-, second-, and first-degree targets at distances of 3 to 6 m (10 to 20 ft), working with both positive and negative fusional vergence • Integrate vergence procedures with changes in accommodative demand • Integrate vergence procedures with versions

During this phase of therapy, it is also important to begin working on establishing normal fusional vergence amplitudes for both convergence and divergence. As discussed earlier in this chapter, divergence excess appears to have a different physiologic basis than conditions such as convergence insufficiency and excess. It cannot be treated simply as a distance exodeviation with low PFV. Rather, studies have shown that PFV is generally normal and NFV may be deficient in divergence excess.

With most binocular conditions, the early emphasis is on expanding the amplitude and improving the dynamics of the compensatory fusional vergence. For example, with convergence insufficiency, PFV is emphasized first, and with convergence excess, NFV is the initial emphasis. With divergence excess, however, the initial phase of therapy is designed to work with both PFV and NFV, with an emphasis on PFV.

Selecting targets that create optimal conditions for fusion is a critical aspect of vision therapy for divergence excess. This careful selection of target characteristics begins in phase 1 and should continue throughout the entire treatment program. In phase 1, therefore, we use detailed third-degree targets (stereopsis) at near, working with both PFV and NFV amplitudes. The same techniques used with other binocular vision conditions are effective with divergence excess. The binocular vision therapy sequence described in Chapter 9 for convergence insufficiency works well as initial near therapy for divergence excess. Tranaglyphs and vectograms are followed by nonvariable tranaglyphs, the Aperture Rule, and Free Space Fusion cards or Eccentric Circles.

A final objective of phase 1 is to establish normal accommodative amplitude and facility. In many cases, divergence excess is associated with an accommodative anomaly. If so, the early emphasis should be on improving the particular aspect of accommodation that is deficient. For example, if an accommodative insufficiency is present, the initial objective would be to improve the patient's ability to stimulate accommodation. Even if accommodation appears adequate, however, some accommodative therapy should be performed early in therapy to maximize accommodative ability. This is important because as the patient begins to develop diplopia awareness, he or she will generally regain fusion by using accommodative convergence to initiate convergence and regain fusion.

Endpoint. Phase 1 of therapy ends when the patient can:

- Experience physiologic diplopia on the Brock string at both near and far distances
- Fuse to about 30 base-out and 15 base-in using detailed third-degree fusion targets at near
- Complete 12 cpm of accommodative facility with +2.00/−2.00 lenses using a 20/30 target

If the patient has normal correspondence, the phase has an additional endpoint, namely, when he or she can

- Experience pathologic diplopia on a consistent basis.

A sample vision therapy program for phase 1 is summarized in Table 10.11.

Phase 2

This second phase of therapy is designed to accomplish the objectives listed in Table 10.10 under Phase 2. Once the patient can effectively fuse third-degree fusion targets at near during both convergence and divergence therapy, the objective is to introduce second-degree (flat fusion) and first-degree (superimposition) targets at near. Both PFV and NFV training should be performed. Procedures that can be used include the Aperture Rule, Lifesaver cards, mirror superimposition, stereoscopic instruments, and computer software programs. Clinicians can also easily construct first- and second-degree targets, such as Eccentric Circles and Free Space Fusion cards and Lifesaver cards. Examples of such targets are illustrated in Chapter 6 (Figs. 6.33 and 6.34). These were made using commercially available computer graphics software (e.g., PC Paintbrush).

Of course, both first- and second-degree targets can be constructed without a computer, using simple drawings and pictures from magazines. A popular technique is to purchase two identical issues of a magazine or coloring book and to utilize the cover or some of the pictures in the magazine. To create a second-degree target, simply draw a vertical line on one picture and a horizontal line on another. When the patient fuses this target, he or she would perceive a cross (Fig. 10.1).

The Aperture Rule is one of the more popular vision therapy techniques and primarily contains second-degree targets. As Figure 10.2 illustrates, there is no stereopsis demand, except for the secondary target containing eccentrically displaced circles on each card. The primary target, however, is second degree. Another excellent instrument for this phase of treatment is the stereoscope. Many different series of stereoscopic cards that contain first-, second-, and third-degree targets are commercially available.

TABLE 10.11 SAMPLE VISION THERAPY PROGRAM FOR DIVERGENCE EXCESS

Phase 1
<p><i>Sessions 1 and 2</i> IN-OFFICE</p> <ul style="list-style-type: none"> • Discuss nature of vision problem, goals of vision therapy, various feedback cues, importance of practice • Brock string: stress antisuppression • Lens sorting • Loose lens rock (begin with plus if accommodative excess, with minus if accommodative insufficiency) • Tranaglyphs or vectograms: convergence and divergence <ul style="list-style-type: none"> • Begin with a peripheral target such as tranaglyph 515 or the Quoit vectogram • Computer Orthoptics Random Dot program: convergence and divergence
<p>HOME THERAPY</p> <ul style="list-style-type: none"> • HTS Vergence and Accommodation programs • Loose lens rock • Brock string • Red/green glasses and penlight for antisuppression
<p><i>Sessions 3 and 4</i> IN-OFFICE</p> <ul style="list-style-type: none"> • Vertical prism/antisuppression • Loose lens rock • Tranaglyphs or vectograms: convergence and divergence <ul style="list-style-type: none"> • Use targets with more central demand (Clown, Bunny tranaglyphs; Clown, Topper vectograms) • Computer Orthoptics Random Dot program: convergence and divergence
<p>HOME THERAPY</p> <ul style="list-style-type: none"> • HTS Vergence and Accommodation programs • Loose lens rock • Red/green glasses and penlight antisuppression • TV trainer
<p><i>Sessions 5 through 8</i> IN-OFFICE</p> <ul style="list-style-type: none"> • Vertical prism/antisuppression • Loose lens rock • Tranaglyphs or vectograms: convergence and divergence <ul style="list-style-type: none"> • Use even more detailed targets such as tranaglyph Sports Slide and Faces targets and the Spirangle vectogram • Computer Orthoptics Random Dot program: convergence and divergence
<p>HOME THERAPY</p> <ul style="list-style-type: none"> • HTS Vergence and Accommodation programs • Red/green glasses and penlight antisuppression • TV trainer
Phase 2
<p><i>Sessions 9 and 10</i> IN-OFFICE</p> <ul style="list-style-type: none"> • Tranaglyphs or vectograms with modifications to create jump vergence demand: convergence and divergence • Nonvariable tranaglyphs • Binocular accommodative therapy techniques: use any of the binocular techniques listed above with \pm lenses • Computer Orthoptics Random Dot program: divergence • Stereoscopes: second-degree targets
<p>HOME THERAPY</p> <ul style="list-style-type: none"> • HTS Vergence and Accommodation programs • Penlight antisuppression • TV trainer • Nonvariable tranaglyphs
<p><i>Sessions 11 and 12</i> IN-OFFICE</p> <ul style="list-style-type: none"> • Tranaglyphs or vectograms with modifications to create jump vergence demand: convergence and divergence • Aperture Rule: convergence and divergence • Binocular accommodative therapy techniques: use any of the binocular techniques listed above with \pm lenses

(Continued)

TABLE 10.11 CONTINUED

<ul style="list-style-type: none"> • Stereoscopes: second-degree targets • Computer Orthoptics second-degree fusion targets: divergence and convergence
<p>HOME THERAPY</p> <ul style="list-style-type: none"> • HTS Vergence and Accommodation programs • Penlight antisuppression • TV trainer
<p><i>Sessions 13 through 16</i></p> <p>IN-OFFICE</p> <ul style="list-style-type: none"> • Eccentric Circles or Free Space Fusion cards • Computer Orthoptics second-degree targets: both divergence and convergence • Aperture Rule: convergence and divergence • Binocular accommodative therapy techniques: use any of the binocular techniques listed above with \pm lenses • Stereoscopes: second-degree targets
<p>HOME THERAPY</p> <ul style="list-style-type: none"> • HTS Vergence and Accommodation programs • TV trainer • Eccentric Circles or Free Space Fusion cards
<p>Phase 3</p> <p><i>Sessions 17 through 20</i></p> <p>IN-OFFICE</p> <ul style="list-style-type: none"> • Tranaglyphs or vectograms projected at distances from 1 to 5 ft (30.5 cm to 1.5 m): convergence and divergence • Computer Orthoptics second-degree targets: convergence and divergence • Stereoscope techniques using second-degree targets set at intermediate distances
<p>HOME THERAPY</p> <ul style="list-style-type: none"> • HTS Vergence and Accommodation programs • Eccentric Circles or Free Space Fusion cards: convergence and divergence • Lifesaver cards • Homemade second-degree targets
<p><i>Sessions 21 and 22</i></p> <p>IN-OFFICE</p> <ul style="list-style-type: none"> • Tranaglyphs or vectograms projected at distances from 1 to 5 ft: convergence and divergence • Computer Orthoptics second-degree fusion targets: convergence and divergence • Stereoscope techniques using second- and first-degree targets • First-degree targets at 1 to 5 ft
<p><i>Sessions 23 and 24</i></p> <p>IN-OFFICE</p> <ul style="list-style-type: none"> • Tranaglyphs or vectograms projected at distances from 1 to 5 ft: convergence and divergence • Computer Orthoptics second-degree fusion targets: convergence and divergence • Stereoscope techniques using first-degree targets • First-degree targets at 1 to 5 ft
<p>HOME THERAPY</p> <ul style="list-style-type: none"> • HTS Vergence and Accommodation programs • Lifesaver cards • Second- and first-degree targets at 1 to 5 ft
<p>Phase 4</p> <p><i>Sessions 25 through 28</i></p> <p>IN-OFFICE</p> <ul style="list-style-type: none"> • Tranaglyphs or vectograms projected at distance from 10 to 20 ft (3 to 6 m): convergence and divergence • Computer Orthoptics Random Dot Vergence program: jump-jump vergence • Stereoscope techniques using first-, second-, and third-degree targets • Cheirosopic tracings • Fusion with versions and saccades at distance
<p>HOME THERAPY</p> <ul style="list-style-type: none"> • HTS Vergence and Accommodation programs • Eccentric Circles at 10 to 15 ft • Second- and first-degree targets at 10 to 15 ft

(Continued)

TABLE 10.11 CONTINUED

Sessions 28 through 32

IN-OFFICE

- Stereoscope techniques using first- and second-degree targets
- Cheirosopic tracings
- First- and second-degree targets at 10 to 15 ft
- Tranaglyphs or vectograms projected with overhead projector
- Fusion with versions and saccades at distance

HOME THERAPY

- HTS Vergence and Accommodation programs
- Eccentric Circles at 10 to 15 ft
- First- and second-degree targets at 10 to 15 ft

The other objective of this phase is to concentrate on developing NFV and PFV facility (jump or phasic vergence demand). The approach and appropriate techniques are similar to those described for convergence insufficiency in Chapter 9.

Endpoint. Phase 2 of therapy ends when the patient can:

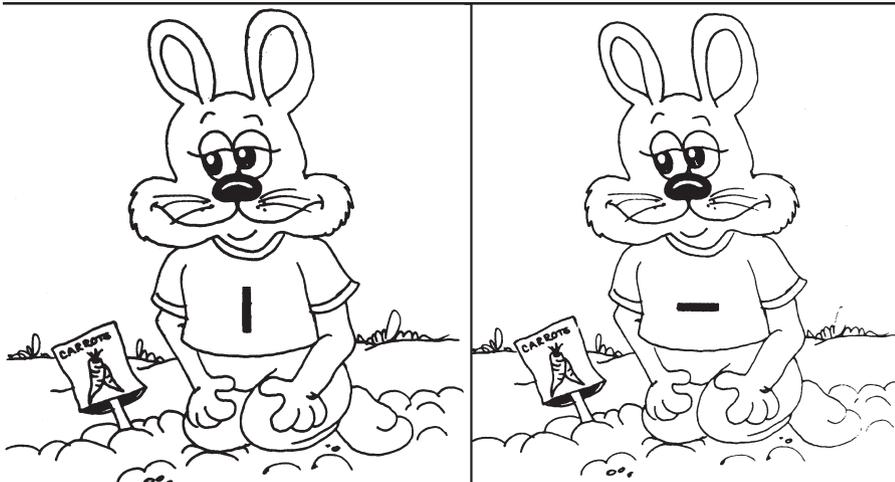
- Fuse to about 30 base-out and 15 base-in using second- and first-degree fusion targets at near
- Fuse card 12 using convergence and card 6 using divergence with the Aperture Rule
- Fuse the Eccentric Circles or Free Space Fusion cards using convergence (12 cm separation) and divergence (6 cm separation).

A sample vision therapy program for phase 2 is summarized in Table 10.11.

Phase 3

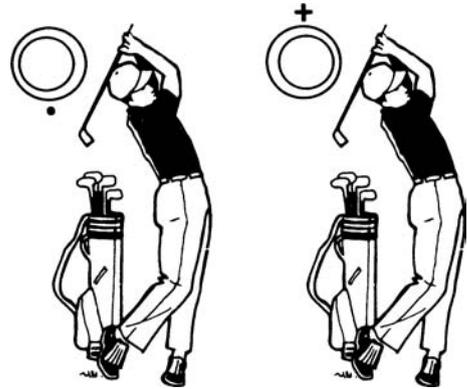
This third phase of therapy is designed to accomplish the objectives listed in Table 10.10 under Phase 3. The most important objective of this phase of therapy is to begin performing the treatment at intermediate distances. Now that the patient can successfully work with the various instruments and procedures at near, it is usually very easy to repeat similar techniques at greater distances. A very effective procedure is to use tranaglyphs projected on the wall or a screen by an overhead projector. This technique works well because the patient is familiar with the tasks from phases 1 and 2 and simply has to apply the same skills learned during earlier sessions.

An overhead projector is also useful when trying to use first- and second-degree targets. The same targets that were constructed for near therapy can be enlarged and printed on overhead transparency material. Alternatively, large first- and second-degree targets can be easily constructed on 8.5 × 11 in. paper by hand



■ **Figure 10.1** Picture from a coloring book modified to create a second-degree fusion target.

■ **Figure 10.2** Close-up of an Aperture Rule target.



or using a computer graphics program. Large third-degree targets, similar to the Eccentric Circles, are commercially available.

Another method of presenting stimuli at intermediate distances is the use of stereoscopes. The working distance can be conveniently changed on most Brewster-type stereoscopes, and a wide variety of targets is readily available.

The second objective of phase 3 is to develop NFV and PFV facility (jump or phasic vergence demand) at intermediate distances. To accomplish this, the clinician simply selects targets and techniques that present jump vergence-type demands, such as the large Eccentric Circles, jump duction stereograms, or first- and second-degree targets that are of the homemade variety.

Endpoint. Phase 3 of therapy ends when the patient can

- Fuse to about 20 base-out and 10 base-in using third-, second-, and first-degree fusion targets at intermediate distances.

A sample vision therapy program for phase 3 is summarized in Table 10.11.

Phase 4

The final phase of therapy is designed to accomplish the objectives listed in Table 10.10 under Phase 4. The main objective of this final phase of therapy is to use third-, second-, and first-degree targets at distances of 3 to 6 m (10 to 20 ft), working with both PFV and NFV. The same techniques and instruments used during phase 3 can be repeated at greater distances.

An important procedure that is used at this stage in therapy is cheirosopic tracings. This procedure is ideal for the last phase of treatment of divergence excess because it is a method of presenting stimuli under the most challenging conditions. Remember that the most difficult condition for divergence excess is a first-degree target placed at a distance setting. Cheirosopic tracings are extremely challenging for these patients because initially there is very little structure to the stimuli and they are set at optical infinity. Cheirosopic tracings are described in detail in Chapter 6.

The final goal is to integrate vergence procedures with versions and saccades. This can be accomplished using the procedures described earlier for convergence excess. With divergence excess, it is important to also perform these techniques at intermediate and far distances.

Endpoint. Phase 4 of therapy ends when the patient can:

- Fuse to about 20 base-out and 5 base-in using second- and first-degree fusion targets at distance.

A sample vision therapy program for phase 4 is summarized in Table 10.11.

A reevaluation should be performed about halfway through the therapy program and again at the end of therapy. Refer to the original complaints and determine whether the patient is now comfortable. All tests of binocular and accommodative function should be repeated and compared to the initial findings as well as the expected findings.

When all vision therapy objectives have been reached, the vision therapy program is complete. We recommend the home vision therapy maintenance program outlined in Table 9.10.

Summary of Vision Therapy for Divergence Excess

The sample vision therapy program described above and outlined in Tables 10.10 and 10.11 represents a systematic approach that will lead to successful elimination of patient symptoms and normalization of optometric data. The number of sessions is approximate and will vary from one patient to another. It is not necessary to work with every procedure described. The objective should be to achieve a successful result as quickly as possible. If it becomes apparent that a procedure is too easy for a patient, move on to the next technique. As stated in Chapter 9, the variable of home therapy is also important. A motivated adult, working many hours at home, may be able to complete therapy in a shorter time frame than the one described above.

Using the approach suggested in this chapter should lead to the achievement of the excellent success rates reported in the literature for divergence excess.

Surgery

Treatment of heterophoria and intermittent strabismus patients with divergence excess involves the judicious application of lenses, prism, and vision therapy. This approach leads to the excellent success rates discussed earlier in this chapter. As a result, surgery should always be deferred until the results of conservative management are known. When a patient is not interested in a nonsurgical approach, is unmotivated, or has a large magnitude of deviation, surgery may be necessary. If the deviation is larger than 30 to 35 Δ (2,5), the literature suggests that a combination of vision therapy followed by surgery and postsurgical vision therapy may be necessary to achieve the best result.

A review of the success of surgery as the sole treatment method for divergence excess, however, reveals very disappointing results. Flax and Selenow (31) performed an extensive literature review and analyzed the data from 1,490 surgical procedures for intermittent exotropia. Although they did not distinguish between different types of exotropia, it is likely that the vast majority of these cases were divergence excess, since surgery for convergence insufficiency is extremely rare (Chapter 9). Only two-thirds of the sample achieved a cosmetic cure, and only one-third attained normal binocular function along with alignment. In addition, 1 in 6 patients in this sample derived no benefit at all or were harmed by the surgery. Cooper and Leyman (10) also reviewed the literature on the efficacy of surgery for divergence excess and found functional cure rates ranging from 12% to 37%.

We suggest that surgery only be considered after aggressive use of lenses, prism, and vision therapy. This approach should lead to excellent success rates, in the range of 85% to 90%.

CASE STUDY

The following case study (Case 10.7) is representative of divergence excess patients that clinicians will encounter.

Case 10.7

History

Angel, a 10-year-old boy in the fifth grade, was brought in for an eye examination because of concern about his left eye drifting outward. Although his mother had noticed this problem since Angel was 2 or 3 years old, she felt it was getting worse. In the past, the eye turned out only when he was tired or at the end of the day. She felt that his left eye was now turning out much of the day. Angel had no complaints at all. He felt his vision was clear and never experienced double vision. We were able to obtain photographs going back to his early childhood years. These photographs confirmed that the deviation was present since as young as 2 years of age. They also showed that it was intermittent when he was younger. In some photographs, his eyes were clearly aligned. Angel was in good health and was not taking any medication.

Examination Results

VA (distance, uncorrected):	OD: 20/20 OS: 20/20
VA (near, uncorrected):	OD: 20/20 OS: 20/20
IPD:	58 mm
Near point of convergence	
Accommodative target:	7 cm
Penlight:	7 cm
Cover test (distance):	20 Δ, intermittent, left exotropia (deviates 25%)
Cover test (near):	5 exophoria
Subjective:	OD: +0.25, 20/20 OS: +0.25, 20/20
Distance lateral phoria:	Suppression
Base-in vergence (distance):	Suppression
Base-out vergence (distance):	Suppression
Near lateral phoria:	6 exophoria
-1.00 gradient:	2 exophoria
Gradient AC/A ratio:	4:1
Calculated AC/A ratio:	12:1
Base-in vergence (near):	10/16/12
Base-out vergence (near):	X/15/10
NRA:	+1.75
PRA:	-1.50
Accommodative amplitude (push-up):	OD: 13 D; OS: 13 D
MAF:	OD: 4 cpm; OS: 4 cpm
BAF:	3 cpm
MEM retinoscopy:	+0.25 OD and OS

Pupils were normal, all external and internal health tests were negative, the deviation was comitant, and color vision testing revealed normal function.

Case Analysis

The cover tests show a much larger exodeviation at distance than at near, and the calculated AC/A ratio is high. When the phoria shows a significant exodeviation, analysis of the data should begin with the PFV group data. In this case, these results suggest a diagnosis of divergence excess. In addition, analysis of the accommodative data indicates problems with both stimulation and relaxation of accommodation. Angel had difficulty with both NRA and PRA; BAF was reduced, as was MAF. The fact that MAF was low confirms that the problem is monocular; this is due to an accommodative rather than a binocular problem. The diagnosis, therefore, was divergence excess and accommodative infacility.

Management

The refractive error was considered insignificant in this case, and glasses were not prescribed. Vision therapy was recommended to treat both the divergence excess and the accommodative infacility. Twenty-two office visits over a 3-month period of time were necessary, along with home vision therapy. We followed the vision therapy program outlined in Table 10.11.

At the final reevaluation we found the following:

Cover test (distance):	16 exophoria
Cover test (near):	4 exophoria

Subjective:	OD: +0.25, 20/20 OS: +0.25, 20/20
Distance lateral phoria:	14 exophoria
Base-in vergence (distance):	X/10/3
Base-out vergence (distance):	12/28/16
Near lateral phoria:	4 exophoria
–1.00 gradient:	1 esophoria
Gradient AC/A ratio:	5:1
Calculated AC/A ratio:	10:1
Base-in vergence (near):	16/24/14
Base-out vergence (near):	X/35/20
NRA:	+2.75
PRA:	–2.50
Accommodative amplitude (push-up):	OD: 13 D; OS: 13 D
MAF:	OD: 14 cpm; OS: 14 cpm
BAF:	10 cpm
MEM retinoscopy:	+0.25 OD and OS

Pupils were normal, all external and internal health tests were negative, the deviation was comitant, and color vision testing revealed normal function.

Summary and Conclusions

This chapter discussed the diagnosis and management of binocular conditions associated with high AC/A ratios. These conditions include divergence excess and two forms of convergence excess—one associated with normal tonic vergence (ortho at distance) and the other associated with high tonic vergence (esophoria at distance).

All three conditions can be very successfully managed using a combination of lenses, added lenses, prism, and vision therapy. We have suggested a specific management sequence that does differ for the conditions. Added lenses and horizontal prism tend to be more useful for convergence excess, and vision therapy is the more valuable technique for divergence excess.

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Normal AC/A Conditions: Fusional Vergence Dysfunction, Basic Esophoria, and Basic Exophoria

This chapter discusses the characteristics, diagnosis, and management of nonstrabismic binocular disorders associated with a normal AC/A ratio. Although there are some significant differences among these conditions, they are grouped together based on the classification system described in Chapter 2. The unifying characteristic of the conditions described in this chapter is the normal AC/A ratio. This similarity is an important one because it is the basis for the development of the management plan. Specifically, the AC/A ratio is the major factor that determines the sequence of management decisions in patients with heterophoria (Chapter 3). Consequently, certain general treatment strategies are shared by all binocular conditions associated with a normal AC/A ratio. However, there are also important differences among these conditions. After a review of general principles that apply to all normal AC/A disorders, each condition is described separately to highlight the differences in characteristics, diagnosis, and management.

The specific conditions that are discussed in this chapter are fusional vergence dysfunction, basic exophoria, and basic esophoria.

Overview of General Management Principles for Heterophoria Associated with Normal AC/A Ratio

Table 11.1 lists the various sequential management issues that we presented in Chapter 3. The specific sequence in which these factors should be considered is primarily dependent on the AC/A ratio. For binocular vision disorders associated with a normal AC/A ratio, the specific management sequences we suggest are listed in Tables 11.2, 11.3, and 11.4.

In contrast to conditions with low AC/A ratios, in which the use of added lenses is not very helpful, in conditions with a normal AC/A ratio, added lenses are sometimes useful. As a result, the consideration of the use of added lenses is moved closer to the top of the list in Tables 11.3 and 11.4.

Optical correction of ametropia still remains the first issue that a clinician should consider. As stated in Chapter 3, the first consideration for all patients with accommodative and nonstrabismic binocular anomalies is optical correction of ametropia. In normal AC/A cases, lenses may have a moderate effect on the size of the deviation. Prescription for hyperopia in basic esophoria or for myopia in basic exophoria will generally be helpful.

When considering the final prescription, it is important to first determine whether a vertical deviation is present. We suggest prescribing for vertical deviations as small as 0.5Δ and basing the prescription on fixation disparity assessment (Chapter 15).

As discussed in earlier chapters, a key difference between the sequential management of esophoria and exophoria is the differential effectiveness of both horizontal prism and vision therapy for these conditions. Horizontal prism tends to be more effective for esophoria than for exophoria. Therefore, the use of prism is an earlier consideration for basic esophoria than for basic exophoria. Fusional vergence dysfunction is, by definition, associated with very small magnitude horizontal phorias. As a result, the use of horizontal prism is never indicated for this condition. Vision therapy tends to be more effective in exophoria than esophoria. Vision therapy, without the assistance of horizontal prism, will often be sufficient to treat basic exophoria. These differences are reflected in the sequential management considerations in Tables 11.2, 11.3, and 11.4.

TABLE 11.1 SEQUENTIAL CONSIDERATIONS IN THE MANAGEMENT OF NONSTRABISMIC BINOCULAR ANOMALIES

Optical correction of ametropia	Vision therapy for amblyopia
Added lens power	Vision therapy for suppression
Horizontal prism	Vision therapy for sensory motor function
Vertical prism	Surgery
Occlusion for amblyopia	

TABLE 11.2 SEQUENTIAL CONSIDERATIONS IN THE MANAGEMENT OF FUSIONAL VERGENCE DYSFUNCTION

Optical correction of ametropia	Vision therapy for sensory motor function
Vertical prism	Added lens power
Occlusion for amblyopia	Horizontal prism
Vision therapy for amblyopia	Surgery
Vision therapy for suppression	

TABLE 11.3 SEQUENTIAL CONSIDERATIONS IN THE MANAGEMENT OF BASIC ESODEVIATIONS

Optical correction of ametropia	Vision therapy for amblyopia
Vertical prism	Vision therapy for suppression
Added lens power	Vision therapy for sensory motor function
Horizontal prism	Surgery
Occlusion for amblyopia	

TABLE 11.4 SEQUENTIAL CONSIDERATIONS IN THE MANAGEMENT OF BASIC EXODEVIATIONS

Optical correction of ametropia	Vision therapy for suppression
Vertical prism	Vision therapy for sensory motor function
Added lens power	Horizontal prism
Occlusion for amblyopia	Surgery
Vision therapy for amblyopia	

Although amblyopia is uncommon in nonstrabismic binocular vision anomalies, it will occur if the phoria is associated with a significant degree of anisometropia. In such cases, one of the early considerations should be treatment of amblyopia using occlusion and vision therapy. The use of occlusion and specific vision therapy procedures for the treatment of the amblyopia and any associated suppression always needs to be considered immediately after prescribing for the anisometropia and considering prism to compensate for a vertical phoria. In cases of basic esophoria, basic exophoria, and fusional vergence dysfunction associated with anisometropia, we recommend part-time occlusion. Several (2 to 3) hours of occlusion, using an opaque patch along with active amblyopia therapy, are usually sufficient to resolve the amblyopia. Complete details regarding the evaluation and management of anisometropic amblyopia are provided in Chapter 17.

In most cases, however, amblyopia will not be present in nonstrabismic normal AC/A binocular disorders. Thus, after consideration of ametropia and prism, vision therapy for suppression and sensory and motor improvement is the next treatment issue.

The final sequential management consideration listed in Tables 11.2, 11.3, and 11.4 is surgery. Surgery is never necessary for fusional vergence dysfunction because it is always associated with a very small phoria. For basic esophoria and exophoria, surgery is also unlikely to be necessary. Generally, a combination of nonsurgical approaches will be effective. However, when the magnitude of the deviation is large and all nonsurgical approaches have been unsuccessful in relieving the patient's symptoms, surgery may occasionally be helpful.

PROGNOSIS FOR THE TREATMENT OF BINOCULAR VISION CONDITIONS ASSOCIATED WITH NORMAL AC/A RATIOS

All of the conditions described in this chapter can be very effectively treated using the management sequence we have suggested. Although there has been little research investigating the treatment of basic esophoria, there is no reason to believe that the combined use of lenses, prism, and vision therapy for basic esophoria should be any less effective than for other esodeviations, such as convergence excess and divergence insufficiency. Daum (1) studied the efficacy of vision training for improving the fusional vergence ranges of 34 asymptomatic adult subjects. He demonstrated significant increases in both positive fusional vergence (PFV) and negative fusional vergence (NFV), using tonic- and phasic-type activities. Thus, there is support for the use of vision therapy to improve NFV in basic esophoria.

Vision therapy has also been shown to be highly successful for basic exodeviations. Daum (2) found that 96% of his patients with basic exodeviations achieved either a total or partial cure with vision therapy. In addition, recent randomized clinical trials have demonstrated that vision therapy is highly successful at improving PFV (3–6).

Several authors have also investigated the effectiveness of vision therapy for fusional vergence dysfunction and general skills cases. Hoffman, Cohen, and Feuer (7) reported a 94% success rate for normalizing binocular findings and eliminating symptoms in such cases. Grisham (8,9) studied subjects with fusional vergence dysfunction and was able to demonstrate that vision therapy can be used to normalize vergence facility.

SUMMARY OF KEY POINTS IN TREATING PHORIA PATIENTS ASSOCIATED WITH NORMAL AC/A

Because of the normal AC/A ratio, added lenses have a moderate effect on the angle of deviation. For basic esophoria, added lenses may be quite helpful, although horizontal prism and vision therapy are often necessary as well. For basic exophoria and fusional vergence dysfunction, vision therapy tends to be the principal treatment modality.

Fusional Vergence Dysfunction

BACKGROUND INFORMATION

Unlike most of the other nonstrabismic binocular vision conditions described in this text, fusional vergence dysfunction is not part of Duane classification. Duane classification and description of binocular vision disorders centers around the AC/A ratio and the magnitude of the phoria at distance or near. It is primarily a classification of disorders in which the deviation is larger or smaller than the average 4 to 6 Δ of exophoria at near and orthophoria at distance. A patient who is symptomatic and has a phoria that falls within the normal range at both distance and near does not fit into any category in Duane classification.

Does such a condition exist? Are there patients who are symptomatic (after correction of refractive error) despite having normal phorias at distance and near and normal accommodative function? Many authors have described such a problem, although they have not consistently used the term *fusional vergence dysfunction* (7–12). Schapero (10) described the characteristics of the 10 basic visual training problems encountered in optometric practice. His ninth category is a condition in which tonic vergence is normal (normal phoria at distance), the AC/A ratio is normal, and both the PFV and NFV are low. He suggested that the etiology in such cases may be a sensory fusion problem, such as uncorrected refractive error or aniseikonia, a small vertical deviation, or some underlying systemic disease process. His recommendation is to rule out systemic disease and eliminate any obstacle to sensory fusion using lenses and prism. He stated that, in most cases, elimination of the sensory disturbance will lead to improved motor fusion without vision therapy.

Hoffman, Cohen, and Feuer (7) described a condition called a *general skills case*. According to the authors, this is a condition in which there is a small esophoria or exophoria with restricted fusional vergence ranges, inadequate saccades and pursuits, suppression, and normal accommodation. Other authors have essentially described the same set of characteristics and have used terms such as *inefficient binocular vision* (13) or *sensory fusion deficiency* (12).

Grisham (8,9) used the term *fusional vergence dysfunction* to describe a binocular vision disorder in which there are deficiencies in fusional vergence dynamics. In a laboratory setting, he used a haploscope to evaluate vergence latency, velocity, and tracking rate for both PFV and NFV. He was able to differentiate a group of patients with no significant phoria at either distance or near who exhibited deficits in response latency and velocity. He also demonstrated that one can identify such patients clinically by performing vergence facility testing. This test is described in Chapter 1.

We agree that clinically there is a condition in which the AC/A is normal, the phorias are within expected values for both distance and near, and the fusional vergence findings are restricted in both positive and negative directions. Sometimes, as Grisham (9) described, the smooth fusional vergence ranges are normal and only vergence facility testing is a problem. These patients also tend to have central suppression and complain of symptoms characteristic of other binocular vision disorders. We feel that the term used by Grisham (9), *fusional vergence dysfunction*, best describes this condition, and it is the term that we use in this text.

Fusional vergence dysfunction is an important diagnostic category, and it is a condition that can easily be missed or dismissed by clinicians not aware of this disorder. For example, a patient presents with asthenopic symptoms; no refractive error; normal eye health, accommodative function, and AC/A ratio; and distance and near phorias that are both within the normal range. In this situation, many clinicians may not even perform vergence testing because the phoria is normal at all distances. Given these findings, a clinician might tell this patient that there is no vision problem present to explain the symptoms. This presentation, however, is characteristic of fusional vergence dysfunction, and the diagnosis requires administration of both smooth vergence and vergence facility testing.

The prevalence of this condition has not been clearly established in our literature. Scheiman et al. (14) studied 1,650 children (ages 6 to 18 years) and found a prevalence of only 0.6%. Porcar and Martinez-Palomera (15) studied a university population and found a prevalence of 1.5%. Based on these two studies, it appears that this condition is considerably less common than convergence insufficiency or convergence excess.

CHARACTERISTICS

Symptoms

Most symptoms (Table 11.5) are associated with reading or other close work. Common complaints include eyestrain and headaches after short periods of reading, blurred vision, sleepiness, difficulty concentrating, and loss of comprehension over time. Some patients with fusional vergence dysfunction are asymptomatic. As discussed in Chapters 9 and 10, this absence of symptoms may be due to suppression, avoidance of near visual tasks, a high pain threshold, or occlusion of one eye when reading. Clinicians should always inquire about avoidance of reading or other near tasks if a patient with fusional vergence dysfunction reports an absence of symptoms. Avoidance is as important a reason for recommending therapy as any of the other symptoms associated with fusional vergence dysfunction.

Signs

See Table 11.5 for the signs of fusional vergence dysfunction.

Refractive Error

Although a clear trend has not been identified in the literature in regard to refractive error, in our experience most people with fusional vergence dysfunction do not have a significant degree of refractive error.

Characteristics of the Deviation

Patients with fusional vergence dysfunction have phorias that fall within the normal range, based on Morgan's table of expected findings. They are generally ortho at distance and have a small degree of exophoria or esophoria at near.

TABLE 11.5 SIGNS AND SYMPTOMS OF FUSIONAL VERGENCE DYSFUNCTION

Symptoms	
All of these symptoms are associated with reading or other sustained near work:	
Eyestrain	Problems with reading comprehension
Headaches	Excessive tearing
Inability to attend and concentrate	Blurred vision
Signs	
Normal AC/A ratio	
Normal phoria at distance and at near	
Reduced smooth positive and negative fusional vergence at distance and/or near	
Reduced positive and negative vergence facility	
Low positive relative accommodation	
Low negative relative accommodation	
Fails ± 2.00 on binocular accommodative facility testing	
Passes monocular accommodative facility	
Normal amplitude of accommodation	
Intermittent central suppression	

AC/A Ratio

A normal AC/A ratio is present in fusional vergence dysfunction.

ANALYSIS OF BINOCULAR AND ACCOMMODATIVE DATA

Because fusional vergence dysfunction is a disorder in which both PFV and NFV are reduced, it is important to perform all tests that either directly or indirectly assess vergence ranges and facility. Thus, direct tests of vergence amplitudes, such as smooth positive and negative vergence testing at distance and near, will tend to be lower than expected. If these findings are normal, it is important to evaluate vergence facility. It is possible to have normal smooth ranges and abnormal vergence facility.

Indirect tests of vergence, such as the negative relative accommodation (NRA), positive relative accommodation (PRA), and binocular accommodative facility (BAF), may also be reduced. In contrast to the other binocular conditions described in previous chapters, both the NRA and PRA will be low, and the patient will have difficulty with both plus and minus on BAF testing. Again, this result suggests problems with both PFV and NFV. Of course, low findings with the NRA, PRA, and BAF could also suggest an accommodative facility disorder. It is important, therefore, to perform monocular accommodative facility (MAF) testing. In fusional vergence dysfunction, the results on this test will be normal, confirming that the problem is in the area of vergence, not accommodation.

It is also common to find central intermittent suppression during binocular vision testing. This type of suppression can be detected during phoria, vergence, and BAF testing.

DIFFERENTIAL DIAGNOSIS

See Table 11.6 for the differential diagnosis of fusional vergence dysfunction.

Figure 2.2 illustrates the clinical reasoning process we suggest relative to the diagnosis of fusional vergence dysfunction. Because these patients tend to be symptomatic and the phoria is normal at all distances, the most likely hypothesis is an accommodative disorder. If accommodative testing is normal, the fusional vergence dysfunction becomes a likely hypothesis. We also suggest ruling out fixation disparity, latent hyperopia, cyclophoria, a small vertical deviation, and aniseikonia. Once these etiologic factors have been eliminated, fusional vergence dysfunction becomes the most likely diagnosis.

One condition that can be confused with fusional vergence dysfunction is accommodative infacility. As discussed in Chapter 12, accommodative infacility is a condition that has many of the same symptoms and signs as fusional vergence dysfunction. The key differential sign is that in fusional vergence dysfunction, all monocular accommodative testing is normal.

TABLE 11.6 DIFFERENTIAL DIAGNOSIS OF FUSIONAL VERGENCE DYSFUNCTION

Functional Disorders to Rule Out	Serious Underlying Disease to Rule Out
Accommodative infacility	Systemic disease causing debilitation
Latent hyperopia	Medication
Vertical or cyclodeviation	
Fixation disparity	
Aniseikonia	

TREATMENT

We recommend the management sequence listed in Table 11.2.

Lenses

The symptoms commonly found in fusional vergence dysfunction may also be present in patients with uncorrected refractive error or latent hyperopia. It is therefore important to eliminate latent hyperopia as a cause, by performing a cycloplegic refraction, and to correct any significant refractive error.

Prism

If a vertical deviation is present, we recommend that vertical prism be prescribed before vision therapy begins. The most effective method for determining the amount of vertical prism is the associated phoria, which can be measured with any fixation disparity device (Chapter 15).

The use of horizontal relieving base-in prism is not necessary in fusional vergence dysfunction because the phoria is normal at both distance and near.

Vision Therapy

A vision therapy program for fusional vergence dysfunction generally requires between 12 to 24 in-office visits, if vision therapy is office based. The total number of therapy sessions depends on the age of the patient and his or her motivation and compliance. Motivated adults can sometimes successfully complete vision therapy for fusional vergence dysfunction in 10 to 12 visits.

Specific Vision Therapy Program

All of the vision therapy techniques recommended below are described in detail in Chapters 6 to 8.

Phase 1

This first phase of therapy is designed to accomplish the objectives listed in Table 11.7 under Phase 1. As discussed in earlier chapters, it is important to develop a working relationship with the patient during the first few sessions and make the patient aware of the various feedback mechanisms that will be used throughout therapy. The basic approach used for fusional vergence dysfunction is to work toward establishing both normal PFV and NFV ranges and facility. Because it is generally easier to work with PFV, we suggest starting the therapy using convergence techniques.

The first goal of the therapy, therefore, is to teach the concept and feeling of converging. The patient should be able to voluntarily converge and diverge to any distance from 5 cm (2 in.) to 6 m (20 ft). Once the patient can voluntarily initiate a controlled convergence movement, the other goals of the vision therapy program become much easier to accomplish. Three commonly used procedures to accomplish this first objective are the Brock string, bug on string, and the red/green Barrel card.

Simultaneously try to normalize PFV amplitudes. The initial goal is to reestablish a normal vergence range for smooth- or tonic-type vergence demand. A smooth vergence demand is easier for the patient to accomplish in the early part of a vision therapy program (Chapter 5). Equipment that can be used to accomplish this objective includes the variable tranaglyphs, variable vectograms, and the Variable Prismatic Stereoscope from Bernell. These three devices can be used to create a smooth, gradual increase in convergence demand. As the patient begins to make progress with PFV, begin working with NFV as well, using the same techniques.

TABLE 11.7 OBJECTIVES OF VISION THERAPY FOR FUSIONAL VERGENCE DYSFUNCTION**Phase 1**

- Develop a working relationship with the patient
- Develop an awareness of the various feedback mechanisms that will be used throughout therapy
- Develop voluntary convergence and divergence
- Normalize positive and negative fusional vergence amplitudes (smooth or tonic vergence demand)
- Normalize accommodative amplitude and ability to stimulate and relax accommodation

Phase 2

- Normalize positive fusional vergence facility (jump or phasic vergence demand)
- Normalize negative fusional vergence facility (jump or phasic vergence demand)

Phase 3

- Develop ability to change from a convergence to a divergence demand
- Integrate vergence procedures with changes in accommodative demand
- Integrate vergence procedures with versions and saccades

By definition, patients with a diagnosis of fusional vergence dysfunction do not have accommodative problems. Nevertheless, accommodative training techniques are often useful in the initial phase of therapy because they can aid in the process of establishing the feeling of looking close and far and of converging and diverging. Certainly, if the patient has an accommodative disorder in addition to the fusional vergence dysfunction, accommodative techniques are important. Accommodative techniques are described in Chapter 7. Lens sorting, loose lens rock, and Hart chart procedures are commonly used in this first phase of therapy.

Endpoint. Phase 1 of therapy ends when the patient can:

- Demonstrate voluntary convergence
- Fuse to about 30 base-out and 15 base-in using a tranaglyph or other comparable technique
- Complete 12 cpm of accommodative facility with +2.00/−2.00 lenses using a 20/30 target.

A sample vision therapy program for phase 1 is summarized in Table 11.8. This program includes several techniques that can be used by the patient at home to supplement the in-office therapy.

Phase 2

This second phase of therapy is designed to accomplish the objectives listed in Table 11.7 under Phase 2. Once smooth PFV and NFV are normalized, phasic or jump vergence demand should be emphasized. Variable tranaglyphs and vectograms can still be used. However, the specific modifications to create a step vergence demand (described in Chapter 6) must be implemented. These include the following:

- Changing fixation from the target to another point in space
- Covering and uncovering one eye
- Loose prism or flip prism
- Flip lenses to create a step vergence change in vergence demand
- Two different tranaglyphs set up in a dual Polachrome illuminated trainer
- Polaroid or red/green flippers.

Other valuable techniques at this stage are nonvariable tranaglyphs, the Aperture Rule, Eccentric Circles, Free Space Fusion cards, Lifesaver cards, and Computer Orthoptics jump vergence activities.

In contrast with phase 1, in which speed was not a factor, during this second phase of therapy the emphasis should be on the qualitative aspects (speed, accuracy) of fusion rather than the quantitative (magnitude) aspects. It is important to increase the speed of the fusional vergence response and the quality of the recovery of fusion.

Endpoint. The endpoint of phase 2 is reached when the patient can:

- Fuse card 12 using convergence and card 6 using divergence with the Aperture Rule
- Fuse the Eccentric Circles or Free Space Fusion cards using convergence (12 cm separation) and divergence (6 cm separation).

A sample vision therapy program for phase 2 is summarized in Table 11.8. This program includes several techniques that can be used by the patient at home to supplement the in-office therapy.

TABLE 11.8 SAMPLE VISION THERAPY PROGRAM FOR FUSIONAL VERGENCE DYSFUNCTION

Phase 1
<p><i>Sessions 1 and 2</i> IN-OFFICE</p> <ul style="list-style-type: none"> • Discuss nature of vision problem, goals of vision therapy, various feedback cues, importance of practice • Brock string • Lens sorting • Loose lens rock (begin with plus if accommodative excess, with minus if accommodative insufficiency) • Tranaglyphs or vectograms: convergence <ul style="list-style-type: none"> • Begin with a peripheral target such as tranaglyph 515 or the Quoit vectogram • Computer Orthoptics Random Dot program: convergence home therapy
<p>HOME THERAPY</p> <ul style="list-style-type: none"> • HTS Vergence and Accommodation programs • Brock string
<p><i>Sessions 3 and 4</i> IN-OFFICE</p> <ul style="list-style-type: none"> • Bug on string • Loose lens rock • Tranaglyphs or vectograms: convergence and divergence <ul style="list-style-type: none"> • Use targets with more central demand (Clown, Bunny tranaglyphs; Clown, Topper vectograms) • Computer Orthoptics Random Dot program: convergence and divergence
<p>HOME THERAPY</p> <ul style="list-style-type: none"> • HTS Vergence and Accommodation programs • Loose lens rock
<p><i>Sessions 5 through 8</i> IN-OFFICE</p> <ul style="list-style-type: none"> • Barrel card • Voluntary convergence • Loose lens rock • Tranaglyphs or vectograms: convergence and divergence <ul style="list-style-type: none"> • Use even more detailed targets such as tranaglyph Sports Slide and Faces targets and the Spirangle vectogram • Computer Orthoptics Random Dot program: convergence and divergence
<p>HOME THERAPY</p> <ul style="list-style-type: none"> • HTS Vergence and Accommodation programs
Phase 2
<p><i>Sessions 9 and 10</i> IN-OFFICE</p> <ul style="list-style-type: none"> • Tranaglyphs or vectograms with modifications to create jump vergence demand: convergence • Nonvariable tranaglyphs: convergence • Binocular accommodative therapy techniques: use any of the binocular techniques listed above with \pm lenses
<p>HOME THERAPY</p> <ul style="list-style-type: none"> • HTS Vergence and Accommodation programs
<p><i>Sessions 11 and 12</i> IN-OFFICE</p> <ul style="list-style-type: none"> • Tranaglyphs or vectograms with modifications to create jump vergence demand: convergence and divergence • Aperture Rule: convergence and divergence • Binocular accommodative therapy techniques: use any of the binocular techniques listed above with \pm lenses
<p>HOME THERAPY</p> <ul style="list-style-type: none"> • HTS Vergence and Accommodation programs
<p><i>Sessions 13 through 16</i> IN-OFFICE</p> <ul style="list-style-type: none"> • Aperture Rule: convergence and divergence • Eccentric Circles or Free Space Fusion cards: convergence and divergence • Computer Orthoptics Random Dot Vergence program: both divergence and convergence • Binocular accommodative therapy techniques: use any of the binocular techniques listed above with \pm lenses

(Continued)

TABLE 11.8 CONTINUED

HOME THERAPY <ul style="list-style-type: none"> • HTS Vergence and Accommodation programs • Eccentric Circles or Free Space Fusion cards
Phase 3
<i>Sessions 17 through 20</i>
IN-OFFICE <ul style="list-style-type: none"> • Tranaglyphs or vectograms with Polaroid or red/green flippers • Eccentric Circles or Free Space Fusion cards • Computer Orthoptics Random Dot Vergence program: step–jump vergence
HOME THERAPY <ul style="list-style-type: none"> • HTS Vergence and Accommodation programs • Eccentric Circles or Free Space Fusion cards: convergence
<i>Sessions 21 and 22</i>
IN-OFFICE <ul style="list-style-type: none"> • Tranaglyphs or vectograms with Polaroid or red/green flippers • Eccentric Circles or Free Space Fusion cards • Lifesaver cards • Computer Orthoptics Random Dot Vergence program: jump–jump vergence
HOME THERAPY <ul style="list-style-type: none"> • HTS Vergence and Accommodation programs • Eccentric Circles or Free Space Fusion cards: divergence
<i>Sessions 23 and 24</i>
IN-OFFICE <ul style="list-style-type: none"> • Tranaglyphs or vectograms with Polaroid or red/green flippers • Eccentric Circles or Free Space Fusion cards with rotation and versions • Lifesaver cards with rotation and version • Computer Orthoptics Vergence program with rotation
HOME THERAPY <ul style="list-style-type: none"> • HTS Vergence and Accommodation programs • Eccentric Circles or Free Space Fusion cards: divergence/convergence

Phase 3

This third phase of therapy is designed to accomplish the objectives listed in Table 11.7 under Phase 3. Until this point, the patient has either worked separately with convergence techniques or divergence techniques. Now the objective is to develop the patient's ability to change from a convergence to a divergence demand and to integrate vergence procedures with versions. Several excellent procedures are available to help accomplish this objective. Vectograms with Polaroid flippers or tranaglyphs with red/green flippers can be used. Each time the flippers are changed, the demand switches from divergence to convergence. The transparent Keystone Eccentric Circles or transparent Bernell Free Space Fusion cards are excellent, inexpensive methods for achieving this objective. The patient has already learned, by this time, to fuse these cards with a divergence or convergence demand separately. Now the patient is taught to switch from convergence and then back to divergence. As this skill improves, speed or the number of cycles per minute is emphasized.

The final objective of therapy is to integrate vergence procedures with versions and saccades. Under normal seeing conditions, patients are constantly trying to maintain accurate vergence while changing fixation from one location to another. It is therefore important to combine vergence therapy with versions and saccades. Techniques such as the Brock string with rotation and Eccentric Circles and Free Space Fusion cards or Lifesaver cards with rotation or lateral movements and saccades can be used to accomplish this goal. The Computer Orthoptics program that combines horizontal vergence with rotation is also useful for this objective.

Endpoint. The endpoint for Phase 3 is reached when the patient can:

- Maintain clear single binocular vision with the Eccentric Circles and Free Space Fusion cards held together, while slowly rotating the cards and converging and diverging.

Because the objectives of vision therapy are to eliminate the patient's symptoms and normalize binocular and accommodative findings, a reevaluation should be performed about halfway through the therapy program

and again at the end of therapy. A reference point for determining when to perform the first reevaluation is when the patient can begin working with jump vergence techniques, such as the Aperture Rule. During these evaluations, the clinician should refer to the original complaints and determine whether the patient is now comfortable. All tests of binocular and accommodative function should be repeated and compared to the initial findings as well as the expected findings.

When all vision therapy objectives have been reached and the vision therapy program is completed, we recommend the home vision therapy maintenance program outlined in Table 9.10.

Summary of Vision Therapy for Fusional Vergence Dysfunction

The sample vision therapy program described above and outlined in Table 11.8 represents one approach that will lead to successful elimination of a patient's symptoms and normalization of optometric data. The number of sessions is approximate and will vary from one patient to another. Remember that it is often not necessary to work with every procedure suggested in this chapter. The objective is to achieve a successful result as quickly as possible. If it becomes apparent that a recommended procedure is easy for the patient, go on to the next technique.

Surgery

Surgery is unnecessary in fusional vergence dysfunction.

CASE STUDY

The following case study (Case 11.1) is representative of the fusional vergence dysfunction patients that clinicians will encounter in practice.

Case 11.1

History

John, a 16-year-old junior in high school, presented with complaints of eyestrain and blurry vision after about 20 minutes of reading. He has had these problems for several years, but in his previous visits to eye doctors, no one has been able to help him. The last doctor who examined him, about 1 year ago, gave him reading glasses. John did not feel that these helped and stopped wearing them after about 4 weeks. His medical history was negative, and he was not taking any medication.

Examination Results

Previous prescription:	+0.50
	+0.50
IPD:	62 mm
VA (distance, uncorrected):	OD: 20/20
	OS: 20/20
VA (near, uncorrected):	OD: 20/20
	OS: 20/20
Near point of convergence	
Accommodative target:	5 cm
Penlight:	5 cm
Cover test (distance):	Orthophoria
Cover test (near):	2 exophoria
Subjective:	OD: +0.25 – 0.25 × 180, 20/20
	OS: +0.25 – 0.25 × 180, 20/20
Cycloplegic:	OD: +0.75 – 0.25 × 180, 20/20
	OS: +0.75 – 0.25 × 180, 20/20

Distance lateral phoria:	Orthophoria
Base-in vergence (distance):	X/4/2
Base-out vergence (distance):	6/10/6
Near lateral phoria:	3 exophoria
–1.00 gradient:	1 esophoria
Gradient AC/A ratio:	4:1
Calculated AC/A ratio:	4.8:1
Base-in vergence (near):	4/8/6
Base-out vergence (near):	6/10/2
Vergence facility:	3 cpm, difficulty with base-out and base-in
NRA:	+1.50
PRA:	–1.25
Accommodative amplitude (push-up):	OD: 11 D; OS: 11 D
MAF:	OD: 11 cpm; OS: 11 cpm
BAF:	2 cpm
Monocular estimation method (MEM) retinoscopy:	+0.25

Pupils were normal, all external and internal health tests were negative, the deviation was comitant, and color vision testing revealed normal function.

Case Analysis

Because the phoria was normal at both distance and near, the most likely cause for John's symptoms was an accommodative disorder. Analysis of the results of accommodative testing revealed a normal amplitude facility and accommodative response. The NRA and PRA were both low, but, given the normal accommodative function, these findings reflected a problem with fusional vergence. The next most likely hypothesis was fusional vergence dysfunction. Both PFV and NFV findings were reduced on direct measures and indirect tests of fusional vergence. The low NRA, PRA, and reduced BAF results suggested problems with fusional vergence. These findings led to a diagnosis of fusional vergence dysfunction.

Management

We advised John that the previous prescription would not relieve his problem. The ametropia was considered insignificant, and because there was no vertical deviation, glasses were not prescribed. We prescribed a program of vision therapy to normalize his fusional vergence findings and eliminate symptoms.

John was seen twice a week and was also given home vision therapy procedures to practice. We followed the sequence outlined in Table 11.8, and 16 visits of in-office vision therapy were necessary to achieve a successful result. At the end of therapy, John reported that he was able to read for as long as he wanted without any discomfort.

A reevaluation after 16 visits revealed the following findings:

Base-out vergence (distance):	X/20/16
Near lateral phoria:	2 exophoria
Base-in vergence (near):	14/26/22
Base-out vergence (near):	20/32/28
Vergence facility	14 cpm
NRA:	+2.50
PRA:	–2.50
BAF:	11 cpm

The maintenance program suggested in Table 9.10 was followed, and a reevaluation in 6 months revealed that John continued to feel comfortable and his findings remained normal.

Basic Esophoria

BACKGROUND INFORMATION

Basic esophoria was first described by Duane (16). It is a condition in which tonic vergence is high and the AC/A ratio is normal. As a result, there is an equal amount of esophoria at distance and near, with reduced NFV at both distances.

The prevalence of this condition has not been clearly established in the literature. Scheiman et al. (14) studied 1,650 children (ages 6 to 18 years) and found a prevalence of only 0.7%. Porcar and Martinez-Palomera (15) studied a university population and found a prevalence of 1.5%.

CHARACTERISTICS

Symptoms

Because esophoria is present at all distances, patients may present with symptoms associated with reading and other close work, as well as symptoms associated with distance activities. Common reading and near point complaints include eyestrain, headaches, blurred vision, diplopia, sleepiness, difficulty concentrating, and loss of comprehension over time (Table 11.9). Problems associated with distance include blurred vision and diplopia when driving and when watching television and movies, as well as in a classroom situation. As in other binocular vision disorders, it is possible for patients to have basic esophoria and yet be asymptomatic.

Signs

Signs of basic esodeviations are presented in Table 11.9.

Refractive Error

Basic esophoria is often associated with hyperopia. This is a desirable characteristic because, with a normal AC/A ratio, correction of the hyperopia will lead to a decrease in the magnitude of the esophoria at both near and at distance.

Characteristics of the Deviation

Patients with basic esophoria have an equal amount of esophoria at distance and at near, with decreased NFV at both distances. Generally, if the deviations are within 5 Δ of one another, they are considered equal. The

TABLE 11.9 SIGNS AND SYMPTOMS OF BASIC ESO DeviATIONS

Signs	Symptoms
Esophoria equal at distance and near	Long-standing
Normal AC/A ratio (calculated method)	Headaches
Hyperopia often present	Eyestrain
Direct tests of negative fusional vergence at both distance and near	Blurred vision
Low step vergence	
Low smooth vergence	
Low jump vergence	
Indirect tests of negative fusional vergence at near	
Low positive relative accommodation	
Low binocular accommodative facility testing with minus lenses	
High monocular estimation method retinoscopy	

deviation can be a phoria, an intermittent strabismus, or a constant strabismus. There is little information in the literature, however, about the prevalence of these various forms of basic esophoria. In our experience, most cases of basic esophoria are either heterophorias or intermittent strabismics.

AC/A Ratio

A normal AC/A ratio is always present in basic esophoria. This is well accepted, based on the calculated AC/A, and is an important factor when treatment is considered.

ANALYSIS OF BINOCULAR AND ACCOMMODATIVE DATA

As illustrated in Figure 2.3, the entry point into the analysis of data for basic esophoria is the esodeviation at both distances. Direct tests of NFV, at both distance and near, will be low in basic esophoria (Table 11.9). This includes step-, smooth-, and jump-type vergences. In addition, all near point tests that indirectly assess NFV (Table 11.9) will be low. Tests performed binocularly with minus lenses evaluate the patient's ability to stimulate accommodation and control binocular alignment using NFV. Two examples are the PRA and BAF testing with minus lenses. A characteristic finding in basic esophoria is a report of diplopia, rather than blur, on the PRA and BAF testing. In fact, it is important to specifically ask about diplopia when performing these tests on a patient suspected of having basic esophoria.

Another important indirect test of NFV is monocular estimate method (MEM) retinoscopy. It is not unusual to find an abnormal result on this test in basic esophoria. An MEM finding of greater plus than expected suggests that the patient is using as little accommodation as possible to decrease the use of accommodative convergence. This reduces the demand on NFV.

DIFFERENTIAL DIAGNOSIS

The differential diagnosis of basic esodeviation is presented in Table 11.10. Basic esophoria is considered to be a benign condition with no serious consequences other than the visual symptoms listed in Table 11.10. It is relatively easy to differentiate from other binocular vision disorders associated with esophoria, such as convergence excess (greater esophoria at near) and divergence insufficiency (greater esophoria at distance).

Basic esophoria or esophoria at near can also be associated with more serious underlying conditions. Of particular importance is the history. As we have stated previously, an acute onset of a binocular vision problem is suspicious. The sudden onset of esophoria warrants consideration of problems such as sixth nerve palsy and divergence paralysis.

Summary

A serious underlying etiology must be ruled out in all cases of basic esophoria. This differential diagnosis depends very much on the nature of the patient's symptoms. Typically, basic esophoria presents with long-standing chronic complaints. The health history is negative, and the patient is not taking any medication known to affect accommodation. Basic esophoria associated with serious underlying disease has an acute onset, and medical problems or neurologic symptoms are usually present. The primary functional disorders that must be differentiated from true basic esophoria are convergence excess and divergence insufficiency.

When managing a case of basic esophoria that is thought to have a functional basis, if symptoms and findings do not improve as expected, it is wise to reconsider the etiology of the condition.

TABLE 11.10 DIFFERENTIAL DIAGNOSIS OF BASIC ESODEVIAATION

Functional Disorders to Rule Out	Serious Underlying Disease to Rule Out
Divergence insufficiency	Sixth nerve palsy
Convergence excess	Divergence paralysis

TREATMENT

We recommend following the management sequence listed in Table 11.3.

Lenses

With basic esophoria, it is important to prescribe maximum plus if a significant degree of hyperopia is present. It is best to perform a cycloplegic examination before determining the prescription.

Added Lenses

Because of the normal AC/A ratio, the use of added plus lenses at near is moderately effective in cases of basic esophoria. Chapter 3 discussed the important clinical data that are used to determine whether additional plus should be prescribed. Although the AC/A ratio is the key finding, it is important to consider all of the data listed in Table 11.11.

How Much Additional Plus Should Be Prescribed

When prescribing added plus lenses, the objective is to determine the lowest amount of plus that will eliminate the patient's symptoms and normalize optometric data. A variety of methods have been suggested for calculating the amount of additional plus to prescribe for patients with basic esophoria. Some of the more popular methods are analysis of the NRA/PRA relationship, MEM retinoscopy or other near point retinoscopy, use of the AC/A ratio, and fixation disparity analysis. We advocate the use of a group of findings rather than relying on any one test. As discussed in Chapter 3, reliance on any one test may be misleading at times. The optometric data listed in Table 11.11 can be used to determine the amount of plus to prescribe.

Prism

If a vertical deviation is present, we recommend that vertical prism be prescribed. The most effective method for determining the amount of vertical prism is the associated phoria, which can be measured with any fixation disparity device (Chapter 15).

Because of the normal AC/A ratio, the use of lenses alone will not always be effective. This is particularly true when there is no significant degree of hyperopia. In such cases, horizontal relieving prism certainly should be considered. If a base-out prism prescription is being considered, fixation disparity testing is the most effective method for determining the amount of horizontal prism (Chapter 15).

Vision Therapy

If basic esophoria is not associated with hyperopia, vision therapy is generally necessary. Other important variables include the status of NFV and the magnitude of the esophoria. The larger the degree of esophoria

TABLE 11.11 CONSIDERATIONS FOR PRESCRIBING ADDED PLUS LENSES

Test	Consider the Use of Added Plus	Added Plus Not Indicated
AC/A ratio	High	Low
Refractive error	Hyperopia	Myopia
Near phoria	Esophoria	Exophoria
Negative relative accommodation (NRA)/ positive relative accommodation (PRA)	Low PRA	Low NRA
Base-out at near	Normal to high	Low
Monocular estimation method (MEM) retinoscopy	High	Low
Amplitude of accommodation	Low	Normal
Accommodative facility testing	Fails –	Fails +

at distance and near, the more likely it is that vision therapy will be necessary. A vision therapy program for basic esophoria generally requires from 12 to 24 in-office visits. The total number of therapy sessions depends on the age of the patient and his or her motivation and compliance.

The vision therapy program for basic esophoria is similar to that recommended for convergence excess in Chapter 10, except that during phases 2 and 3, therapy is performed at intermediate and far distances.

Specific Vision Therapy Program

All of the vision therapy techniques recommended below are described in detail in Chapters 6 to 8.

Phase 1

This first phase of therapy is designed to accomplish the objectives listed in Table 11.12 under Phase 1. The first goal of the therapy itself is to teach the concept and feeling of diverging, and the ability to accurately diverge. The patient should be able to voluntarily converge and diverge to any distance from 5 cm (2 in.) to 6 m (20 ft). Commonly used procedures to accomplish this first objective are the Brock string and bug on string.

Basic esophoria patients generally have very limited base-in blur, break, and recovery findings. Therefore, another objective of the first phase of vision therapy is to normalize NFV amplitudes. The initial goal is to reestablish a normal vergence range for smooth- or tonic-type vergence demand.

In some cases of basic esophoria in presbyopes, an accommodative problem may also be present. If so, the final objective of the first phase of therapy is to normalize accommodative amplitude and the ability to stimulate and relax accommodation. If, however, accommodative function is normal, there is generally no need to spend a lot of time working with the accommodative system. Lens sorting, loose lens rock, and Hart chart procedures are commonly used in this first phase of therapy.

Endpoint. Phase 1 of therapy ends when the patient can:

- Accurately diverge using the Brock string to 3 m (10 ft)
- Fuse to about 15 base-in with a tranaglyph or other comparable technique
- Complete 12 cpm of accommodative facility with +2.00/−2.00 lenses using a 20/30 target.

A sample vision therapy program for phase 1 is summarized in Table 11.13.

Phase 2

This second phase of therapy is designed to accomplish the objectives listed in Table 11.12 under Phase 2. Once smooth NFV is normalized, phasic or jump vergence demand should be emphasized. Variable

TABLE 11.12 OBJECTIVES OF VISION THERAPY FOR BASIC ESO DeviATIONS

Phase 1

- Develop a working relationship with the patient
- Develop an awareness of the various feedback mechanisms that will be used throughout therapy
- Develop the feeling of diverging
- Normalize negative fusional vergence (NFV) amplitudes (smooth or tonic vergence demand)
- Normalize accommodative amplitude and ability to stimulate and relax accommodation

Phase 2

- Normalize positive fusional vergence (PFV) amplitudes (smooth or tonic vergence demand)
- Normalize NFV facility (jump or phasic vergence demand)
- Normalize PFV facility (jump or phasic vergence demand)
- Normalize NFV at intermediate distances

Phase 3

- Develop ability to change from a convergence to a divergence demand
- Integrate vergence procedures with changes in accommodative demand
- Integrate vergence procedures with versions
- Normalize NFV at distance

TABLE 11.13 SAMPLE VISION THERAPY PROGRAM FOR BASIC ESODEVIATIONS

Phase 1
<p><i>Sessions 1 and 2</i> IN-OFFICE</p> <ul style="list-style-type: none"> • Discuss nature of vision problem, goals of vision therapy, various feedback cues, importance of practice • Brock string; concentrate on developing feeling of diverging • Lens sorting • Loose lens rock (begin with plus if accommodative excess, with minus if accommodative insufficiency) • Tranaglyphs or vectograms: divergence <ul style="list-style-type: none"> • Begin with a peripheral target such as tranaglyph 515 or the Quoit vectogram • Computer Orthoptics Random Dot program: divergence
<p>HOME THERAPY</p> <ul style="list-style-type: none"> • HTS Vergence and Accommodation programs • Brock string
<p><i>Sessions 3 and 4</i> IN-OFFICE</p> <ul style="list-style-type: none"> • Bug on string; concentrate on feeling of diverging • Loose lens rock • Tranaglyphs or vectograms: divergence <ul style="list-style-type: none"> • Use targets with more central demand (Clown, Bunny tranaglyphs; Clown, Topper vectograms) • Computer Orthoptics Random Dot program: divergence
<p>HOME THERAPY</p> <ul style="list-style-type: none"> • HTS Vergence and Accommodation programs • Loose lens rock
<p><i>Sessions 5 through 8</i> IN-OFFICE</p> <ul style="list-style-type: none"> • Loose lens rock • Tranaglyphs or vectograms: divergence <ul style="list-style-type: none"> • Use even more detailed targets such as tranaglyph Sports Slide and Faces targets and the Spirangle vectogram • Computer Orthoptics Random Dot program: divergence
<p>HOME THERAPY</p> <ul style="list-style-type: none"> • HTS Vergence and Accommodation programs
Phase 2
<p><i>Sessions 9 and 10</i> IN-OFFICE</p> <ul style="list-style-type: none"> • Tranaglyphs or vectograms with modifications to create jump vergence demand: divergence • Nonvariable tranaglyphs • Tranaglyph 515 or the Quoit vectogram: convergence • Binocular accommodative therapy techniques: use any of the binocular techniques listed above with \pm lenses
<p>HOME THERAPY</p> <ul style="list-style-type: none"> • HTS Vergence and Accommodation programs
<p><i>Sessions 11 and 12</i> IN-OFFICE</p> <ul style="list-style-type: none"> • Tranaglyphs or vectograms with modifications to create jump vergence demand: divergence • Aperture Rule: divergence • More central tranaglyphs or the vectograms: convergence • Binocular accommodative therapy techniques: use any of the binocular techniques listed above with \pm lenses
<p>HOME THERAPY</p> <ul style="list-style-type: none"> • HTS Vergence and Accommodation programs
<p><i>Sessions 13 through 16</i> IN-OFFICE</p> <ul style="list-style-type: none"> • Aperture Rule: divergence and convergence • Eccentric Circles or Free Space Fusion cards: divergence • Computer Orthoptics Random Dot Vergence program: both divergence and convergence • Tranaglyphs or vectograms with modifications to create jump vergence demand: convergence • Tranaglyphs or vectograms at 1 m

(Continued)

TABLE 11.13 CONTINUED

HOME THERAPY <ul style="list-style-type: none"> • HTS Vergence and Accommodation programs • Eccentric Circles or Free Space Fusion cards: divergence
Phase 3
<i>Sessions 17 through 20</i>
IN-OFFICE <ul style="list-style-type: none"> • Tranaglyphs or vectograms with Polaroid or red/green flippers • Eccentric Circles or Free Space Fusion cards • Computer Orthoptics Random Dot Vergence program: step–jump vergence • Tranaglyphs or vectograms at 1 m • Eccentric Circles or Free Space Fusion cards: divergence at 1 m • Computer Orthoptics Random Dot Vergence program: step–jump vergence at 1 m
HOME THERAPY <ul style="list-style-type: none"> • HTS Vergence and Accommodation programs • Eccentric Circles or Free Space Fusion cards: divergence
<i>Sessions 21 and 22</i>
IN-OFFICE <ul style="list-style-type: none"> • Tranaglyphs or vectograms with Polaroid or red/green flippers • Eccentric Circles or Free Space Fusion cards • Lifesaver cards • Computer Orthoptics Random Dot Vergence program: jump–jump vergence • Tranaglyphs or vectograms projected with overhead projector • Large Eccentric Circles at distance
HOME THERAPY <ul style="list-style-type: none"> • HTS Vergence and Accommodation programs • Eccentric Circles or Free Space Fusion cards: convergence and divergence
<i>Sessions 23 and 24</i>
IN-OFFICE <ul style="list-style-type: none"> • Tranaglyphs or vectograms with Polaroid or red/green flippers • Eccentric Circles or Free Space Fusion cards with rotation and versions • Lifesaver cards with rotation and versions • Computer Orthoptics Vergence program with rotation • Tranaglyphs or vectograms projected with overhead projector • Large Eccentric Circles at distance
HOME THERAPY <ul style="list-style-type: none"> • HTS Vergence and Accommodation programs • Eccentric Circles or Free Space Fusion cards: divergence and convergence

tranaglyphs and vectograms can still be used. However, the specific modifications to create a step vergence demand (described in Chapter 6) must be implemented. Valuable techniques at this stage are the nonvariable tranaglyphs, the Aperture Rule, Eccentric Circles, Free Space Fusion cards, Lifesaver cards, and Computer Orthoptics jump vergence activities.

In contrast with phase 1, in which speed was not a factor, during this second phase of therapy the emphasis should be on the qualitative aspects of fusion rather than magnitude. It is important to increase the speed of the fusional vergence response and the quality of the recovery of fusion.

A second objective of this phase of therapy is to begin working with PFV amplitudes. The same techniques used in phase 1 to work with NFV are repeated for PFV. During the end of this phase of therapy, begin to incorporate PFV facility-type techniques, using the same procedures as listed above for jump vergence demand for NFV.

Finally, an important objective of this phase of therapy is to begin performing the treatment at intermediate distances. Now that the patient can successfully work with the various instruments and procedures at near, it is usually very easy to repeat similar techniques at greater distances. A very effective procedure is to use tranaglyphs projected on the wall or a screen by an overhead projector. This technique works well because the patient is very familiar with the task and simply has to try to apply the same skills learned during earlier sessions.

Another method of presenting stimuli at intermediate distances is through the use of stereoscopes. The working distance can be conveniently changed on most Brewster-type stereoscopes, and a wide variety of targets is readily available.

Endpoint. The endpoint of phase 2 is reached when the patient can:

- Fuse card 12 using convergence and card 6 using divergence with the Aperture Rule
- Fuse the Eccentric Circles or Free Space Fusion cards using convergence (12 cm separation) and divergence (6 cm separation)
- Fuse up to 20 Δ base-out and 10 Δ base-in with tranaglyph targets projected at 3 m (10 ft) using the overhead projector.

A sample vision therapy program for phase 2 is summarized in Table 11.13.

Phase 3

This third phase of therapy is designed to accomplish the objectives listed in Table 11.12 under Phase 3. Until this point, the patient has worked in the convergence or divergence directions separately. Now the objective is to develop the patient's ability to change from a convergence to a divergence demand and to integrate vergence procedures with versions and saccades. Several excellent procedures are available to help accomplish these objectives. Vectograms with Polaroid flippers or tranaglyphs with red/green flippers can be used. Each time the flippers are changed, the demand switches from divergence to convergence. The transparent Keystone Eccentric Circles or transparent Bernell Free Space Fusion cards are excellent, inexpensive methods for achieving this objective.

Another objective of therapy is to integrate vergence procedures with versions and saccades. Techniques such as the Brock string with rotation, Eccentric Circles and Free Space Fusion cards with rotation and/or lateral movements, and the Lifesaver cards with rotation can be used to accomplish this goal. The Computer Orthoptics program that combines horizontal vergence with rotation is also useful for this objective.

The final objective of this final phase of therapy is to work with divergence at distances of 3 to 6 m. The same procedures used at 1.5 m to 3 m (5 to 10 ft) during phase 2 can be repeated at even greater distances. In addition, the techniques recommended for training the divergence excess patient at distance can be used (Chapter 10).

Endpoint. The endpoint for phase 3 is reached when the patient can:

- Maintain clear single binocular vision with the Eccentric Circles and Free Space Fusion cards held together, while slowly rotating the cards and performing convergence and divergence therapy
- Maintain clear single binocular vision with the large Eccentric Circles and other targets at distance.

When all vision therapy objectives have been reached, the vision therapy program is complete, and we recommend the home vision therapy maintenance program outlined in Table 9.10 and described in Chapter 9.

Summary of Vision Therapy for Basic Esophoria

The phases and objectives outlined above and in Tables 11.12 and 11.13 represent one approach that will lead to successful elimination of a patient's symptoms and normalization of optometric data. The number of sessions is approximate and will vary from one patient to another.

Surgery

The use of lenses, prism, and vision therapy in the treatment of basic esophoria is so successful that surgery is virtually never necessary.

CASE STUDY

The following case study (Case 11.2) is representative of the basic esophoria patients that clinicians will encounter in practice.

Case 11.2

History

Susan, a 14-year-old ninth grader, presented with a complaint of intermittent double vision in school. The double vision was worse when she was looking up at the teacher or chalkboard. She had complained on and off about this problem for several years, but had not received any treatment. Her mother remembered that when Susan was about 2 or 3 years old, she brought her to an eye doctor because her eyes looked crossed. The doctor said that Susan had a mild eye turn and would outgrow it. Her health was normal, and she was not taking any medication.

Examination Results

VA (distance, uncorrected):	OD: 20/20 OS: 20/20
VA (near, uncorrected):	OD: 20/20 OS: 20/20
Near point of convergence:	5 cm
Cover test (distance):	16 Δ esophoria
Cover test (near):	14 Δ esophoria
Subjective:	OD: +1.00, 20/20 OS: +1.00, 20/20
Cycloplegic:	OD: +1.50 OS: +1.50
Distance lateral phoria:	18 esophoria
Base-in vergence (distance):	Diplopia; needs 8 base-out to fuse
Base-out vergence (distance):	Diplopia; needs 8 base-out to fuse, breaks at 26 base-out, and recovers at 18 base-out
Near lateral phoria:	16 esophoria
−1.00 gradient:	22 esophoria
Gradient AC/A ratio:	6:1
Calculated AC/A ratio:	5:1
Base-in vergence (near):	X/2/−4
Base-out vergence (near):	X/28/20
Vergence facility:	0 cpm, diplopia with base in
NRA:	+2.50
PRA:	−0.25
Accommodative amplitude (push-up):	OD: 12 D; OS: 12 D
MAF:	OD: 10 cpm; OS: 10 cpm
BAF:	Diplopia with −2.00
MEM retinoscopy:	+1.50 OU

Fixation disparity testing with the American Optical vectographic slide at distance revealed an associated phoria of 4 base-out.

Pupils were normal, all external and internal health tests were negative, the deviation was comitant, and color vision testing revealed normal function.

Case Analysis

The entry point into analysis of the data in this case is the large magnitude esophoria at distance and near. NFV at both distance and near is very reduced, with diplopia on base-in testing at distance. The

equal magnitude esophoria at distance and near, reduced NFV, poor vergence facility, and normal AC/A ratio clearly suggest a diagnosis of basic esophoria.

Management

Following the management sequence in Table 11.3, we prescribed for the full amount of hyperopia, which reduced the angle of deviation to about 12 Δ at distance and 10 Δ at near. Based on the fixation disparity results, we also prescribed 4 base-out prism. The final prescription given was OD +1.00 and OS +1.00, with a +1.00 add and 2 base-out in each eye. Susan wore these glasses for 4 weeks and returned for reevaluation. She reported relief of symptoms, and no further treatment was necessary.

Basic Exophoria

BACKGROUND INFORMATION

Basic exophoria was first described by Duane (16). It is a condition in which tonic vergence is low and the AC/A ratio is normal. As a result, there is an equal amount of exophoria at distance and at near, with reduced PFV at both distances. Daum (1) reported on a population of 177 patients with exodeviations. Convergence insufficiency was the most common type of exodeviation, with a prevalence of 62.1%. Basic exophoria was the next most prevalent exodeviation, with a prevalence of 27.6%.

The prevalence of this condition has not been clearly established in the literature. Scheiman et al. (14) studied 1,650 children (ages 6 to 18 years) and found a prevalence of only 0.3%. Porcar and Martinez-Palomera (15) studied a university population and found a prevalence of 3.1%.

CHARACTERISTICS

Symptoms

Because exophoria is present at all distances, patients may present with symptoms associated with reading and other close work, as well as symptoms associated with distance activities. Common reading and near point complaints include eyestrain, headaches, blurred vision, diplopia, sleepiness, difficulty concentrating, and loss of comprehension over time (Table 11.14). Problems associated with distance include blurred vision and diplopia when driving and while watching television and movies, as well as in a classroom situation. As in other binocular vision disorders, it is possible for patients to have basic exophoria and yet be asymptomatic.

Signs

Signs of basic exodeviations are presented in Table 11.14.

Refractive Error

Refractive error is not a significant etiologic factor in basic exophoria. If myopia is present, correction of the refractive error will lead to a moderate decrease in the magnitude of the exophoria at both near and at distance.

Near Point of Convergence

Because the magnitude of the exodeviation tends to be large in basic exophoria, the near point of convergence is often receded.

TABLE 11.14 SYMPTOMS AND SIGNS OF BASIC EXODEVIATIONS**Signs**

Receded near point of convergence
 Equal exophoria at near and at distance
 Normal AC/A ratio
Direct tests of positive fusional vergence at both distance and near
 Low step vergence
 Low smooth vergence
 Low jump vergence
Indirect tests of negative fusional vergence at near
 Low negative relative accommodation
 Low binocular accommodative facility testing with plus lenses
 Low monocular estimation method retinoscopy

Symptoms

These symptoms are generally related to the use of the eyes for reading or other near tasks:

Eyestrain	Difficulty concentrating on reading material
Headaches	Loss of comprehension over time
Blurred vision distance and near	A pulling sensation around the eyes
Double vision at distance and near	Movement of the print
Sleepiness	

Characteristics of the Deviation

Patients with basic exophoria have an equal amount of exophoria at distance and at near, with decreased PFV at both distances. Generally, if the deviations are within 5 Δ of one another, they are considered equal. Daum (17) suggested that if the distant deviation is greater than 6 Δ , the near deviation can be within 9 Δ to be considered basic exophoria, and that if the distance deviation is 5 Δ or less, the near deviation has to be within 3 Δ . Another interesting finding from Daum's study is that basic exophoria had the largest percentage of constant strabismus of the three categories of exodeviations; 16% of the basic exodeviations in his sample were constant strabismics, 49% were intermittent, and 35% were latent. In contrast, only 2% of the convergence insufficiency patients and 1% of the divergence excess patients were constant. The mean angle of deviation was 15.5 Δ at both distance and near for basic exodeviations.

AC/A Ratio

A normal AC/A ratio is always present in basic exophoria. This is well accepted, based on the calculated AC/A, and is an important factor when treatment is considered. Daum (1) found an AC/A ratio of 6.2:1 in his sample of 49 equal exodeviations.

ANALYSIS OF BINOCULAR AND ACCOMMODATIVE DATA

The entry point into the analysis of data for basic exophoria is the exodeviation at both distances. Direct tests of PFV at both distance and near will tend to be low in basic exophoria (Table 11.14). This includes step-, smooth-, and jump-type vergences. In addition, all near point tests that indirectly assess PFV (Table 11.14) will be low as well. Tests performed binocularly with plus lenses evaluate the patient's ability to relax accommodation and to control binocular alignment using PFV. Two examples are the NRA and BAF testing with plus lenses. Another important indirect test of PFV is MEM retinoscopy. It is not unusual to find an abnormal result on this test in basic exophoria. An MEM finding of less plus than expected suggests that the patient is using as much accommodation as possible to increase the use of accommodative convergence. This reduces the demand on PFV.

TABLE 11.15 DIFFERENTIAL DIAGNOSIS OF BASIC EXOPHORIAS**Functional disorders to rule out**

- Convergence insufficiency
- Divergence excess

Serious underlying disease to rule out

Convergence paralysis secondary to:

- Ischemic infarction
- Demyelination
- Flu or other viral infection
- Parkinson disease
- Parinaud syndrome

Medial rectus weakness due to:

- Multiple sclerosis
- Myasthenia gravis
- Previous strabismus surgery

DIFFERENTIAL DIAGNOSIS

The differential diagnosis of basic exophorias is presented in Table 11.15. Basic exophoria is considered to be a benign condition with no serious consequences other than the visual symptoms listed in Table 11.15. It is relatively easy to differentiate from other binocular vision disorders associated with exophoria, such as convergence insufficiency (greater exophoria at near) and divergence excess (greater exophoria at distance).

Although it is unusual for basic exophoria to be associated with more serious underlying conditions, this possibility should always be considered. The key factor is the history of the deviation. Generally, functional exodeviations tend to be long-standing, with patients reporting a history of chronic symptoms and previous attempts to solve the problem. It is important to be suspicious about the etiology when the history suggests an acute onset of the deviation. Basic exophoria associated with serious underlying disease has an acute onset, and medical problems or neurologic symptoms are usually present.

Table 11.15 lists the conditions that should be considered in the differential diagnosis of basic exophoria. When managing a case of basic exophoria that is thought to have a functional basis, if symptoms and findings do not improve as expected, it is wise to reconsider the etiology of the condition.

TREATMENT

We recommend following the management sequence listed in Table 11.4.

Lenses

Significant refractive error is usually not present in basic exodeviations. If myopia is present, it is helpful to prescribe glasses. Because of the normal AC/A ratio, prescription of minus lenses will tend to moderately reduce the angle of deviation at both distance and near. In the presence of hyperopia, the decision about prescribing is more complex. With low to moderate degrees of hyperopia—up to about +1.50—we suggest waiting until the patient begins making progress in vision therapy. Prescribing before vision therapy will increase the magnitude of the exodeviation and may exacerbate the patient's symptoms. When the amount of hyperopia is greater than +1.50, it is generally wise to prescribe a partial prescription initially and to make modifications as the patient progresses in vision therapy. As we have recommended previously, it is important to prescribe for significant degrees of astigmatism and anisometropia.

Added Lenses

Added lenses can be an effective tool in the treatment of basic exodeviations because of the normal AC/A ratio. With esodeviations, added lenses are often prescribed for full-time wear in a bifocal format. With exodeviations, added lenses are generally not worn full time. Rather, they are used as aids during vision therapy or

to facilitate fusion in basic exodeviations. If the deviation is large, intermittent or constant, and the patient is experiencing difficulty in the early stages of vision therapy, added lenses may be helpful.

Prism

Daum (2) found that 51% of his sample had vertical deviations. If a vertical deviation is present under fused conditions, we recommend that vertical prism be prescribed. The most effective method for determining the amount of vertical prism is the associated phoria, which can be measured with any fixation disparity device (Chapter 15).

Horizontal relieving prism should be a consideration in basic exodeviations. Because of the excellent prognosis with vision therapy, however, the use of base-in prism for this condition is generally not necessary. When the magnitude of the initial deviation is large (greater than 30 Δ), base-in prism may be helpful at the end of vision therapy if the patient is not totally comfortable.

Vision Therapy

A vision therapy program for basic exophoria generally requires 12 to 24 in-office visits if the deviation is latent or intermittent. Treatment can sometimes take longer if a constant strabismus is present. The total number of therapy sessions depends on the age of the patient and his or her motivation and compliance.

The vision therapy program for basic exophoria is very similar to that recommended for convergence insufficiency in Chapter 9, except that during phases 2 and 3, therapy is performed at intermediate and far distances.

Specific Vision Therapy Program

All of the vision therapy techniques recommended below are described in detail in Chapters 6 to 8.

Phase 1

This first phase of therapy is designed to accomplish the objectives listed in Table 11.16 under Phase 1. The first goal of the therapy itself is to teach the concept and feeling of converging. The patient should be able to voluntarily converge and diverge to any distance from 5 cm (2 in.) to 6 m (20 ft). Once the patient can voluntarily initiate a controlled convergence movement, the other goals of the vision therapy program become much easier to accomplish. Three commonly used procedures to accomplish this first objective are the Brock string, bug on string, and the red/green Barrel card.

TABLE 11.16 OBJECTIVES OF VISION THERAPY FOR BASIC EXOPHORIAS

Phase 1

- Develop a working relationship with the patient
- Develop an awareness of the various feedback mechanisms that will be used throughout therapy
- Develop voluntary convergence
- Normalize positive fusional vergence (PFV) amplitudes (smooth or tonic vergence demand)
- Normalize accommodative amplitude and ability to stimulate and relax accommodation

Phase 2

- Normalize negative fusional vergence (NFV) amplitudes (smooth or tonic vergence demand)
- Normalize PFV facility (jump or phasic vergence demand)
- Normalize NFV facility (jump or phasic vergence demand)
- Normalize PFV at intermediate distances

Phase 3

- Develop ability to change from a convergence to a divergence demand
- Integrate vergence procedures with changes in accommodative demand
- Integrate vergence procedures with versions and saccades
- Normalize PFV at distance

Basic exophoria patients generally have very limited base-out blur, break, and recovery findings. Therefore, another objective of the first phase of vision therapy is to normalize PFV amplitudes. The initial goal is to reestablish a normal vergence range for smooth- or tonic-type vergence demand. It is important, however, to move to the next phase involving jump vergence as soon as possible. This tends to shorten the duration of therapy.

Instrumentation that can be used to accomplish these objectives includes variable tranaglyphs, variable vectograms, and the Variable Prismatic Stereoscope from Bernell. These three devices can be used to create a smooth, gradual increase in convergence demand.

If an accommodative problem is also present, the final objective of the first phase of therapy is to normalize accommodative amplitude and the ability to stimulate and relax accommodation. If accommodative function is normal, however, there is generally no need to spend a lot of time working with the accommodative system. Accommodative techniques are described in Chapter 7. Lens sorting, loose lens rock, and Hart chart procedures are commonly used in this first phase of therapy.

Endpoint. Phase 1 of therapy ends when the patient can:

- Demonstrate voluntary convergence
- Fuse to about 30 base-out with a tranaglyph or other comparable technique
- Complete 12 cpm of accommodative facility with +2.00/−2.00 lenses using a 20/30 target.

A sample vision therapy program for phase 1 is summarized in Table 11.17. This program includes several techniques that can be used by the patient at home to supplement the in-office therapy.

Phase 2

This second phase of therapy is designed to accomplish the objectives listed in Table 11.16 under Phase 2. Once smooth PFV is normalized, phasic or jump vergence demand should be emphasized. Variable tranaglyphs and vectograms can still be used. However, the specific modifications to create a step vergence demand (described in Chapter 6) must be implemented. Other valuable techniques at this stage are non-variable tranaglyphs, the Aperture Rule, Eccentric Circles, Free Space Fusion cards, Lifesaver cards, and Computer Orthoptics jump vergence activities.

In contrast to phase 1, in which speed was not a factor, during this second phase of therapy the emphasis should be on the qualitative aspects (speed, accuracy) of fusion rather than the quantitative (magnitude) aspects. It is important to increase the speed of the fusional vergence response and the quality of the recovery of fusion.

A second objective of this phase of therapy is to begin working with NFV amplitudes. Once the patient begins to demonstrate normal smooth PFV, it is important to also implement therapy with smooth negative vergence demand. The same techniques used in phase 1 to work with PFV are repeated for NFV. Also incorporate NFV facility-type techniques, using the same procedures as listed above for jump vergence demand for PFV.

Finally, an important objective of this phase of therapy is to begin performing the treatment at intermediate distances. Now that the patient can successfully work with the various instruments and procedures at near, it is usually very easy to repeat similar techniques at greater distances. A very effective procedure is to use tranaglyphs projected on the wall or a screen by an overhead projector. This technique works well because the patient is very familiar with the task and simply has to try to apply the same skills learned during earlier sessions. The targets, printed on 8.5×11 in. paper and discussed in Chapter 9 for divergence insufficiency, are helpful for basic exodeviations as well. Another method of presenting stimuli at intermediate distances is through the use of stereoscopes. The working distance can be conveniently changed on most Brewster-type stereoscopes, and a wide variety of targets is readily available.

Endpoint. The endpoint of phase 2 is reached when the patient can:

- Fuse card 12 using convergence and card 6 using divergence with the Aperture Rule
- Fuse the Eccentric Circles or Free Space Fusion cards using convergence (12 cm separation) and divergence (6 cm separation)
- Fuse up to 20 Δ using convergence and 10 Δ using divergence with tranaglyph targets projected at 3 m (10 ft) using an overhead projector.

A sample vision therapy program for phase 2 is summarized in Table 11.17.

TABLE 11.17 SAMPLE VISION THERAPY PROGRAM FOR BASIC EXOPHORIA

Phase 1
<p><i>Sessions 1 and 2</i></p> <p>IN-OFFICE</p> <ul style="list-style-type: none"> • Discuss nature of vision problem, goals of vision therapy, various feedback cues, importance of practice • Brock string • Lens sorting • Loose lens rock (begin with plus if accommodative excess, with minus if accommodative insufficiency) • Tranaglyphs or vectograms: base-out <ul style="list-style-type: none"> • Begin with a peripheral target such as tranaglyph 515 or the Quoit vectogram • Computer Orthoptics Random Dot program: base-out
<p>HOME THERAPY</p> <ul style="list-style-type: none"> • HTS Vergence and Accommodation programs • Brock string
<p><i>Sessions 3 and 4</i></p> <p>IN-OFFICE</p> <ul style="list-style-type: none"> • Bug on string • Loose lens rock • Tranaglyphs or vectograms: base-out <ul style="list-style-type: none"> • Use targets with more central demand (Clown, Bunny tranaglyphs; Clown, Topper vectograms) • Computer Orthoptics Random Dot program: base-out
<p>HOME THERAPY</p> <ul style="list-style-type: none"> • HTS Vergence and Accommodation programs • Loose lens rock
<p><i>Sessions 5 through 8</i></p> <p>IN-OFFICE</p> <ul style="list-style-type: none"> • Barrel card • Voluntary convergence • Loose lens rock • Tranaglyphs or vectograms: base-out <ul style="list-style-type: none"> • Use even more detailed targets such as tranaglyph Sports Slide and Faces targets and the Spirangle vectogram • Computer Orthoptics Random Dot program: base-out
<p>HOME THERAPY</p> <ul style="list-style-type: none"> • HTS Vergence and Accommodation programs
Phase 2
<p><i>Sessions 9 and 10</i></p> <p>IN-OFFICE</p> <ul style="list-style-type: none"> • Tranaglyphs or vectograms with modifications to create jump vergence demand: base-out • Nonvariable tranaglyphs • Tranaglyph 515 or the Quoit vectogram: base-in • Binocular accommodative therapy techniques: use any of the binocular techniques listed above with \pm lenses
<p>HOME THERAPY</p> <ul style="list-style-type: none"> • HTS Vergence and Accommodation programs
<p><i>Sessions 11 and 12</i></p> <p>IN-OFFICE</p> <ul style="list-style-type: none"> • Tranaglyphs or vectograms with modifications to create jump vergence demand: base-out • Aperture Rule: base-out • More central tranaglyphs or the vectograms: base-in • Binocular accommodative therapy techniques: use any of the binocular techniques listed above with \pm lenses
<p>HOME THERAPY</p> <ul style="list-style-type: none"> • HTS Vergence and Accommodation programs

(Continued)

TABLE 11.17 CONTINUED

<p><i>Sessions 13 through 16</i></p> <p>IN-OFFICE</p> <ul style="list-style-type: none"> • Aperture Rule: convergence and divergence • Eccentric Circles or Free Space Fusion cards • Computer Orthoptics Random Dot Vergence program: both base-in and base-out • Tranaglyphs or vectograms with modifications to create jump vergence demand: base-in • Binocular accommodative therapy techniques: use any of the binocular techniques listed above with \pm lenses • Tranaglyphs or vectograms at 1 m
<p>HOME THERAPY</p> <ul style="list-style-type: none"> • HTS Vergence and Accommodation programs • Eccentric Circles or Free Space Fusion cards
<p>Phase 3</p>
<p><i>Sessions 17 through 20</i></p> <p>IN-OFFICE</p> <ul style="list-style-type: none"> • Tranaglyphs or vectograms with Polaroid or red/green flippers • Eccentric Circles or Free Space Fusion cards • Computer Orthoptics Random Dot Vergence program: step–jump vergence • Tranaglyphs or vectograms at distance
<p>HOME THERAPY</p> <ul style="list-style-type: none"> • HTS Vergence and Accommodation programs • Eccentric Circles or Free Space Fusion cards: base-out
<p><i>Sessions 21 and 22</i></p> <p>IN-OFFICE</p> <ul style="list-style-type: none"> • Tranaglyphs or vectograms with Polaroid or red/green flippers • Eccentric Circles or Free Space Fusion cards • Lifesaver cards • Computer Orthoptics Random Dot Vergence program: jump–jump vergence • Distance fusion targets at distance
<p>HOME THERAPY</p> <ul style="list-style-type: none"> • HTS Vergence and Accommodation programs • Eccentric Circles or Free Space Fusion cards: base-in
<p><i>Sessions 23 and 24</i></p> <p>IN-OFFICE</p> <ul style="list-style-type: none"> • Tranaglyphs or vectograms with Polaroid or red/green flippers • Eccentric Circles or Free Space Fusion cards with rotation and versions • Lifesaver cards with rotation and versions • Computer Orthoptics Vergence program with rotation
<p>HOME THERAPY</p> <ul style="list-style-type: none"> • HTS Vergence and Accommodation programs • Eccentric Circles or Free Space Fusion cards: base-in/base-out

Phase 3

This third phase of therapy is designed to accomplish the objectives listed in Table 11.16 under Phase 3. Until this point, the patient has either worked in the convergence or divergence directions separately. Now the objective is to develop the patient's ability to change from a convergence to a divergence demand and to integrate vergence procedures with versions and saccades. Several excellent procedures are available to help accomplish this objective. Vectograms with Polaroid flippers or tranaglyphs with red/green flippers can be

used. Each time the flippers are changed, the demand switches from divergence to convergence. The transparent Keystone Eccentric Circles or transparent Bernell Free Space Fusion cards are excellent, inexpensive methods for achieving this objective.

Another objective of therapy is to integrate vergence procedures with versions and saccades. Techniques such as the Brock string with rotation, Eccentric Circles and Free Space Fusion cards with rotation and/or lateral movements, and the Lifesaver cards with rotation can be used to accomplish this goal. The Computer Orthoptics program that combines horizontal vergence with rotation is also useful for this objective.

The final objective of this final phase of therapy is to work with convergence at distances of 3 m to 6 m (10 to 20 ft). The same techniques used in phase 2 at intermediate distances are repeated at even greater distances.

Endpoint. The endpoint for phase 3 is reached when the patient can:

- Maintain clear single binocular vision with the Eccentric Circles and Free Space Fusion cards held together, while slowly rotating the cards and performing convergence and divergence therapy
- Maintain clear single binocular vision with the large Eccentric Circles and other targets at distance.

When all vision therapy objectives have been reached and the vision therapy program is completed, we recommend the home vision therapy maintenance program outlined in Table 9.10 and described in Chapter 9.

Summary of Vision Therapy for Basic Exophoria

The phases and objectives outlined above and in Tables 11.16 and 11.17 represent one approach that will lead to successful elimination of a patient's symptoms and normalization of optometric data. The number of sessions is approximate and will vary from one patient to another.

Surgery

The use of lenses, prism, and vision therapy in the treatment of basic exophoria is so successful that surgery is virtually never necessary. If the magnitude of the deviation is greater than 30 Δ , however, some patients may not achieve full relief of symptoms. In these instances, a surgical referral should be considered.

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Accommodative Dysfunction

Many authors have suggested that anomalies of accommodation are commonly encountered in optometric practice (1–10). Although there are few studies on the prevalence of accommodative disorders in the general or clinical populations, those that are available do tend to confirm this contention. Hokoda (7) studied a sample of 119 symptomatic patients and found that accommodative dysfunction was the most commonly encountered condition: 25 of the 119 subjects had binocular or accommodative disorders, and 80% of the 25 had accommodative problems. Hoffman, Cohen, and Feuer (10) reported on the effectiveness of vision therapy for nonstrabismics, using a sample of 129 subjects. Of the 129 subjects studied, 62% had accommodative dysfunction. In a study of 1,650 children between the ages of 6 and 18 years, Scheiman et al. (8) found that 2.2% of the children had accommodative excess, 1.5% had accommodative infacility, and 2.3% had accommodative insufficiency. The overall prevalence of accommodative problems was 6%. In a study of 65 university students, Porcar and Martinez-Palomera (9) found that 10.8% of the subjects had accommodative excess and 6.2% had accommodative insufficiency, for an overall prevalence of 17%.

One of the early attempts at classifying accommodative anomalies was by Duane in 1915 (11). He reported on the results of 170 patients and developed a classification that included insufficiency of accommodation, ill-sustained accommodation, inertia of accommodation, excessive accommodation, inequality of accommodation, and paralysis of accommodation. This classification has received wide acceptance. Many other authors, discussing the classification, diagnosis, and management of accommodative anomalies, have essentially used Duane's initial classification with minor modifications (1,2,12–15). The classification of accommodative anomalies that we use in this chapter is also based on Duane's system and is summarized below.

Classification of Accommodative Anomalies

- Accommodative insufficiency
- Ill-sustained accommodation
- Paralysis of accommodation
- Unequal accommodation
- Accommodative excess
- Accommodative infacility

General Treatment Strategies for Accommodative Dysfunction

SEQUENTIAL MANAGEMENT CONSIDERATIONS

- Correction of ametropia
- Added lenses
- Vision therapy

The concepts that we discussed for the sequential management considerations of binocular vision disorders also apply to accommodative problems. Accommodative fatigue can occur secondary to uncorrected refractive error, such as hyperopia and astigmatism (13). A 3 D hyperope must accommodate 2.50 D for a working distance of 40 cm and an additional 3 D to overcome the hyperopia. The muscular fatigue resulting from

5.50 D of accommodation will often lead to the symptoms associated with accommodative problems. Low degrees of astigmatism and anisometropia can also lead to accommodative fatigue, if the accommodative level oscillates back and forth in an attempt to obtain clarity. It is also not unusual for myopes to experience discomfort when reading with their eyeglasses. This may be due to accommodative fatigue and must be considered in any management plan. The first management consideration, therefore, is correction of refractive error. We recommend applying the same criteria for prescribing that we discussed in Chapter 3.

Added lenses also play an important role in the treatment of accommodative dysfunction. Of the various accommodative problems, accommodative insufficiency and ill-sustained accommodation respond best to added plus lenses. Walberg et al. (16) randomized 22 subjects with accommodative insufficiency to either +1.00D or +2.00 reading glasses for 8 weeks. The results showed a statistically significant improvement in symptoms in both groups, but only the +1.0 group showed a significant improvement in accommodative amplitude. The important concept is that any accommodative disorder in which the patient is experiencing problems stimulating accommodation will benefit from added plus lenses. Accommodative problems in which the difficulty is with relaxation of accommodation or facility do not respond as well to added lenses. Thus, accommodative excess and accommodative infacility generally require treatment other than added lenses.

Prism, which is so important in cases of binocular vision disorders, is not used for accommodative dysfunction unless there is an associated binocular problem. For purposes of this chapter, we assume that the accommodative dysfunction is present in isolation. Therefore, prism is not listed as part of the sequential management for accommodative dysfunction.

The final treatment consideration is the use of vision therapy to restore normal accommodative function. Vision therapy is generally necessary in the management of accommodative excess and accommodative infacility. In many cases, it is also critical in the treatment of accommodative insufficiency and ill-sustained accommodation.

Surgery, which was a consideration for binocular vision problems, has no role relative to accommodative dysfunction.

PROGNOSIS FOR TREATING ACCOMMODATIVE DISORDERS

There have been many studies documenting the effectiveness of vision therapy for improving accommodative function, along with several reviews of the literature (17–21). In his review of research on the treatment of accommodative dysfunction, Rouse (20) reached the following conclusions:

- The literature provides a solid base of research supporting vision therapy as an effective treatment mode for accommodative deficiencies.
- Vision therapy procedures have been shown to improve accommodative function effectively and to eliminate or reduce associated symptoms.
- The actual physiologic accommodative response variables modified by therapy have been identified, eliminating the possibility of Hawthorne or placebo effects accounting for treatment success.
- The improved accommodative function appears to be fairly durable after treatment.

The support in the literature comes from two sources: basic scientific investigation and clinical research. Basic scientists have shown that subjects can learn to voluntarily change accommodative response (22–24). These studies demonstrate that voluntary control of accommodation can be trained and transferred to a variety of stimulus conditions. Other researchers have tried to determine the underlying physiologic basis for improved accommodative function. Liu et al. (3) and Bobier and Sivak (24) designed studies to identify which aspects of accommodation are affected by vision therapy. The importance of these two studies is that they used objective procedures to monitor accommodative function. These two investigations clearly demonstrated objective improvement in the dynamics of the accommodative response. The velocity of the accommodative response increased and the latency of the response decreased in both studies. In addition, both studies were able to show that the clinical testing of accommodative facility correlated well with the objective laboratory techniques. This result underscores the importance of the clinical use of accommodative facility testing.

Clinical studies of the effectiveness of vision therapy for accommodative dysfunction have consistently demonstrated excellent success rates. Recently Scheiman, Cotter, Kulp, et al. (21) published the first data from a randomized clinical trial about the effectiveness of vision therapy for the treatment of accommodative problems. They reported that after 12 weeks of treatment, the increases in amplitude of accommodation

with office-based vergence/accommodative therapy with home reinforcement group (OBVAT) 9.9 D, with home-based computer vergence/accommodative therapy group (HBCVAT+) 6.7 D, and home-based pencil push-up therapy group (HBPP) 5.8 D were significantly greater than in the office-based placebo therapy (OBPT) group (2.2D). Significant increases in accommodative facility were found in all groups (OBVAT: 9 cpm, HBCVAT+: 7 cpm, HBPP: 5 cpm, OBPT: 5.5 cpm); only the improvement in the OBVAT group was significantly greater than that found in the OBPT group. One year after completion of therapy, reoccurrence of decreased accommodative amplitude was present in only 12.5% and accommodative facility in only 11%. The authors concluded that vision therapy is effective in improving accommodative amplitude and accommodative facility in school-aged children with symptomatic convergence insufficiency and accommodative dysfunction.

The following retrospective studies included almost 300 patients. Hoffman, Cohen, and Feuer (10) reported on a sample of 80 patients with accommodative dysfunction and found an 87.5% success rate for normalizing accommodative ability. About 25 visits, on average, were required. Wold, Pierce, and Keddington (25) studied the effect of vision therapy on 100 consecutive patients. They found statistically significant changes in both accommodative amplitude and facility. Patients were seen three times per week, for an average of about 35 visits. In a retrospective study of 114 patients with accommodative dysfunction, Daum (15) found that 96% achieved either total or partial success with an average of about 4 weeks of therapy.

Several prospective studies have also been done to control for placebo or Hawthorne effects. In addition to the work done by Liu et al. (3) and Bobier and Sivak (24) discussed above, Cooper et al. (26) used a matched-subjects crossover design to control for placebo effects. They studied five subjects with accommodative disorders and asthenopia. The subjects were divided into control and experimental groups. The experimental group received twelve 30-minute sessions of accommodative therapy, whereas the control group received the same number of sessions of therapy using plano lenses. After the first phase of therapy, the experimental group received an additional 6 weeks of training, identical to that of the control group, and the control group received training identical to that of the experimental group. Four of the five subjects showed increased accommodative amplitude or facility and improvement in symptoms after therapy. These changes occurred only during the experimental phase of the training.

Two other controlled studies (27,28) not only showed improvements in accommodative function and elimination of symptoms but also were able to demonstrate a transfer effect on performance. Weisz (27) showed that performance on a paper and pencil task improved after accommodative therapy, and Hoffman (28) demonstrated improved perceptual performance after treatment.

Another important treatment option for accommodative dysfunction is the use of plus lenses. As discussed later in this chapter, added plus lenses are indicated in accommodative insufficiency and ill-sustained accommodation. Daum (29) evaluated the effectiveness of plus lenses for the treatment of accommodative insufficiency. Of the 17 subjects in his study, 53% reported total relief of symptoms, and 35% experienced partial alleviation of their difficulties. A greater percentage of patients received no relief at all with plus lenses compared to vision therapy (12% versus 4%). This suggests that even for the category of accommodative insufficiency, there are some situations in which vision therapy is the only effective treatment alternative. Daum concluded that “for most patients, it would appear that the relative ease with which the training may be completed (and in view of the optical limitations and inconvenience of a near plus lens addition) makes orthoptic therapy the treatment method of choice.”

Accommodative insufficiency (Ill-sustained Accommodation, Paralysis of Accommodation, and Unequal Accommodation)

BACKGROUND INFORMATION

Accommodative insufficiency is a condition in which the patient has difficulty stimulating accommodation. The characteristic finding is an accommodative amplitude below the lower limit of the expected value for the patient's age. To determine the lower limit for a patient, we suggest using Hofstetter's formula, which states that the lower limit is equal to $15 - (0.25 \times \text{age of patient})$ (30). If the amplitude is 2 D or more below this value, it is considered abnormal. In addition to the low amplitude of accommodation, which is the hallmark of accommodative insufficiency, there are other important characteristics, which are discussed in the next section.

It is important to realize that presbyopia, by definition, is a different entity from accommodative insufficiency. Presbyopia is a condition in which the amplitude of accommodation has diminished to the point at which clear or comfortable vision at the near point is not achievable. This usually occurs between the ages of 40 and 45. The symptoms of presbyopia are identical to those of accommodative insufficiency. However in presbyopia, the amplitude of accommodation is not abnormal relative to the patient's age. Rather, the amplitude is appropriate for the patient's age, although it is too low to permit clear comfortable vision at near. When we talk about accommodative insufficiency, therefore, we are generally referring to a condition that affects prepresbyopes.

Ill-sustained accommodation, or accommodative fatigue, has been categorized by most authors as a subclassification of accommodative insufficiency. Both Duane (11) and Duke-Elder and Abrams (2) described ill-sustained accommodation as an early stage of accommodative insufficiency. It is a condition in which the amplitude of accommodation is normal under typical test conditions, but deteriorates over time. If ill-sustained accommodation is suspected, it is important, therefore, to repeat the amplitude of accommodation measurement several times (Chapter 1). Chase et al. (31) used a Grand-Seiko WAM 5500 autorefractor to measure accommodative response. They evaluated visual discomfort symptoms using the Conlon survey. They found a strong and positive correlation between accommodative lag and visual discomfort symptoms during near work. The prevalence of accommodative insufficiency was much higher than estimated by clinical measures. Based on their results they suggested that accommodative insufficiency and fatigue should be defined and described by objective methods using extended viewing times to assess function. It could be that some of the patients diagnosed with ill-sustained accommodation could have true accommodative insufficiency if assessed with objective recordings or over extended periods of time as suggested by Chase et al.

Another condition that can be categorized under accommodative insufficiency is accommodative paralysis. It is a very rare condition that is associated with a variety of organic causes, such as infections, glaucoma, trauma, lead poisoning, and diabetes. It can also occur as a temporary or permanent consequence of head trauma. Paralysis of accommodation can be unilateral or bilateral, sudden or insidious. If it is unilateral, it leads to the other category of accommodative dysfunction called unequal accommodation. Another possible cause of unequal accommodation is functional amblyopia.

Some authors have found that of the various accommodative problems, accommodative insufficiency is the most common. In a study of the prevalence of accommodative and binocular vision disorders, Hokoda (7) found that 55% of the patients with accommodative anomalies had accommodative insufficiency. Daum (15) studied 114 patients who had been diagnosed as having accommodative dysfunction and found that 84% had accommodative insufficiency. However, Scheiman et al. (8) found about an equal mix of the three primary accommodative problems in their study (accommodative excess, 2.2%; accommodative infacility, 1.5%; and accommodative insufficiency, 2.3%). Porcar and Martinez-Palomera (9) found that 10.8% of their subjects had accommodative excess and 6.2% had accommodative insufficiency.

CHARACTERISTICS

Symptoms

The symptoms of accommodative insufficiency are presented in Table 12.1. The most common complaints include blur, headaches, eyestrain, double vision, reading problems, fatigue, difficulty changing focus from one distance to another, and sensitivity to light (15). Patients may also complain of an inability to concentrate, a loss of comprehension over time, and words moving on the page. All of these symptoms are associated with reading or other close work. A number of authors have reported a relationship between accommodative insufficiency and academic performance (32–34). Borsting, Rouse, and Chu (32) reported that children with symptomatic accommodative dysfunction have a higher frequency of behaviors related to school performance and attention. Palomo-Alvarez and Puell (33) conducted a cross-sectional study on 87 poor readers and 32 control children 8–13 years old. They found that monocular accommodative amplitude was significantly lower in the group of poor readers. Chase et al. (34) used the Conlon symptom survey (35) and an Academic Problems Survey with 68 college students in an attempt to identify a threshold value for the Conlon that predicted academic problems. The Conlon strongly correlated with the Academic Problems Survey, accounting for 62% of variance in self-reported academic problems. A cutoff score of 28 or more was established as a good predictor for problems with grades, homework, and reading. A cutoff score of 27 or more was predictive of accommodative insufficiency. The authors concluded that the Conlon survey is a useful tool to identify students with near work problems that negatively affect academic performance or are associated with accommodative insufficiency.

TABLE 12.1 SYMPTOMS AND SIGNS OF ACCOMMODATIVE INSUFFICIENCY

Symptoms	
These symptoms are generally related to the use of the eyes for reading or other near tasks:	
Long-standing	Fatigue and sleepiness
Blurred vision	Loss of comprehension over time
Headaches	A pulling sensation around the eyes
Eyestrain	Movement of the print
Reading problems	Avoidance of reading and other close work
Signs	
<i>Direct measures of accommodative stimulation</i>	
Reduced amplitude of accommodation	
Difficulty clearing –2.00 with monocular accommodative facility	
High monocular estimation method retinoscopy finding	
High fused cross-cylinder finding	
<i>Indirect measures of accommodative stimulation</i>	
Reduced positive relative accommodation	
Difficulty clearing –2.00 with binocular accommodative facility	
Low base-out to blur finding at near	

Some patients with accommodative insufficiency are asymptomatic. For example, Daum (15) found that 2% of the patients in his sample had no symptoms, although they clearly had accommodative insufficiency. In such cases, the most likely explanation is avoidance of reading and other close work. Because clinicians generally base their treatment decisions on the presence and severity of the patient's symptoms, it is important to remember that avoidance should be regarded as a symptom and is as important a reason for recommending therapy as any of the other symptoms associated with accommodative insufficiency.

Signs

The signs of accommodative insufficiency are presented in Table 12.1. Accommodative insufficiency is a disorder in which the patient experiences difficulty with any optometric testing that requires stimulation of accommodation. Any test that involves the use of minus lenses will generally yield a reduced finding. The most characteristic sign is the reduced amplitude of accommodation. The patient with accommodative insufficiency will also have low findings on the positive relative accommodation (PRA), minus lenses with both monocular accommodative facility (MAF) and binocular accommodative facility (BAF) testing, and more plus than expected with monocular estimation method (MEM) retinoscopy and the fused cross-cylinder test.

Accommodative insufficiency may also be associated with a binocular vision problem. It is not unusual to find a small degree of esophoria in cases of accommodative insufficiency. A likely explanation is that the patient uses additional innervation to try to overcome the accommodative problem, which stimulates accommodative convergence, causing an esophoria. A condition known as pseudoconvergence insufficiency has also been related to accommodative insufficiency (36). In such cases, the patient has difficulty accommodating and therefore underaccommodates relative to the stimulus. As a result, less accommodative convergence is available, the measured exophoria is larger, and a greater demand is placed on positive fusional convergence. Typically, such patients will also have a receded near point of convergence because of the reduced amplitude of accommodation and the lack of accommodative convergence. We presented a case of pseudoconvergence insufficiency in Chapter 9.

ANALYSIS OF BINOCULAR AND ACCOMMODATIVE DATA

The entry point into the analysis of accommodative and binocular vision data is the phoria at distance and near. In cases of accommodative dysfunction, it is not unusual for the phoria to fall outside expected values. As discussed above, accommodative insufficiency can be associated with exophoria or esophoria. It is important in such cases to carefully analyze the appropriate group data. For example, the patient in Case 12.1 (discussed later in the chapter) presented with symptoms of blurred vision and eyestrain after reading for 15 minutes. The cover test at distance is ortho, and at near, 2 esophoria. After eliminating refractive error and organic causes, the best initial approach is to be concerned about an esophoria and a problem of the low negative

fusional vergence (NFV) type at near. We would therefore analyze the NFV group data, which includes base-in vergence at near, the PRA, BAF testing with minus lenses, MEM retinoscopy, and the fused cross-cylinder test. Case 12.1 illustrates that the indirect measures of NFV are abnormal. The patient has a low PRA and BAF finding, and MEM retinoscopy shows more plus than expected. These data can be a reflection of either an accommodative problem in which the patient has difficulty stimulating accommodation or a convergence excess. The key to differentiating these two hypotheses is the direct measures of NFV. In this case, both the smooth and step vergence findings are essentially normal. This eliminates the possibility of a binocular problem.

Case 12.1 Accommodative Insufficiency

History

Janet, a 17-year-old 11th grader, presented with complaints of blurred vision and eyestrain after reading for more than 15 minutes. Although she reported similar symptoms throughout high school, the problems had become worse since the beginning of the school year. Her medical history was negative, and she was not taking any medication. Janet had been examined about 2 years ago, and the doctor said her eyes were fine.

Examination Results

VA (distance, uncorrected):	OD: 20/20 OS: 20/20
VA (near, uncorrected):	OD: 20/20 OS: 20/20
Near point of convergence	
Accommodative target:	7 cm
Penlight:	7 cm
Cover test (distance):	Orthophoria
Cover test (near):	2 esophoria
Subjective:	OD: +0.50, 20/20 OS: +0.50, 20/20
Distance lateral phoria:	Orthophoria
Base-in vergence (distance):	X/7/4
Base-out vergence (distance):	X/18/10
Near lateral phoria:	2 esophoria
–1.00 gradient:	8 esophoria
Gradient AC/A ratio:	6:1
Calculated AC/A ratio:	6.8:1
Base-in vergence (near):	8/20/12
Base-out vergence (near):	6/17/10
Vergence facility:	14 cpm
NRA:	+2.50
PRA:	–1.00
Accommodative amplitude (push-up):	OD: 7 D; OS: 7 D
MAF:	OD: 0 cpm, fails minus OS: 0 cpm, fails minus
BAF:	0 cpm, fails minus
MEM retinoscopy:	+1.50 OD and OS

Pupils were normal, all external and internal health tests were negative, the deviation was comitant, and color vision testing revealed normal function.

Case Analysis

From the history, Janet's symptoms seemed to be related to the use of her eyes. Her medical history was negative, and she was not taking any medication. The problems worsened at the beginning of the school year, and her symptoms occurred shortly after the onset of reading. This history tends to suggest a functional rather than organic cause. Because of the esophoria at near, the analysis should begin with the data in the NFV group. The indirect findings (PRA, BAF, and MEM retinoscopy) all suggest a potential problem with NFV. However, the direct findings (base-in vergence at near and vergence facility) are normal. Therefore, the difficulty Janet experiences with minus lenses does not seem to be due to low NFV. The most likely cause is an accommodative problem. If we analyze the ACC group data, it becomes clear that Janet demonstrates difficulty with all tasks requiring stimulation of accommodation. The low amplitude of accommodation, reduced PRA, poor performance on MAF and BAF testing, and the high MEM retinoscopy result are all characteristic of accommodative insufficiency.

Management

Reading glasses were prescribed for Janet. The final prescription was based on analysis of the accommodative and binocular tests and the refraction. Through the subjective, the NRA/PRA relationship showed a need for a +0.75 add, MEM retinoscopy was about +1.00 higher than expected, and the near phoria was 2 esophoria with a 6:1 AC/A ratio. Based on these findings, we prescribed a near vision prescription of +1.25 OD and OS. We asked Janet to wear these glasses for reading over the next 6 weeks, and she returned for a reevaluation at that time.

After 6 weeks, Janet reported complete relief of all symptoms when using the glasses. The reevaluation at this point revealed the following findings through the subjective:

NRA:	+2.50
PRA:	-1.50
MAF:	4 cpm
BAF:	4 cpm
MEM retinoscopy:	+1.00
Amplitude of accommodation:	9D OD and OS

Although the patient was asymptomatic, the findings continued to show that she had difficulty with accommodative stimulation. We chose not to recommend any additional treatment because she was very content with the result, even though she had to use reading glasses. Another possible option could have been to recommend vision therapy to try to normalize accommodative function, making her less dependent on the reading glasses.

This case is representative of the most common type of accommodative insufficiency. Refractive correction and added lenses are often sufficient to relieve the patient's symptoms. If the patient continues to experience discomfort or the findings are not normal after wearing the glasses for 4 to 6 weeks, the vision therapy program outlined in Tables 12.3 and 12.4 can be recommended.

Once a binocular vision problem is eliminated, we recommend analysis of the accommodative system (ACC) group data. These data reveal a low amplitude of accommodation and inability to clear -2.00 with MAF, along with the reduced PRA, high MEM finding, and inability to clear -2.00 lenses binocularly. These findings, analyzed as a group, suggest that the patient has difficulty with all tests requiring stimulation of accommodation, confirming a diagnosis of accommodative insufficiency.

DIFFERENTIAL DIAGNOSIS

The differential diagnosis of accommodative insufficiency is presented in Table 12.2. Accommodative insufficiency is considered to be a benign condition, with no serious consequences other than the visual symptoms listed in Table 12.1. It is relatively easy to differentiate from other accommodative

TABLE 12.2 DIFFERENTIAL DIAGNOSIS OF ACCOMMODATIVE INSUFFICIENCY

Functional disorders to rule out	
Pseudoconvergence insufficiency	
Basic exophoria	
Divergence excess	
Accommodative excess	
Accommodative infacility	
Nonfunctional causes of accommodative insufficiency	
<i>Bilateral^a</i>	<i>Unilateral</i>
DRUGS	LOCAL EYE DISEASE
Alcohol	Iridocyclitis
Artane	Glaucoma
Ganglion blockers	Choroidal metastasis
Phenothiazides	Tear in iris sphincter
Antihistamines	Blunt trauma
Cycloplegics	Ciliary body aplasia
Central nervous system stimulants	Scleritis
Marijuana	Adie syndrome
GENERAL DISEASE: ADULTS	GENERAL DISEASE: ADULTS
Anemia	Sinusitis
Encephalitis	Dental caries
Diabetes mellitus	Posterior communicating artery aneurysm
Multiple sclerosis	Parkinsonism
Myotonic dystrophy	Wilson disease
Malaria	Midbrain lesions
Typhoid	
Toxemia	
Botulism	
GENERAL DISEASE: CHILDREN	Whooping cough
Anemia	Tonsillitis
Mumps	Diphtheria
Measles	Lead and arsenic poisoning
Scarlet fever	
NEUROOPHTHALMIC	NEUROOPHTHALMIC
Lesions in Edinger-Westphal syndrome	Fascicular nerve III lesion
Trauma to craniocervical region (whiplash)	Herpes zoster
Pineal tumor	Horner syndrome
Parinaud syndrome	
Polyneuropathy	
Anterior poliomyelitis	

^aA bilateral problem may start unilaterally.

Source: From London R. Accommodation. In: Barresi BJ, ed. *Ocular assessment: the manual of diagnosis for office practice*. Boston, MA: Butterworth-Heinemann, 1984:123–130, with permission.

disorders. Accommodative insufficiency is the only condition associated with a reduced amplitude of accommodation. In addition, whereas the accommodative insufficiency patient has difficulty with all tests requiring stimulation of accommodation, the accommodative excess patient has difficulty with all tests requiring relaxation of accommodation. The accommodative facility patient has difficulty with both stimulation and relaxation of accommodation. Accommodative paralysis is a condition in which the amplitude of accommodation is dramatically reduced; there is usually some local or systemic disease or medication that can explain the problem.

Although accommodative insufficiency generally has a functional etiology, it may occur in association with primary ocular disease, generalized systemic and neurologic disorders, as well as with lesions that produce focal interruption of the parasympathetic innervation of the ciliary body (9). A variety of ocular and systemic drugs can also lead to accommodative insufficiency. Several comprehensive sources describe these nonfunctional etiologies in detail (12,37). Table 12.2, compiled by London (12), lists the nonfunctional causes of accommodative problems. It is always important to

rule out these nonfunctional causes before deciding on any treatment plan for accommodative insufficiency. This differential diagnosis depends very much on the case history. Patients presenting with accommodative insufficiency secondary to any of the diseases listed in Table 12.2 will have a history of being ill in the past or at the present time. A history of diseases such as diabetes, encephalitis, multiple sclerosis, malaria, and typhoid, for example, would certainly be easy to elicit from a patient with any of these problems. The same is true of the various medications listed in Table 12.2. Accommodative insufficiency secondary to functional causes will present with long-standing chronic complaints and a negative health and medication history.

In most cases, therefore, the differential diagnosis is not difficult. However, if symptoms and findings do not improve as expected when managing a case of accommodative insufficiency that is thought to have a functional basis, it is prudent to reconsider the etiology of the condition.

TREATMENT

We recommend the management sequence listed on page 335.

Lenses

Because uncorrected refractive error can be a cause of accommodative fatigue, we recommend that correction of ametropia be the first management consideration. When dealing with patients with accommodative insufficiency, even small degrees of refractive error may be significant. Prescribing for small degrees of hyperopia, astigmatism, and small differences in refractive error between the two eyes may provide some immediate relief of symptoms for the patient.

Added Lenses

Analysis of the near point findings in accommodative insufficiency clearly shows that these patients benefit from the use of added plus lenses. The low PRA, difficulty clearing minus during accommodative facility testing, the low amplitude of accommodation, and high MEM retinoscopy are all examples of data suggesting the need for plus lenses for near. The amount of added plus can easily be determined by analyzing this data. Referring to Case 12.1, the NRA was +2.50 and the PRA -1.00 . This suggests an add of +0.75. This patient could not clear -2.00 lenses during accommodative facility testing, and MEM retinoscopy was +1.00. Since the normal finding is +0.50, this suggests an add of +0.50.

Occasionally, myopic patients will experience difficulty with accommodation after they receive their first prescription or a large change in prescription. Esophoria at near is also a common finding in such cases. If the findings reveal accommodative insufficiency, a bifocal should be prescribed.

When there is an organic cause of the accommodative insufficiency or even paralysis of accommodation, added lenses are an important treatment consideration. In some cases, the accommodative paralysis is temporary. Added plus lenses are useful as a temporary solution while treatment of the underlying condition occurs. If the underlying cause of the paralysis of accommodation cannot be eliminated and the condition is stable and nonprogressive, then added plus lenses may need to be permanent. A trial period of vision therapy can also be attempted after medical concerns have been addressed.

Unequal accommodation secondary to organic causes also responds well to added plus lenses. In such cases, it is frequently necessary to consider prescribing unequal adds.

Vision Therapy

A vision therapy program for accommodative insufficiency generally requires from 12 to 24 in-office visits, if vision therapy is office based. The total number of therapy sessions depends on the age of the patient and his or her motivation and compliance.

Specific Vision Therapy Program

All of the vision therapy techniques recommended below are described in detail in Chapters 6 to 8.

TABLE 12.3 OBJECTIVES OF VISION THERAPY FOR ACCOMMODATIVE INSUFFICIENCY AND ILL-SUSTAINED ACCOMMODATION**Phase 1**

- Develop a working relationship with the patient
- Develop an awareness of the various feedback mechanisms that will be used throughout therapy
- Normalize accommodative amplitude and ability to stimulate accommodation
- Develop voluntary convergence
- Develop feeling of looking close and accommodating
- Normalize positive fusional vergence (PFV) amplitudes (smooth or tonic vergence demand)

Phase 2

- Normalize ability to stimulate and relax accommodation
- Incorporate speed of response into accommodative techniques
- Normalize negative fusional vergence (NFV) amplitudes (smooth or tonic vergence demand)
- Normalize PFV facility (jump or phasic vergence demand)
- Normalize NFV facility (jump or phasic vergence demand)

Phase 3

- Integrate accommodative facility therapy with binocular vision techniques
- Develop ability to change from a convergence to a divergence demand
- Integrate vergence procedures with versions and saccades

Phase 1

This first phase of therapy is designed to accomplish the objectives listed in Table 12.3 under Phase 1. After establishing a working relationship with the patient and developing an awareness of the various feedback mechanisms that will be used throughout therapy, the first goal of the therapy itself is to improve the patient's ability to stimulate accommodation and normalize the amplitude of accommodation. The emphasis during this phase is on the magnitude rather than the speed of the accommodative response. Minus lenses are primarily used initially; however, toward the end of phase 1, we begin to use plus and minus lenses. Useful procedures include lens sorting, the Hart chart, and loose lens rock.

Because of the interactions that occur between accommodation and vergence, it is also helpful to simultaneously work with convergence techniques. The objective is to help the patient appreciate the feeling and concept of looking close, converging, and accommodating. It is therefore helpful to perform convergence procedures during phase 1. Useful procedures include the Brock string, tranaglyphs, and the Computer Orthoptics Random Dot program. Home-based therapy procedures are listed in Table 12.4. The Home Therapy System (HTS)^a software contains excellent procedures for both accommodative and vergence therapy.

Endpoint. Phase 1 of therapy ends when the patient can:

- Clear +2.00/−6.00 lenses monocularly with 20/30-size print
- Fuse up to 30 Δ using convergence with the tranaglyphs or other convergence technique
- Fuse up to 45 Δ using convergence with the Computer Orthoptics Random Dot program.

A sample vision therapy program for phase 1 is summarized in Table 12.4. This program includes several techniques that can be used by the patient at home to supplement in-office therapy.

Phase 2

This second phase of therapy is designed to accomplish the objectives listed in Table 12.3 under Phase 2. In contrast to phase 1, the speed of the accommodative response should now be emphasized. In addition, it is important to continue using plus as well as minus lenses. The objective is for the patient to be able to relax and stimulate accommodation as quickly as possible. The same techniques used during phase 1 can be repeated using plus and minus lenses, with an emphasis on the speed of the accommodative response. We also begin working with BAF procedures, such as red–red rock and bar readers, and binocular facility with targets such as vectograms and tranaglyphs.

We now incorporate divergence therapy in addition to convergence therapy, and move toward binocular vision techniques that emphasize phasic vergence changes. By the end of this phase, the patient should be using the Aperture Rule and the Computer Orthoptics Random Dot program for both convergence and divergence therapy.

TABLE 12.4 SAMPLE VISION THERAPY PROGRAM FOR ACCOMMODATIVE INSUFFICIENCY

Phase 1
<p><i>Sessions 1 and 2</i></p> <p>IN-OFFICE</p> <ul style="list-style-type: none"> • Discuss nature of vision problem, goals of vision therapy, various feedback cues, importance of practice • Lens sorting • Loose lens rock (begin with minus lenses) • Brock string • Tranaglyphs or vectograms: base-out <ul style="list-style-type: none"> • Begin with a peripheral target such as tranaglyph 515 or the Quoit vectogram • Computer Orthoptics Random Dot program: base-out
<p>HOME THERAPY</p> <ul style="list-style-type: none"> • HTS Accommodation program • Loose lens rock • Brock string
<p><i>Sessions 3 and 4</i></p> <p>IN-OFFICE</p> <ul style="list-style-type: none"> • Hart chart rock • Loose lens rock; minus lenses • Bug on string • Tranaglyphs or vectograms: base-out <ul style="list-style-type: none"> • Use targets with more central demand (Clown, Bunny tranaglyphs; Clown, Topper vectograms) • Computer Orthoptics Random Dot program: base-out
<p>HOME THERAPY</p> <ul style="list-style-type: none"> • HTS Accommodation program • Loose lens rock • Brock string
<p><i>Sessions 5 through 8</i></p> <p>IN-OFFICE</p> <ul style="list-style-type: none"> • Hart chart rock • Loose lens rock; add plus lenses • Barrel card • Voluntary convergence • Tranaglyphs or vectograms: base-out <ul style="list-style-type: none"> • Use even more detailed targets such as tranaglyph Sports Slide and Faces targets and the Spirangle vectogram • Computer Orthoptics Random Dot program: base-out
<p>HOME THERAPY</p> <ul style="list-style-type: none"> • HTS Accommodation program • Hart chart rock • HTS Vergence program
Phase 2
<p><i>Sessions 9 and 10</i></p> <p>IN-OFFICE</p> <ul style="list-style-type: none"> • Loose lens rock; use both plus and minus lenses and incorporate speed as a factor • Tranaglyphs or vectograms with modifications to create jump vergence demand: base-out • Nonvariable tranaglyphs • Tranaglyph 515 or the Quoit vectogram: base-in • Binocular accommodative therapy techniques: use any of the binocular techniques listed above with \pm lenses
<p>HOME THERAPY</p> <ul style="list-style-type: none"> • HTS Accommodation program • HTS Vergence program • Loose lens rock (emphasize speed)
<p><i>Sessions 11 and 12</i></p> <p>IN-OFFICE</p> <ul style="list-style-type: none"> • Loose lens rock; use both plus and minus lenses and incorporate speed as a factor • Binocular accommodative therapy techniques: use any of the binocular techniques listed above with \pm lenses • Tranaglyphs or vectograms with modifications to create jump vergence demand: base-out • Aperture Rule: base-out • More central tranaglyphs or the vectograms: base-in

(Continued)

TABLE 12.4 CONTINUED

HOME THERAPY <ul style="list-style-type: none"> • HTS Vergence program
<i>Sessions 13 through 16</i>
IN-OFFICE <ul style="list-style-type: none"> • Binocular accommodative therapy techniques: use any of the binocular techniques listed above with \pm lenses • Aperture Rule: base-out • Eccentric Circles or Free Space Fusion cards: base-out • Computer Orthoptics Random Dot Vergence program: both base-in and base-out • Aperture Rule: base-in • Tranaglyphs or vectograms with modifications to create jump vergence demand: base-in
HOME THERAPY <ul style="list-style-type: none"> • Eccentric Circles or Free Space Fusion cards: base-out • HTS Vergence program
Phase 3
<i>Sessions 17 through 20</i>
IN-OFFICE <ul style="list-style-type: none"> • Binocular accommodative therapy with \pm lenses and the Aperture Rule • Tranaglyphs or vectograms with Polaroid or red/green flippers • Eccentric Circles or Free Space Fusion cards: base-out • Computer Orthoptics Random Dot Vergence program: step–jump vergence
HOME THERAPY <ul style="list-style-type: none"> • Eccentric Circles or Free Space Fusion cards: base-out • HTS Vergence program
<i>Sessions 21 and 22</i>
IN-OFFICE <ul style="list-style-type: none"> • Binocular accommodative therapy with \pm lenses and the Aperture Rule • Tranaglyphs or vectograms with Polaroid or red/green flippers • Eccentric Circles or Free Space Fusion cards: base-in • Computer Orthoptics Random Dot Vergence program: jump–jump vergence
HOME THERAPY <ul style="list-style-type: none"> • HTS Vergence program • Eccentric Circles or Free Space Fusion cards: base-in
<i>Sessions 23 and 24</i>
IN-OFFICE <ul style="list-style-type: none"> • Binocular accommodative therapy with \pm lenses and the Eccentric Circles • Tranaglyphs or vectograms with Polaroid or red/green flippers • Eccentric Circles or Free Space Fusion cards with rotation and versions • Lifesaver cards with rotation and versions • Computer Orthoptics Vergence program with rotation
HOME THERAPY <ul style="list-style-type: none"> • Eccentric Circles or Free Space Fusion cards: base-in/base-out with \pm flip lenses • HTS Vergence program

Endpoint. The endpoint of phase 2 is reached when the patient can:

- Clear +2.00/−6.00 lenses monocularly with 20/30-size print, 20 cpm
- Clear +2.00/−2.00 lenses binocularly with 20/30-size print, 15 cpm
- Fuse card 12 using convergence and card 6 using divergence with the Aperture Rule.

A sample vision therapy program for phase 2 is summarized in Table 12.4. This program includes several techniques that can be used by the patient at home to supplement the in-office therapy.

Phase 3

This third phase of therapy is designed to accomplish the objectives listed in Table 12.3 under Phase 3. During phase 3, the emphasis is on integration of accommodation and binocular therapy. Phasic binocular techniques such as the Aperture Rule, Eccentric Circles, Free Space cards, and the Computer Orthoptics step–jump vergence

program are useful. BAF with flip lenses should be used with the phasic binocular techniques listed above. It is also important to integrate accommodative and binocular therapy with saccades and versions. Moving the Eccentric Circles or Free Space Fusion cards into different positions of gaze or using several sets of cards in various positions, along with flip lenses, is an excellent procedure to accomplish this goal. Other techniques, such as the Brock string with rotation and Computer Orthoptics vergence procedures with rotation, are useful. *Endpoint.* The endpoint for this phase of therapy is reached when the patient is able to maintain clear single binocular vision with the Free Space Fusion cards or the Eccentric Circle cards together, while slowly rotating the cards and using +2.00/−2.00 flip lenses.

A reevaluation should be performed after about 3 to 4 weeks to determine whether any progress has been made. If no improvement is evident, there may be an underlying organic basis to the low amplitude of accommodation, and added plus lenses should be prescribed and vision therapy discontinued. If progress is adequate, reevaluate again at about halfway through the therapy program and again at the end of therapy. When all vision therapy objectives have been reached and the vision therapy program is completed, we recommend the home vision therapy maintenance program discussed in Chapter 9 (Table 9.10).

CASE STUDIES

The following case studies (Cases 12.1–12.3) are representative of the types of accommodative insufficiency patients that clinicians will encounter in practice.

Case 12.2 III-Sustained Accommodation

History

Stan, a 13-year-old seventh grader, presented with complaints of discomfort, blurred vision, and tearing after 30 to 40 minutes of reading. These problems began about 6 to 9 months ago, and he had already been to two other eye doctors. Neither had been able to find any problem with his eyes. Stan had never had any problem with his eyes before and did not wear glasses. He was healthy and was not taking any medication.

Examination Results

VA (distance, uncorrected):	OD: 20/20 OS: 20/20
VA (near, uncorrected):	OD: 20/20 OS: 20/20
Near point of convergence	
Accommodative target:	5 cm
Penlight:	5 cm
Cover test (distance):	Ortho
Cover test (near):	4 exophoria
Subjective:	OD: plano OS: plano
Cycloplegic:	OD: +0.50 OS: +0.50
Distance lateral phoria:	Ortho
Base-in vergence (distance):	X/6/4
Base-out vergence (distance):	X/16/9
Near lateral phoria:	4 exophoria
−1.00 gradient:	Ortho
Gradient AC/A ratio:	4:1

Calculated AC/A ratio:	4.4:1
Base-in vergence (near):	9/15/10
Base-out vergence (near):	10/17/10
Vergence facility:	16 cpm
NRA:	+2.50
PRA:	-2.00
Accommodative amplitude (push-up):	OD: 10 D; OS: 10 D
MAF:	OD: 5 cpm; difficulty with minus lenses, and performance deteriorates after 30 seconds OS: 5 cpm; difficulty with minus lenses, and performance deteriorates after 30 seconds
BAF:	3 cpm; difficulty with minus lenses, and quad performance deteriorates after 30 seconds
MEM retinoscopy:	+0.75 OD and OS

Pupils were normal, all external and internal health tests were negative, the deviation was comitant, and color vision testing revealed normal function.

Case Analysis

The distance and near phoria are both normal in this case. Therefore, the best initial approach is to analyze the ACC group data. Looking at these data reveals subtle difficulties with MAF and BAF testing. The overall cycles per minute are borderline. The significant finding, however, is the gradual deterioration in performance with minus lenses after 30 seconds. After observing this, we repeated the amplitude of accommodation about 10 times over the course of 1 minute. Stan's amplitude of accommodation gradually decreased over this time, and the final reading was 8 D OD and OS. All other findings were essentially in the expected range, although the PRA was slightly reduced and the MEM finding was on the high side of normal.

This case is characteristic of ill-sustained accommodation. It is easy to understand how the two previous doctors had not found any problem. It is highly likely that accommodative facility testing was not performed, and that the amplitude of accommodation was only performed once. It is therefore important to be aware of this subtle condition and perform the type of testing that is likely to elicit meaningful results.

Management

The use of lenses and added lenses were considered first in this case. No refractive error was present, but there was a subtle decrease in the PRA and a high-normal MEM finding. Both of these suggest that added plus lenses for near might be helpful. In discussing the treatment options with the patient and parents, it became clear that they wanted to try to eliminate this problem without the need for glasses, if possible. We therefore recommended vision therapy and followed the sample vision therapy program outlined in Tables 12.3 and 12.4. Eighteen visits of therapy were required; at the end of the treatment, a reevaluation was performed, with the following results:

Accommodative amplitude:	14 D OD and OS
MAF:	18 cpm OD and OS
BAF:	15 cpm
MEM retinoscopy:	+0.50 OD and OS

Stan was now comfortable when reading and could read for as long as he desired without blur or discomfort. We dismissed him from active vision therapy and prescribed the maintenance program described in Chapter 9 (Table 9.10).

Case 12.3 Accommodative Insufficiency Associated with Convergence Insufficiency (Pseudoconvergence Insufficiency)

Accommodative insufficiency can sometimes be associated with convergence insufficiency. In such cases, the accommodative disorder may be the primary problem. Refer to Case 9.3 in Chapter 9 for an example of pseudoconvergence insufficiency.

Accommodative Excess

BACKGROUND INFORMATION

Accommodative excess is a condition in which the patient has difficulty with all tasks requiring relaxation of accommodation. There is some confusion and disagreement in the literature about this condition. Other terms that have been used interchangeably with *accommodative excess* are *ciliary spasm*, *accommodative spasm*, *spasm of the near reflex*, and *pseudomyopia*. Rutstein, Daum, and Amos (38) reviewed 17 cases of accommodative spasm. They defined accommodative spasm as a condition in which the accommodative response exceeds the accommodative stimulus, and used dynamic retinoscopy to assess accommodative response. Based partially on their experience of finding only 17 cases of accommodative spasm at their clinic in a 4-year period, they concluded that accommodative spasm is a rare condition. In a study by Daum (15), only 2.6% of 114 patients with accommodative problems had accommodative excess. Rouse, Hutter, and Shiftlett (39) performed MEM retinoscopy on 721 schoolchildren and found that only 1% showed overaccommodation of 0.50 or greater. In his discussion on accommodative spasm and spasm of the near reflex, Miller (37) defined it as a condition seen most frequently as a functional disorder in patients without organic disease. He described the problem as one characterized by intermittent attacks of accommodation, convergence, and miosis. He stressed that miosis is always present and of considerable magnitude. The condition he described is also commonly associated with bilateral or unilateral limitation of abduction and severe myopia. This is the classic definition of spasm of the near reflex, which is indeed a rare condition, based on the limited research that has been done investigating its prevalence.

However, this is not the condition that we describe here. The description above and most of the studies to date have used a definition of accommodative spasm or excess that we feel is too restrictive. It may be that the disorder that has been called accommodative spasm—or spasm of the near reflex in other reports—is a very severe form of the milder condition that we describe as accommodative excess. However, the condition that we describe as accommodative excess is a subtler condition whose diagnosis requires analysis of all of the ACC group data described in Chapter 2. This consists of the amplitude of accommodation, MAF and BAF, the NRA and PRA, MEM retinoscopy, and the fused cross-cylinder test. We often find cases of accommodative dysfunction in which the response on MEM and fused cross-cylinder testing is plano or +0.25, yet the patients have difficulty clearing plus lenses on MAF testing and the NRA. We would still classify such a condition as accommodative excess, even though there is no dramatic overaccommodation, miosis, or limitation of abduction. If the criteria for the diagnosis of accommodative excess described below are used, this condition is not at all rare. We suggest that *accommodative excess* be used for the subtler condition we refer to in this chapter, and *spasm of the near reflex* be used to describe the severe form of accommodative spasm. The use of the term *pseudomyopia* as a synonym for accommodative excess is another area of confusion. Accommodative excess certainly may be associated with pseudomyopia. It often occurs in isolation of pseudomyopia, however. The definition of accommodative excess that we suggest includes pseudomyopia as one of the variable signs of accommodative excess. It is not essential, however, for this diagnosis.

Using this less restrictive definition, both Scheiman et al. (8) and Porcar and Martinez-Palomera (9) found that accommodative excess is more common than previously reported. Scheiman et al. found that 2.2% of 1,650 children had accommodative excess, and Porcar and Martinez-Palomera found that 10.8% of the university students they examined had accommodative excess.

TABLE 12.5 **SIGNS AND SYMPTOMS OF ACCOMMODATIVE EXCESS****Symptoms**

These symptoms are generally related to the use of the eyes for reading or other near tasks:

Long-standing
 Blurred vision worse after reading or other close work
 Headaches
 Eyestrain
 Difficulty focusing from far to near
 Sensitivity to light

Signs

Direct measures of accommodative relaxation

Difficulty clearing +2.00 with monocular accommodative facility
 Low monocular estimation method retinoscopy finding

Indirect measures of accommodative relaxation

Reduced negative relative accommodation
 Difficulty clearing +2.00 with binocular accommodative facility
 Low fused cross-cylinder finding
 Low base-in to blur finding at near

CHARACTERISTICS

Symptoms

Most symptoms are associated with reading or other close work. Common complaints include blurred vision, eyestrain, and headaches after short periods of reading, photophobia, difficulty attending and concentrating on reading tasks, and diplopia (Table 12.5). The symptom of blurred vision may be associated with both near work and distance tasks, such as looking at the chalkboard, watching television, and driving. A characteristic of the blurred vision associated with accommodative excess is that it is often variable and worse toward the end of the day or after extensive near work.

Signs

The signs of accommodative excess are presented in Table 12.5. All optometric testing requiring the patient to relax accommodation will be reduced in accommodative excess. The patient will have difficulty with MAF and BAF testing with plus lenses and with the NRA. The MEM retinoscopy and fused cross-cylinder testing will show less plus than normal. As with all accommodative disorders, it is common to find an associated binocular vision disorder (Table 12.5). It is important to remember that this set of criteria is more expansive than that suggested by other authors.

Both esophoria and exophoria can be present with accommodative excess. If the accommodative problem is primary, the patient will overaccommodate relative to the stimulus. This leads to excessive accommodative convergence and esophoria at near. Another possible scenario is that convergence insufficiency is the primary disorder, and accommodative excess is secondary. For example, many convergence insufficiency patients use accommodative convergence to supplement their inadequate positive fusional vergence (PFV). Continued use of excessive accommodative convergence may lead to accommodative excess.

ANALYSIS OF BINOCULAR AND ACCOMMODATIVE DATA

The entry point into the analysis of accommodative and binocular vision data is the phoria at distance and near. In cases of accommodative dysfunction, it is not unusual for the phoria to fall outside expected values. As we discussed above, accommodative excess can be associated with exophoria or esophoria. It is important, in such cases, to carefully analyze the appropriate group data.

For example, the patient in Case 12.4 (discussed later in this chapter) presented with symptoms of blurred vision after reading for 15 to 20 minutes. He also complained that when driving home after a day of work, his vision would be blurry compared to his vision in the morning. The cover test at distance is ortho, and at near, 2 esophoria. As Figure 2.4 in Chapter 2 illustrates, after eliminating refractive and organic causes, the best

Case 12.4 Accommodative Excess

History

Jim, a 22-year-old accountant, presented with complaints of occasional blurred vision when driving and tired eyes at the end of the workday. Some days his eyes are so tired that he does not even feel like reading the newspaper at home in the evening. In regard to the driving vision complaint, Jim felt that his vision was fine driving to work, but blurry at night coming home. He started his current job about a year ago, after graduating from college, and he noted that his problems have been progressing. He had his eyes examined several times as a child; on each occasion, his eyes were normal.

Jim had just been examined recently by his general physician and all was normal. He was not taking any medication.

Examination Results

VA (distance, uncorrected):	OD: 20/20 −2 OS: 20/20 −2
VA (near, uncorrected):	OD: 20/20 OS: 20/20
Near point of convergence	
Accommodative target:	5 cm
Penlight:	5 cm
Cover test (distance):	Orthophoria
Cover test (near):	2 esophoria
Subjective:	OD: −0.25, 20/20 OS: plano −0.25 × 90, 20/20
Distance lateral phoria:	Orthophoria
Base-in vergence (distance):	X/6/3
Base-out vergence (distance):	10/20/9
Near lateral phoria:	2 esophoria
−1.00 gradient:	5 esophoria
Gradient AC/A ratio:	3:1
Calculated AC/A ratio:	6.8:1
Base-in vergence (near):	4/16/12
Base-out vergence (near):	18/25/16
Vergence facility:	12 cpm
NRA:	+1.25
PRA:	−2.50
Accommodative amplitude (push-up):	OD: 10 D; OS: 10 D
MAF:	OD: 2 cpm, slow response with plus OS: 2 cpm, slow response with plus
BAF:	0 cpm, cannot clear plus
MEM retinoscopy:	−0.25 OD and OS

Pupils were normal, all external and internal health tests were negative, the deviation was comitant, and color vision testing revealed normal function.

Case Analysis

Because the near phoria is eso, analysis should begin with the NFV group data. In this case, both the direct and indirect measures indicate adequate NFV. The smooth vergences are normal, as are the

PRA and BAF findings. As suggested in Chapter 2, the next step is to analyze the data from the ACC group. All accommodative testing revealed difficulty relaxing accommodation. The NRA and MAF test findings are both low, and MEM retinoscopy revealed overaccommodation. Based on this analysis, we reached a diagnosis of accommodative excess.

The symptoms in this case are characteristic of accommodative excess. Jim complained of blurred distance vision that was worse at the end of the day. This can be readily explained based on the diagnosis. After a full day of work, his accommodative system is in a spasm and causes blurred distance vision.

Management

We prescribed a program of vision therapy that lasted 15 visits over a 3-month period. A reevaluation at the end of therapy revealed the following:

VA (distance, uncorrected):	OD: 20/20 OS: 20/20
VA (near, uncorrected):	OD: 20/20 OS: 20/20
Cover test (distance):	Orthophoria
Cover test (near):	Orthophoria
Subjective:	OD: plano, 20/20 OS: plano, 20/20
Distance lateral phoria:	Orthophoria
Base-in vergence (distance):	X/7/4
Base-out vergence (distance):	10/20/10
Near lateral phoria:	Orthophoria
-1.00 gradient:	4 esophoria
Base-in vergence (near):	9/20/14
Base-out vergence (near):	22/30/20
Vergence facility:	16 cpm
NRA:	+2.25
PRA:	-2.50
Accommodative amplitude (push-up):	OD: 10 D; OS: 10 D
MAF:	OD: 10 cpm OS: 10 cpm
BAF:	8 cpm
MEM retinoscopy:	+0.25 OD and OS

initial approach is to be concerned about an esophoria and low NFV-type problem at near. We would therefore analyze the NFV group data, which includes base-in vergence at near, the PRA, BAF testing with minus lenses, MEM retinoscopy, and the fused cross-cylinder test. Case 12.4 illustrates that the indirect measures of NFV are all normal. The patient has a normal PRA and BAF finding with minus lenses. The MEM retinoscopy shows less plus than expected. The smooth and step vergence findings are also normal. These data, therefore, do not suggest a problem such as convergence excess or esophoria with low NFV. As the flowchart in Figure 2.5 illustrates, once a binocular vision problem is eliminated, we recommend analysis of the ACC group data. These data reveal a normal amplitude of accommodation, inability to clear +2.00 with MAF along with the reduced NRA, a low MEM finding, and inability to clear +2.00 lenses binocularly. These findings, analyzed as a group, suggest that the patient has difficulty with all tests requiring relaxation of accommodation, confirming a diagnosis of accommodative excess.

TABLE 12.6 DIFFERENTIAL DIAGNOSIS OF ACCOMMODATIVE EXCESS**Functional disorders to rule out**

Convergence excess
 Basic esophoria
 Accommodative insufficiency
 Accommodative infacility

Nonfunctional causes of accommodative excess

<i>Bilateral^a</i>	<i>Unilateral</i>
DRUGS	LOCAL EYE DISEASE
Cholinergic drugs	None
Morphine	
Digitalis	
Sulfonamides and carbonic anhydrase inhibitors	
GENERAL DISEASE: ADULTS	GENERAL DISEASE: ADULTS
Encephalitis	Trigeminal neuralgia
Syphilis	
GENERAL DISEASE: CHILDREN	
Influenza	
Encephalitis	
Meningitis	

^aA bilateral problem may start unilaterally.

Source: From London R. Accommodation. In: Barresi BJ, ed. *Ocular assessment: the manual of diagnosis for office practice*. Boston, MA: Butterworth-Heinemann, 1984:123–130, with permission.

DIFFERENTIAL DIAGNOSIS

The differential diagnosis of accommodative excess is presented in Table 12.6. Accommodative excess is considered to be a benign condition, with no serious consequences other than the visual symptoms listed in Table 12.5. It must be differentiated from other accommodative disorders. The key to the differential diagnosis is that a patient with accommodative excess will perform poorly on all tests that probe the ability to relax accommodation. In accommodative insufficiency, the problem will be with minus lenses, and accommodative infacility performance on both plus and minus lenses will be reduced.

As discussed earlier in this chapter, a less common form of accommodative excess has been reported in the literature that may have an organic cause. Spasm of the near reflex has been reported to be secondary to the diseases and medications listed in Table 12.6. These more serious underlying etiologies must be ruled out in all cases of accommodative excess. This differential diagnosis depends very much on the nature of the patient's symptoms. Typically, the accommodative excess patient presents with long-standing chronic complaints and a negative health history. The history is also negative for any medication known to affect accommodation. When managing a case of accommodative excess that is thought to have a functional basis, if symptoms and findings do not improve as expected, it is wise to reconsider the etiology of the condition.

TREATMENT

We recommend the management sequence listed on page 335.

Lenses

Because uncorrected refractive error can be a cause of accommodative fatigue, we recommend that correction of significant ametropia be the first management consideration. When dealing with patients with accommodative excess, even small degrees of refractive error may be significant. Prescribing for small degrees of hyperopia, astigmatism, and small differences in refractive error between the two eyes may provide some immediate relief of symptoms for the patient.

Added Lenses

Analysis of the near point findings in accommodative excess clearly shows that these patients would not benefit from the use of added plus lenses. The low NRA, difficulty clearing plus during accommodative facility testing, the normal amplitude of accommodation, and low MEM retinoscopy are all examples of data suggesting that plus will not be helpful.

Vision Therapy

A vision therapy program for accommodative excess generally requires from 12 to 24 in-office visits, if vision therapy is office based. The total number of therapy sessions also depends on the age of the patient and his or her motivation and compliance.

Specific Vision Therapy Program

All of the vision therapy techniques recommended below are described in detail in Chapters 6 to 8.

Phase 1

This first phase of therapy is designed to accomplish the objectives listed in Table 12.7 under Phase 1. After establishing a working relationship with the patient and developing an awareness of the various feedback mechanisms that will be used throughout therapy, the first goal of the therapy itself is to improve the patient's ability to relax accommodation. The emphasis during this phase is on the magnitude rather than the speed of the accommodative response. Useful procedures include lens sorting, the Hart chart, and loose lens rock.

Because of the interactions that occur between accommodation and vergence, it is also helpful to simultaneously work with divergence techniques. The objective is to help the patient appreciate the feeling and concept of relaxing convergence and accommodation. It is therefore helpful to perform divergence procedures during phase 1. Useful procedures include the vectograms, tranaglyphs, and the Computer Orthoptics Random Dot program. Home-based therapy procedures are listed in Table 12.8. The HTS software has excellent procedures for both accommodative and vergence therapy.

Endpoint. Phase 1 of therapy ends when the patient can:

- Clear +2.00 lenses monocularly with 20/30-size print
- Fuse up to 15 Δ using divergence with the tranaglyphs or other convergence technique
- Fuse up to 15 Δ using divergence with the Computer Orthoptics Random Dot program.

A sample vision therapy program for phase 1 is summarized in Table 12.8. This program includes several techniques that can be used by the patient at home to supplement the in-office therapy.

TABLE 12.7 OBJECTIVES OF VISION THERAPY FOR ACCOMMODATIVE EXCESS

Phase 1

- Develop a working relationship with the patient
- Develop an awareness of the various feedback mechanisms that will be used throughout therapy
- Develop feeling of diverging, looking away, relaxing accommodation
- Normalize negative fusional vergence (NFV) amplitudes at near (smooth or tonic vergence demand)
- Normalize accommodative amplitude and ability to stimulate and relax accommodation

Phase 2

- Normalize positive fusional vergence (PFV) amplitudes (smooth or tonic vergence demand)
- Normalize NFV facility at near (jump or phasic vergence demand)
- Normalize PFV facility (jump or phasic vergence demand)

Phase 3

- Normalize NFV amplitudes at intermediate distances
- Normalize NFV facility at far

TABLE 12.8 SAMPLE VISION THERAPY PROGRAM FOR ACCOMMODATIVE EXCESS

Phase 1
<p><i>Sessions 1 and 2</i> IN-OFFICE</p> <ul style="list-style-type: none"> • Discuss nature of vision problem, goals of vision therapy, various feedback cues, importance of practice • Lens sorting • Loose lens rock (begin with plus lenses) • Brock string • Tranaglyphs or vectograms: base-in <ul style="list-style-type: none"> • Begin with a peripheral target such as tranaglyph 515 or the Quoit vectogram • Computer Orthoptics Random Dot program: base-in
<p>HOME THERAPY</p> <ul style="list-style-type: none"> • HTS Accommodation program • Loose lens rock • Brock string
<p><i>Sessions 3 and 4</i> IN-OFFICE</p> <ul style="list-style-type: none"> • Hart chart rock • Loose lens rock; plus lenses • Bug on string • Tranaglyphs or vectograms: base-in <ul style="list-style-type: none"> • Use targets with more central demand (Clown, Bunny tranaglyphs; Clown, Topper vectograms) • Computer Orthoptics Random Dot program: base-in
<p>HOME THERAPY</p> <ul style="list-style-type: none"> • HTS Accommodation program • Loose lens rock • Bug on string
<p><i>Sessions 5 through 8</i> IN-OFFICE</p> <ul style="list-style-type: none"> • Hart chart rock • Bug on string • Loose lens rock; add minus lenses • Tranaglyphs or vectograms: base-in <ul style="list-style-type: none"> • Use even more detailed targets such as tranaglyph Sports Slide and Faces targets and the Spirangle vectogram • Computer Orthoptics Random Dot program: base-in
<p>HOME THERAPY</p> <ul style="list-style-type: none"> • HTS Accommodation program • Hart chart rock • HTS Vergence program
Phase 2
<p><i>Sessions 9 and 10</i> IN-OFFICE</p> <ul style="list-style-type: none"> • Loose lens rock; use both plus and minus lenses and incorporate speed as a factor • Tranaglyphs or vectograms with modifications to create jump vergence demand: base-in • Nonvariable tranaglyphs • Tranaglyph 515 or the Quoit vectogram: base-out • Binocular accommodative therapy techniques: use any of the binocular techniques listed above with \pm lenses
<p>HOME THERAPY</p> <ul style="list-style-type: none"> • HTS Vergence program • HTS Accommodation program • Loose lens rock (emphasize speed)
<p><i>Sessions 11 and 12</i> IN-OFFICE</p> <ul style="list-style-type: none"> • Loose lens rock; use both plus and minus lenses and incorporate speed as a factor • Binocular accommodative therapy techniques: use any of the binocular techniques listed above with \pm lenses • Tranaglyphs or vectograms with modifications to create jump vergence demand: base-in • Aperture Rule: base-in • Nonvariable tranaglyphs with \pm flip lenses

(Continued)

TABLE 12.8 CONTINUED

HOME THERAPY <ul style="list-style-type: none"> • More central tranaglyphs or the vectograms: base-out
<i>Sessions 13 through 16</i>
IN-OFFICE <ul style="list-style-type: none"> • Binocular accommodative therapy techniques: use any of the binocular techniques listed above with \pm lenses • Aperture Rule: base-in and base-out • Eccentric Circles or Free Space Fusion cards: base-in • Computer Orthoptics Random Dot Vergence program: both base-in and base-out • Tranaglyphs or vectograms with modifications to create jump vergence demand: base-out
HOME THERAPY <ul style="list-style-type: none"> • HTS Vergence program • Eccentric Circles or Free Space Fusion cards: base-in
Phase 3
<i>Sessions 17 through 20</i>
IN-OFFICE <ul style="list-style-type: none"> • Binocular accommodative therapy with \pm lenses and the Aperture Rule • Tranaglyphs or vectograms with Polaroid or red/green flippers • Eccentric Circles or Free Space Fusion cards: base-in and base-out • Computer Orthoptics Random Dot Vergence program: step–jump vergence
HOME THERAPY <ul style="list-style-type: none"> • HTS Vergence program • Eccentric Circles or Free Space Fusion cards: base-in and base-out
<i>Sessions 21 and 22</i>
IN-OFFICE <ul style="list-style-type: none"> • Binocular accommodative therapy with \pm lenses and the Aperture Rule • Tranaglyphs or vectograms with Polaroid or red/green flippers • Eccentric Circles or Free Space Fusion cards: base-in and base-out • Computer Orthoptics Random Dot Vergence program: jump–jump vergence
HOME THERAPY <ul style="list-style-type: none"> • HTS Vergence program • Eccentric Circles or Free Space Fusion cards: base-in and base-out
<i>Sessions 23 and 24</i>
IN-OFFICE <ul style="list-style-type: none"> • Binocular accommodative therapy with \pm lenses and the Eccentric Circles • Tranaglyphs or vectograms with Polaroid or red/green flippers • Eccentric Circles or Free Space Fusion cards with rotation and versions • Computer Orthoptics Vergence program with rotation
HOME THERAPY <ul style="list-style-type: none"> • HTS Vergence program • Eccentric Circles or Free Space Fusion cards: divergence/convergence with \pm flip lenses

Phase 2

This second phase of therapy is designed to accomplish the objectives listed in Table 12.7 under Phase 2. In contrast to Phase 1, the speed of the accommodative response should now be emphasized. In addition, it is important to begin using minus as well as plus lenses. The objective is for the patient to be able to relax and stimulate accommodation as quickly as possible. The same techniques used during phase 1 can be repeated using plus and minus lenses, with an emphasis on the speed of the accommodative response. We also begin working with BAF procedures, such as red–red rock and bar readers, and binocular facility with targets such as vectograms and tranaglyphs.

We now incorporate convergence therapy, in addition to divergence therapy, and move toward binocular vision techniques that emphasize phasic vergence changes. By the end of this phase, the patient should be using the Aperture Rule and the Computer Orthoptics Random Dot program for both convergence and divergence therapy.

Endpoint. The endpoint of phase 2 is reached when the patient can:

- Clear +2.00/−6.00 lenses monocularly with 20/30-size print, 20 cpm
- Clear +2.00/−2.00 lenses binocularly with 20/30-size print, 15 cpm
- Fuse card 12 using convergence and card 6 using divergence with the Aperture Rule.

A sample vision therapy program for phase 2 is summarized in Table 12.8. This program includes several techniques that can be used by the patient at home to supplement the in-office therapy.

Phase 3

This third phase of therapy is designed to accomplish the objectives listed in Table 12.7 under Phase 3. During phase 3, the emphasis is on integration of accommodation and binocular therapy. Phasic binocular techniques such as the Aperture Rule, Eccentric Circles, Free Space cards, and the Computer Orthoptics step–jump vergence program are useful. BAF with flip lenses should be used with the phasic binocular techniques listed above. It is also important to integrate accommodative and binocular therapy with saccades and versions. Moving the Eccentric Circles or Free Space Fusion cards into different positions of gaze or using several sets of cards in various positions, along with flip lenses, is an excellent procedure to accomplish this goal. Other techniques, such as the Brock string with rotation and Computer Orthoptics vergence procedures with rotation, are also useful.

Endpoint. The endpoint for this phase of therapy is reached when the patient is able to maintain clear single binocular vision with the Free Space Fusion cards or the Eccentric Circle cards together, while slowly rotating the cards and using +2.00/−2.00 flip lenses.

As recommended in previous chapters, a reevaluation should be performed about halfway through the therapy program and again at the end of therapy. When all vision therapy objectives have been reached and the vision therapy program is completed, we recommend the home vision therapy maintenance program discussed in Chapter 9 (Table 9.10).

CASE STUDIES

The following case studies (Cases 12.4 and 12.5) are representative of the types of accommodative excess patients that clinicians will encounter in practice.

Case 12.5 Accommodative Excess Secondary to Convergence Insufficiency

Accommodative excess is commonly associated with convergence insufficiency. In most cases, the accommodative disorder is secondary to the convergence problem. A patient with convergence insufficiency will generally have a receded near point of convergence, exophoria at near, and reduced PFV. Such patients often use excessive accommodation to stimulate accommodative convergence to supplement the inadequate PFV. If this pattern continues for long periods of time, accommodative excess can occur. Refer to Case 9.5 in Chapter 9 for an example.

Accommodative Infacility

BACKGROUND INFORMATION

Accommodative infacility is a condition in which the patient experiences difficulty changing the accommodative response level. An important characteristic of accommodative infacility is that it is a condition in which the latency and speed of the accommodative response (the dynamics of the accommodative response) are abnormal. Thus, it is a disorder in which the amplitude is normal, yet the patient's ability to make use of this amplitude quickly, and for long periods of time, is inadequate. This distinction between amplitude

and facility of response is similar to that present for binocular vision anomalies. In previous chapters, we described disorders of fusional amplitude, such as convergence insufficiency and convergence excess, and disorders of vergence facility, such as fusional vergence dysfunction.

Clinicians who only evaluate the amplitude of the accommodative response will invariably miss the diagnosis of accommodative infacility. A common issue raised by students and clinicians about this condition is as follows: “If the patient has 15 D of accommodative amplitude, I would expect that he should be able to stimulate and relax 2 D of accommodation.” Many authors have clearly demonstrated that this is not necessarily true (3,5,40–42). It is possible to have a disorder of the dynamics of the accommodative response in the presence of a normal accommodative amplitude. A study by Wick and Hall (43) underscores the importance of a clinical assessment of accommodation that includes facility and response, in addition to amplitude. They screened the accommodative status of 123 schoolchildren and assessed amplitude, lag, and facility of accommodation. Their results indicate that if only one aspect of accommodation is evaluated, there is a reasonable likelihood of missing an accommodative dysfunction. A patient may be labeled erroneously as having no accommodative dysfunction when, in fact, one exists.

There have not been many studies investigating the prevalence of accommodative infacility. Hokoda (7), in the study referred to earlier in this chapter, reported that 30% of the accommodative problems found in his sample had accommodative infacility, 55% had accommodative insufficiency, and 15% had accommodative excess. Daum (15) found that 12% of the patients with accommodative dysfunction had accommodative infacility. Scheiman et al. (8) found that 1.5% of the 1,650 children studied had accommodative infacility.

CHARACTERISTICS

Symptoms

Most symptoms are associated with reading or other close work. Common complaints are blurred vision, difficulty changing focus from one distance to another, headaches, eyestrain, difficulty sustaining and attending to reading and other close work, and fatigue (Table 12.9). The symptom most characteristic of accommodative infacility is difficulty changing focus from one distance to another. Daum (15) found that 43% of patients with accommodative infacility complained of this symptom, whereas patients with accommodative insufficiency only mentioned this 7% of the time. As with other accommodative and binocular vision disorders, some patients with accommodative infacility may be asymptomatic. Avoidance should be considered a symptom of accommodative infacility.

Signs

The signs of accommodative infacility are presented in Table 12.9. Optometric test results that require the patient to both relax and stimulate accommodation will be reduced in accommodative infacility. The characteristic findings are poor performance with MAF and BAF testing with both plus *and* minus lenses, and

TABLE 12.9 SYMPTOMS AND SIGNS OF ACCOMMODATIVE INFACILITY

Symptoms

These symptoms are generally related to the use of the eyes for reading or other near tasks:	
Long-standing	Fatigue and sleepiness
Blurred vision, particularly when looking from near to far or far to near	Loss of comprehension over time
Headaches	A pulling sensation around the eyes
Eyestrain	Movement of the print
Reading problems	Avoidance of reading and other close work

Signs

Direct measures of accommodative facility

Difficulty clearing -2.00 and $+2.00$ with monocular accommodative facility

Indirect measures of accommodative facility

Reduced positive relative accommodation and negative relative accommodation

Difficulty clearing -2.00 and $+2.00$ with binocular accommodative facility

Low base-out and base-in to blur finding at near

reduced findings with the NRA and PRA. The diagnosis of accommodative infacility is used only when there are deficiencies in *both* stimulation and relaxation of accommodation. This is an important distinction because the diagnosis is often based on the results of accommodative infacility testing. If a 20-year-old patient, for instance, can only complete 3 cpm during this testing, the term *accommodative infacility* is often mistakenly used. The inability of a patient to complete the expected number of cycles per minute is not sufficient for the diagnosis. If the reason for the low number of cycles was difficulty clearing both plus and minus, the diagnosis of accommodative infacility is appropriate. If the reason, however, was slow performance with only minus and normal response with plus, or problems with only plus and normal response with minus, the diagnosis is not accommodative infacility.

The amplitude of accommodation, MEM retinoscopy, and the fused cross-cylinder tests are generally in the normal range. As with all accommodative disorders, it is common to find an associated binocular vision disorder. Esophoria at near is the most common binocular vision problem associated with accommodative infacility, although exophoria and even intermittent exotropia have been reported (44).

ANALYSIS OF BINOCULAR AND ACCOMMODATIVE DATA

The entry point into the analysis of accommodative and binocular vision data is the phoria at distance and near. In cases of accommodative dysfunction, it is not unusual for the phoria to fall outside expected values. As discussed above, accommodative infacility can be associated with exophoria or esophoria. Figure 2.4 in Chapter 2 illustrates that after eliminating refractive error and organic causes, the best initial approach is to be concerned about an esophoria or exophoria and to analyze the PFV or NFV group data. As the flowchart in Figure 2.5 illustrates, once a binocular vision problem is eliminated, we recommend analysis of the ACC group data. In a case of accommodative infacility, these data would reveal a normal amplitude of accommodation and an inability to clear both -2.00 and $+2.00$ lenses with MAF and BAF, along with reduced NRA and PRA. These findings, analyzed as a group, suggest that the patient has difficulty with tests requiring both stimulation and relaxation of accommodation, confirming a diagnosis of accommodative infacility.

DIFFERENTIAL DIAGNOSIS

The differential diagnosis of accommodative infacility is presented in Table 12.10. Accommodative infacility is considered to be a benign condition, with no serious consequences other than the visual symptoms listed in Table 12.10. It must be differentiated from other accommodative disorders. The most important test finding in the diagnosis of accommodative infacility is poor performance with MAF testing. However, the same is true for all accommodative disorders. The key differential is that only in accommodative infacility does the patient have difficulty with both plus and minus lenses. With accommodative insufficiency, the patient fails accommodative facility testing because of inability to clear -2.00 lenses, whereas in accommodative excess, the problem is $+2.00$ lenses.

There is a great deal of literature suggesting that there may be organic causes for both accommodative insufficiency and excess. Similar literature does not exist for accommodative infacility. In spite of this lack of documentation, we believe that it is prudent to consider the list of organic causes in Table 12.10 before making any treatment recommendations for accommodative infacility. This differential diagnosis depends very much on the nature of the patient's symptoms. Typically, accommodative infacility presents with long-standing chronic complaints and a negative health history. The history is also negative for any medication known to affect accommodation. When managing a case of accommodative infacility that is thought to have a functional basis, if symptoms and findings do not improve as expected, it is wise to reconsider the etiology of the condition.

TREATMENT

We recommend the management sequence listed on page 335.

Lenses

The first management consideration is correction of ametropia. When dealing with patients with accommodative infacility, even small degrees of refractive correction may be significant. Prescribing for small degrees

TABLE 12.10 DIFFERENTIAL DIAGNOSIS OF ACCOMMODATIVE INFACILITY

Functional disorders to rule out	
Convergence excess	
Basic esophoria	
Accommodative insufficiency	
Accommodative infacility	
Nonfunctional causes of accommodative infacility	
<i>Bilateral^a</i>	<i>Unilateral</i>
DRUGS	LOCAL EYE DISEASE
Alcohol	Iridocyclitis
Artane	Glaucoma
Ganglion blockers	Choroidal metastasis
Phenothiazides	Tear in iris sphincter
Antihistamines	Blunt trauma
Cycloplegics	Ciliary body aplasia
Central nervous system stimulants	Scleritis
Marijuana	Adie syndrome
Cholinergic drugs	
Digitalis	
Sulfonamides and carbonic anhydrase inhibitors	
GENERAL DISEASE: ADULTS	GENERAL DISEASE: ADULTS
Anemia	Sinusitis
Encephalitis	Dental caries
Diabetes mellitus	Posterior communicating artery aneurysm
Multiple sclerosis	Parkinsonism
Myotonic dystrophy	Wilson disease
Malaria	Midbrain lesions
Typhoid	
Toxemia	
Botulism	
GENERAL DISEASE: CHILDREN	GENERAL DISEASE: CHILDREN
Anemia	Scarlet fever
Mumps	Whooping cough
Measles	Tonsillitis
Influenza	Diphtheria
Encephalitis	Lead and arsenic poisoning
Meningitis	
NEUROOPHTHALMIC	NEUROOPHTHALMIC
Lesions in Edinger-Westphal syndrome	Fascicular nerve III lesion
Trauma to craniocervical region (whiplash)	Herpes zoster
Pineal tumor	Horner syndrome
Parinaud syndrome	
Polyneuropathy	
Anterior poliomyelitis	

^aA bilateral problem may start unilaterally.

of hyperopia, astigmatism, and small differences in refractive error between the two eyes may provide some immediate relief of symptoms for the patient.

Added Lenses

Analysis of the near point findings in accommodative infacility clearly shows that these patients would not benefit from the use of added plus lenses. The low NRA and PRA, difficulty clearing plus and minus during

accommodative facility testing, the normal amplitude of accommodation, and normal MEM retinoscopy are all examples of data suggesting that plus will not be helpful.

Vision Therapy

A vision therapy program for accommodative infacility generally requires from 12 to 24 in-office visits, if vision therapy is office based. The total number of therapy sessions also depends on the age of the patient and his or her motivation and compliance.

Specific Vision Therapy Program

All of the vision therapy techniques recommended below are described in detail in Chapters 6 to 8.

Phase 1

This first phase of therapy is designed to accomplish the objectives listed in Table 12.11 under Phase 1. After establishing a working relationship with the patient and developing an awareness of the various feedback mechanisms that will be used throughout therapy, the first goal of the therapy is to improve the patient's ability to stimulate and relax accommodation. The emphasis during this phase is on the magnitude, rather than the speed, of the accommodative response. Useful procedures include lens sorting, the Hart chart, and loose lens rock.

Because of the interactions that occur between accommodation and vergence, it is also helpful to simultaneously work with convergence and divergence techniques. The objective is to help the patient appreciate the feeling and concept of looking close and far, converging and accommodating, and diverging and relaxing accommodation. It is therefore helpful to perform convergence and divergence procedures during phase 1. Useful procedures include the Brock string, tranaglyphs, and the Computer Orthoptics Random Dot program. Home-based therapy procedures are listed in Table 12.12. The HTS software has excellent procedures for both accommodative and vergence therapy.

Endpoint. Phase 1 of therapy ends when the patient can:

- Clear +2.00/−6.00 lenses monocularly with 20/30-size print
- Fuse up to 30 Δ using convergence and 15 Δ using divergence with the tranaglyphs or other convergence technique
- Fuse up to 45 Δ using convergence and 15 base-in using divergence with the Computer Orthoptics Random Dot program.

A sample vision therapy program for phase 1 is summarized in Table 12.12. This program includes several techniques that can be used by the patient at home to supplement the in-office therapy.

TABLE 12.11 OBJECTIVES OF VISION THERAPY FOR ACCOMMODATIVE INFACILITY

Phase 1

- Develop a working relationship with the patient
- Develop an awareness of the various feedback mechanisms that will be used throughout therapy
- Develop feeling of diverging and converging, looking close and looking far, accommodating and relaxing accommodation
- Normalize negative and positive fusional vergence amplitudes at near (smooth or tonic vergence demand)
- Normalize accommodative amplitude and ability to stimulate and relax accommodation

Phase 2

- Normalize positive fusional vergence (PFV) amplitudes (smooth or tonic vergence demand)
- Normalize negative fusional vergence (NFV) facility at near (jump or phasic vergence demand)
- Normalize PFV facility (jump or phasic vergence demand)

Phase 3

- Normalize NFV amplitudes at intermediate distances
- Normalize NFV facility at far

TABLE 12.12 SAMPLE VISION THERAPY PROGRAM FOR ACCOMMODATIVE INFACILITY

Phase 1
<p><i>Sessions 1 and 2</i> IN-OFFICE</p> <ul style="list-style-type: none"> • Discuss nature of vision problem, goals of vision therapy, various feedback cues, importance of practice • Lens sorting • Loose lens rock (begin with minus lenses) • Brock string • Tranaglyphs or vectograms: base-out <ul style="list-style-type: none"> • Begin with a peripheral target such as tranaglyph 515 or the Quoit vectogram • Computer Orthoptics Random Dot program: base-out
<p>HOME THERAPY</p> <ul style="list-style-type: none"> • HTS Accommodation program • Loose lens rock • Brock string
<p><i>Sessions 3 and 4</i> IN-OFFICE</p> <ul style="list-style-type: none"> • Hart chart rock • Loose lens rock; minus lenses • Bug on string • Tranaglyphs or vectograms: base-out <ul style="list-style-type: none"> • Use targets with more central demand (Clown, Bunny tranaglyphs; Clown, Topper vectograms) • Computer Orthoptics Random Dot program: base-out
<p>HOME THERAPY</p> <ul style="list-style-type: none"> • HTS Accommodation program • Loose lens rock • Brock string
<p><i>Sessions 5 through 8</i> IN-OFFICE</p> <ul style="list-style-type: none"> • Hart chart rock • Loose lens rock; add plus lenses • Barrel card • Voluntary convergence • Tranaglyphs or vectograms: base-out and base-in <ul style="list-style-type: none"> • Use even more detailed targets such as tranaglyph Sports Slide and Faces targets and the Spirangle vectogram • Computer Orthoptics Random Dot program: base-out
<p>HOME THERAPY</p> <ul style="list-style-type: none"> • HTS Accommodation program • HTS Vergence program • Hart chart rock • Tranaglyphs: base-out
Phase 2
<p><i>Sessions 9 and 10</i> IN-OFFICE</p> <ul style="list-style-type: none"> • Loose lens rock; use both plus and minus lenses and incorporate speed as a factor • Tranaglyphs or vectograms with modifications to create jump vergence demand: base-out • Nonvariable tranaglyphs • Tranaglyph 515 or the Quoit vectogram: base-in • Binocular accommodative therapy techniques: use any of the binocular techniques listed above with \pm lenses
<p>HOME THERAPY</p> <ul style="list-style-type: none"> • HTS Accommodation program • HTS Vergence program • Loose lens rock (emphasize speed)
<p><i>Sessions 11 and 12</i> IN-OFFICE</p> <ul style="list-style-type: none"> • Loose lens rock; use both plus and minus lenses and incorporate speed as a factor • Binocular accommodative therapy techniques: use any of the binocular techniques listed above with \pm lenses

(Continued)

TABLE 12.12 CONTINUED

<ul style="list-style-type: none"> • Tranaglyphs or vectograms with modifications to create jump vergence demand: base-out • Aperture Rule: base-out • More central tranaglyphs or the vectograms: base-in
<p>HOME THERAPY</p> <ul style="list-style-type: none"> • HTS Accommodation program • HTS Vergence program
<p><i>Sessions 13 through 16</i></p> <p>IN-OFFICE</p> <ul style="list-style-type: none"> • Binocular accommodative therapy techniques: use any of the binocular techniques listed above with \pm lenses • Aperture Rule: base-out • Eccentric Circles or Free Space Fusion cards: base-out • Computer Orthoptics Random Dot Vergence program: both base-in and base-out • Aperture Rule: base-in • Tranaglyphs or vectograms with modifications to create jump vergence demand: base-in
<p>HOME THERAPY</p> <ul style="list-style-type: none"> • HTS Vergence program • Eccentric Circles or Free Space Fusion cards: base-out
<p>Phase 3</p>
<p><i>Sessions 17 through 20</i></p> <p>IN-OFFICE</p> <ul style="list-style-type: none"> • Binocular accommodative therapy with \pm lenses and the Aperture Rule • Tranaglyphs or vectograms with Polaroid or red/green flippers • Eccentric Circles or Free Space Fusion cards: base-out • Computer Orthoptics Random Dot Vergence program: step–jump vergence
<p>HOME THERAPY</p> <ul style="list-style-type: none"> • HTS Vergence program • Eccentric Circles or Free Space Fusion cards: base-out
<p><i>Sessions 21 and 22</i></p> <p>IN-OFFICE</p> <ul style="list-style-type: none"> • Binocular accommodative therapy with \pm lenses and the Aperture Rule • Tranaglyphs or vectograms with Polaroid or red/green flippers • Eccentric Circles or Free Space Fusion cards: base-in • Computer Orthoptics Random Dot Vergence program: jump–jump vergence
<p>HOME THERAPY</p> <ul style="list-style-type: none"> • HTS Vergence program • Eccentric Circles or Free Space Fusion cards: base-in
<p><i>Sessions 23 and 24</i></p> <p>IN-OFFICE</p> <ul style="list-style-type: none"> • Binocular accommodative therapy with \pm lenses and the Eccentric Circles • Tranaglyphs or vectograms with Polaroid or red/green flippers • Eccentric Circles or Free Space Fusion cards with rotation and versions • Lifesaver cards with rotation and versions • Computer Orthoptics Vergence program with rotation
<p>HOME THERAPY</p> <ul style="list-style-type: none"> • HTS Vergence program • Eccentric Circles or Free Space Fusion cards: base-in/base-out with \pm flip lenses

Phase 2

This second phase of therapy is designed to accomplish the objectives listed in Table 12.11 under Phase 2. In contrast to phase 1, the speed of the accommodative response should now be emphasized. The objective is for the patient to be able to relax and stimulate accommodation as quickly as possible. The same techniques used during phase 1 can be repeated using plus and minus lenses, with an emphasis on the speed of the accommodative response. We also begin working with BAF procedures, such as red–red rock and bar readers, and binocular facility with targets such as vectograms and tranaglyphs.

In addition, we now emphasize phasic vergence techniques. By the end of this phase, the patient should be using the Aperture Rule and the Computer Orthoptics Random Dot program for both convergence and divergence therapy.

Endpoint. The endpoint of phase 2 is reached when the patient can:

- Clear +2.00/−6.00 lenses monocularly with 20/30-size print, 20 cpm
- Clear +2.00/−2.00 lenses binocularly with 20/30-size print, 15 cpm
- Fuse card 12 using convergence and card 6 using divergence with the Aperture Rule.

A sample vision therapy program for phase 2 is summarized in Table 12.12. This program includes several techniques that can be used by the patient at home to supplement the in-office therapy.

Phase 3

This third phase of therapy is designed to accomplish the objectives listed in Table 12.11 under Phase 3. During phase 3, the emphasis is on integration of accommodation and binocular therapy. Phasic binocular techniques, such as the Aperture Rule, Eccentric Circles, Free Space Fusion cards, and the Computer Orthoptics step–jump vergence program, are useful techniques. BAF with flip lenses should be used with the phasic binocular techniques listed above. It is also important to integrate accommodative and binocular therapy with saccades and versions. Moving the Eccentric Circles or Free Space Fusion cards into different positions of gaze or using several sets of cards in various positions, along with flip lenses, is an excellent procedure to accomplish this goal. Other techniques, such as the Brock string with rotation and Computer Orthoptics vergence procedures with rotation, are also useful.

Endpoint. The endpoint for this phase of therapy is reached when the patient is able to maintain clear single binocular vision with the Free Space Fusion cards or the Eccentric Circle cards together, while slowly rotating the cards and using +2.00/−2.00 flip lenses.

As recommended in previous chapters, a reevaluation should be performed about halfway through the therapy program and again at the end of therapy. When all vision therapy objectives have been reached and the vision therapy program is completed, we recommend the home vision therapy maintenance program discussed in Chapter 9 (Table 9.10).

CASE STUDY

The following case study (Case 12.6) is representative of the types of accommodative infacility patients that clinicians will encounter in practice.

Case 12.6 Accommodative Infacility

History

Danny, an 8-year-old third grader, presented with a complaint of blurry vision in school. Upon further questioning, it became apparent that his vision was not blurred at all times. Rather, he experienced blurred vision when looking up at the board after reading or other close work. This was his first eye examination. He was healthy and had not been taking any medication.

Examination Results

VA (distance, uncorrected):	OD: 20/20 OS: 20/20
VA (near, uncorrected):	OD: 20/20 OS: 20/20
Near point of convergence	
Accommodative target:	5 cm
Penlight:	5 cm
Cover test (distance):	Orthophoria
Cover test (near):	2 exophoria

Subjective:	OD: +0.25, 20/20 OS: +0.25, 20/20
Distance lateral phoria:	Orthophoria
Base-in vergence (distance):	X/7/3
Base-out vergence (distance):	X/20/11
Near lateral phoria:	2 exophoria
-1.00 gradient:	2 esophoria
Gradient AC/A ratio:	4:1
Calculated AC/A ratio:	5.2:1
Base-in vergence (near):	9/18/10
Base-out vergence (near):	10/20/10
Vergence facility:	13 cpm
NRA:	+1.25
PRA:	-1.50
Accommodative amplitude (push-up):	OD: 13 D; OS: 13 D
MAF:	OD: 0 cpm, cannot clear plus or minus OS: 0 cpm, cannot clear plus or minus
BAF:	0 cpm, cannot clear plus or minus
MEM retinoscopy:	+0.50 OD and OS

Pupils were normal, all external and internal health tests were negative, the deviation was comitant, and color vision testing revealed normal function.

Case Analysis

There is no significant refractive error and no indication of any organic problem. Because there is no significant phoria, the ACC group data should be analyzed first. This analysis indicates that the patient has difficulty with both plus and minus lenses on facility testing and the NRA and PRA. These findings, along with the classic symptom of blurred vision when looking from one distance to another, support the diagnosis of accommodative infacility. This is an example of a patient who presents with a normal amplitude of accommodation, yet has an accommodative disorder. A clinician who only performs accommodative amplitude testing to assess accommodation would routinely miss this diagnosis.

Management

Lenses or added plus lenses were not used in this case because there is no significant refractive error and no indication from the data that plus would be helpful. The NRA and PRA are balanced, even though both are low and MEM retinoscopy is normal. We therefore recommended vision therapy for this patient and followed the program outlined in Tables 12.11 and 12.12. Twenty-one visits (twice per week) were necessary; after treatment, Danny reported elimination of all blur. A reevaluation after vision therapy revealed the following:

Near lateral phoria:	4 exophoria
Base-in vergence (near):	12/24/16
Base-out vergence (near):	18/34/22
NRA:	+2.25
PRA:	-2.50
Accommodative amplitude (push-up):	OD: 15 D; OS: 15 D
MAF:	OD: 12 cpm OS: 12 cpm
BAF:	12 cpm
MEM retinoscopy:	+0.50 OD and OS

Summary and Conclusions

Accommodative anomalies occur often, and management of these conditions can be one of the more satisfying aspects of optometric care. Patients generally present with bothersome symptoms that interfere with school and work performance. We have stressed the importance of assessing all aspects of accommodative function and ruling out any of the organic causes of accommodative dysfunction. Once the specific accommodative diagnosis has been reached, treatment using lenses, added lenses, and vision therapy is almost always successful.

SOURCE OF EQUIPMENT

(a) Computer Orthoptics: 6788 Kings Ranch Rd, Ste 4, Gold Canyon, AZ 85218; 800-346-4925; www.visiontherapysolutions.net.

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Eye Movement Disorders

This chapter discusses the characteristics, diagnosis, and management of fixational, saccadic, and pursuit eye movement disorders. We use the term *ocular motor dysfunction* to refer to the condition in which there are problems in all three areas of eye movement function. In our experience, this is the most common clinical presentation. It is unusual to find saccadic dysfunction in isolation of fixational or pursuit anomalies, or pursuit dysfunction in isolation of fixational or saccadic anomalies.

Eye movement disorders are a diagnostic and management concern of optometrists because of the effect such problems may have on the functional capability of an individual. Unlike accommodative (1) and binocular vision skills (2), which reach adult levels of development very early in infancy, clinical assessment indicates that eye movement development is considerably slower, continuing through the early elementary school years (3,4). The clinical picture of slow development is not consistent with the basic research data that suggest the presence of normal eye movements by approximately age 1 or 2 years. This apparent difference is likely to be related to cognitive and attentional factors affecting eye movements through about age 12. Because of the long developmental process for eye movement control, slow development can leave a child with inadequate skills to meet the demands of the classroom (5). Saccadic and pursuit dysfunction, therefore, primarily interfere with performance in schoolchildren, although some authors have reported the presence of these problems in adults as well (6,7).

Much of the emphasis of both researchers and clinicians has been on the relationship between eye movements and reading. During reading, the three important components of eye movements are saccades, fixations, and regressions. Saccades take up approximately 10% of the reading time. The average saccade is about 8 to 9 character spaces, which is about a 2-degree visual angle (8). The duration of the saccade is a function of the distance covered. For instance, a 2-degree saccade takes about 25 to 30 milliseconds (ms), and a 5-degree saccade takes about 35 to 40 ms (8). Between saccades, the eye is relatively still in a fixational pause. For normal readers, the average duration of the fixation is 200 to 250 ms. An important characteristic of normal reading eye movements is the great variability both within and between subjects. Saccade lengths can vary from 2 to 18 character spaces, and fixation duration values can range from 100 to over 500 ms, for a single reader within a single passage (8). The third important characteristic of reading eye movements is the regression. A regression is a right-to-left movement, and it occurs 10% to 20% of the time in skilled readers. Regressions occur when the reader overshoots the target, misinterprets the text, or has difficulty understanding the text.

Because eye movement deficiencies intuitively seem to be so closely linked with reading, there have been numerous studies investigating this relationship. Unfortunately, the results of these investigations are equivocal and, at times, confusing. Limitations and differences in experimental design, methodology, statistical procedures, and assumptions among these studies have created difficulty in their interpretation (6). Two basic viewpoints have evolved about the relationship between eye movements and reading. The first suggests that eye movement disorders can cause below-average reading ability (9–27). Investigators, using a variety of methods to assess eye movements, have found that poor readers tend to make more fixations and regressions than normal readers (10–20,27). The second view is that the random and unskilled eye movement skills observed in poor readers are secondary to deficient language skills that cause reading disorders. Thus, the reading difficulty itself leads to erratic and inconsistent eye movements (26,28–32).

A third perspective is probably most likely to be correct and is essentially a combination of the first two viewpoints. This alternative (4) suggests that, in some cases, problems with fixation and saccadic abilities may be a primary factor interfering with a child's ability to read quickly, comfortably, and with adequate comprehension. In other cases, the eye movement deficiencies observed during reading may simply be a reflection of poor reading ability.

Another important background issue is that during reading, eye movements are integrated with higher cognitive processes such as attention, memory, and the utilization of the perceived visual information (3,33–40). Some optometrists believe that there is a relationship between poor ocular motor skills and attentional problems (41). When such a relationship exists, treatment of eye movement disorders may lead to improvement in attention and concentration (38–41).

There have been few studies of the prevalence of eye movement disorders, particularly in the population of normally achieving children and adults. In children with reading and other learning difficulties, several studies have found a very high prevalence of eye movement anomalies (42–44). In a sample of 50 children between the ages of 6 and 13 years with learning disabilities, Sherman (42) found that 96% had problems with ocular motor inefficiency (saccadic and pursuit problems). He did not state how eye movements were evaluated or his criteria for establishing a diagnosis of ocular motor inefficiency. Hoffman (43) reported on a sample of 107 children between the ages of 5 and 14 years with learning problems. He evaluated pursuits and saccades using the qualitative scales described in Chapter 1 along with an objective assessment using the Eye Trac. The criteria for a diagnosis of ocular motor dysfunction were performance below a 3+ on the subjective clinical observation or 2 years below age-expected values on the objective assessment. His results revealed that 95% of the sample had ocular motor problems. He also reported on the results of 25 children without learning problems and found that 24% had ocular motor problems. It is interesting to note that both Hoffman and Sherman found that ocular motor dysfunction was the most prevalent vision disorder in their samples of learning disabled children. Lieberman (44) studied the prevalence of vision disorders in 55 children between the ages of 8 and 10 years at a school for children with emotional disorders. He used observational scales and the New York State Optometric Association King-Devick test (NYSOA K-D) test to evaluate saccades. The NYSOA K-D test is similar to the developmental eye movement (DEM) test described in Chapter 1. Pursuits were evaluated using subjective observational scales; 53% of the children had saccadic dysfunction and 43% had pursuit anomalies. In this same study, Lieberman reported that in a sample of 1,681 children in a normal population, the prevalence of saccadic dysfunction (using the NYSOA K-D test) was 22.6%.

Jainta and Kapoula (45) examined the relationship between saccades and vergence control during real text reading. Thirteen dyslexic and seven non-dyslexic children read the French text “L’Allouette” in two viewing distances (40 cm vs. 100 cm), while binocular eye movements were measured with an objective eye-tracking system. They found that the binocular yoking of reading saccades was poor in dyslexic children (relative to non-dyslexics) resulting in vergence errors and fixation disparity. The fixation disparity was larger for dyslexic children, making a larger demand on their sensory fusion processes. The authors concluded that visual/ocular motor imperfections may exist in dyslexics that lead to fixation instability and thus, to instability of the letters or words during reading.

In our experience, and in the three studies described above (42–44), eye movement disorders are rarely present in isolation. Rather, they are generally found associated with accommodative, binocular, and visual perceptual dysfunctions. As a result, treatment of eye movement deficiencies generally occurs within the context of an overall treatment approach designed to deal with other problems as well.

It is clear that more investigation is needed into the prevalence of eye movement disorders to clarify their role in reading and other areas of function. Regardless of these shortcomings in the literature, clinicians are regularly faced with children and adults presenting with signs and symptoms suggestive of fixation, saccadic, and pursuit disorders. Psychologists and educators often refer children with concerns about poor tracking, skipping words and lines, and losing place when reading. In addition, Solan (6) has demonstrated that there are adults with eye movement problems that interfere with their performance in school and at work. Although these individuals often achieve at satisfactory levels, they complain of slow and inefficient reading (7). It is important for clinicians to be able to evaluate eye movement function and to prescribe appropriate treatment if a disorder is detected. An important concept that must be emphasized is that optometrists treat eye movement disorders to normalize these functions and eliminate the patient’s symptoms. We are not directly treating the reading disorders, although in some cases more accurate and efficient eye movements may lead to better reading performance.

Prognosis with Treatment

The primary treatment approach for ocular motor dysfunction is vision therapy. This suggests, of course, that eye movement function can be modified and improved through therapy. Two very different approaches have been used to investigate whether eye movement function can be altered and improved with treatment.

The plasticity and adaptability of the oculomotor system have been studied extensively by basic scientists. This approach has uncovered a broad range of behaviorally induced adaptive responses and a strong potential for central nervous system plasticity within the vestibular-oculomotor system (46,47). Many of these studies have involved investigation aimed at identifying adaptive effects in human neuroophthalmologic disorders such as oculomotor paresis. This line of investigation has generally found the presence of adaptive mechanisms that serve to offset degradation of ocular motor performance resulting from interference in neural conduction, neuromuscular transmission, and muscle function due to such factors as aging, injury, and disease (46,47).

One investigative approach that has been used to demonstrate that saccades can be modified involves the use of a paradigm called parametric adjustment. This is an approach in which the subject's saccades toward a target are made artificially inaccurate by shifting the target while the eye is already in flight (48). Using this approach, researchers have demonstrated substantial recalibration of saccadic amplitude after only a small number of saccades (48–51). Another basic science approach has been to study the changes that occur in ocular motility function after a paresis. Kommerrell et al. (52) studied the adaptability of the human saccadic system after the development of a sixth nerve paresis. They found evidence that the central nervous system can readjust saccadic innervation and thereby improve performance. Abel et al. (53) performed a similar study with patients with third nerve palsies. They were able to demonstrate that the adaptive readjustment of saccadic amplitude that occurs after a third nerve paresis depends on alteration of saccadic duration, not saccadic velocity. These basic science studies have demonstrated ocular motor adaptation and plasticity, even in adult subjects. The studies described above have found that saccadic function can be modified in both normal subjects and those with ocular motor disorders.

Clinical studies have also been performed to investigate the efficacy of treating ocular motor dysfunction. Wold et al. (54) reported on a sample of 100 patients who had completed a vision therapy program for a variety of problems, including accommodation, binocular vision, pursuits, and saccades. Saccadic and pursuit functions were determined using subjective clinical performance scales such as those described in Chapter 1. Vision therapy consisted of three 1-hour visits per week. The number of visits ranged from 22 to 53. It is important to understand that these patients did not only have eye movement disorders, but almost all patients had accommodative and binocular vision problems too. Pretesting and posttesting revealed statistically significant changes in both saccadic and pursuit function.

In a study of 63 achieving high school students, Solan (55) found increased reading rate, fewer fixations, and fewer regressions after treatment. A shortcoming of this study was that subjects received other forms of treatment along with vision therapy. The subjects each received twelve 2-hour sessions of treatment consisting of work with a tachistoscope, a controlled reader, and vocabulary, skimming and scanning, and study skills. Rounds, Manley, and Norris (56) used a Visagraph Eye-Movement Recording System^a to assess reading eye movements before and after vision therapy. This investigation is one of the few to specifically study eye movement therapy alone. They used a study population of 19 adults with reading problems and assigned 12 to the experimental group and 9 to a control group. The experimental group received 4 weeks (12 hours) of exclusively oculomotor skill enhancement vision therapy. The therapy consisted of three 20-minute office sessions and six 20-minute home sessions per week for 4 weeks. The control group received no intervention of any kind. The experimental group trended toward improving reading eye movement efficiency (fewer regressions and number of fixations and increased span of recognition) compared to the control group. Statistically significant differences, however, were not evident.

Young et al. (57) also used an objective eye-movement recording instrument (Eye Trac) to assess reading eye movements before and after therapy. The authors studied 13 schoolchildren who had failed a vision screening. Each child had three 5-minute vision therapy sessions per day for 6 weeks, receiving a total of 6 hours of eye movement vision therapy. Testing after the therapy revealed a significant decrease in the number of fixations, an increase in reading speed, and a decrease in fixation duration.

Fujimoto, Christensen, and Griffin (58) investigated the potential for using vision therapy procedures prerecorded on videocassettes for eye movement vision therapy. They had three groups of subjects. The first group of nine subjects received standard eye movement vision therapy. The second group received videocassette-based eye movement therapy, and the third group received no treatment. The results showed that both standard eye movement vision therapy and videocassette-based therapy were equally effective in improving saccadic ability, whereas the control group showed no significant change.

Punnett and Steinhauer (59) also studied two different approaches for eye movement therapy. They compared the effectiveness of vision therapy for eye movements using feedback versus no feedback. They used the Eye Trac to monitor eye movements and studied nine subjects. They found that the use of verbal feedback and reinforcement during vision therapy led to better treatment results.

Solan, Feldman, and Tujak (7) provided vision therapy to improve the efficiency of reading eye movements in 20 older adults (aged 62 to 75 years). Subjects were divided into a training group and a control group. The training group received 16 sessions of vision therapy over an 8-week period. The control group did not receive any treatment for 8 weeks. After posttesting, 8 of the 12 subjects in the control group were randomly selected to receive the 16 sessions of vision therapy. The authors reported statistically and clinically significant improvement in all aspects of reading efficiency, including reduced number of fixations and regressions per 100 words, increased average span of recognition, and improved reading rate without loss of comprehension. There were no gains in the control group. The authors concluded that vision therapy to improve reading eye movement skills is appropriate at all age levels.

More recently, Solan et al. (38) identified 31 sixth graders with reading comprehension scores about 1.5 to 3.5 years below grade level. The Visagraph II was used to evaluate eye movements and obtain baseline data. The 31 subjects were divided into two groups. Half of the subjects received individualized reading comprehension therapy first, while the others received individual eye movement therapy for twelve 1-hour sessions. After 12 sessions of treatment, reading comprehension and eye movements were reassessed. The eye movement and reading comprehension treatment groups were reversed for the next 12 sessions. After completion of 24 sessions, reading comprehension and eye movement ability were reevaluated. They found significant improvements in the number of fixations, regressions, and rate of reading after the eye movement therapy. This was true whether the eye movement therapy was done first or second.

In a subsequent study Solan et al. (40) identified 30 children (mean age 11.3 years) with moderate reading disorders; 15 children received attention therapy, and 15 children were placed in a control group. The treatment therapy group received twelve 1-hour sessions of individually monitored, computer-based attention therapy. This attention therapy included five procedures commonly used in traditional vision therapy treatment: three programs from Computerized Perceptual Therapy^b and two programs from the Perceptual Accuracy/Visual Efficiency (PAVE) Program.^a Attention and reading scores improved significantly in the treatment group, whereas there were no significant improvements in reading scores after 12 weeks in the control group.

Other researchers have investigated the use of biofeedback to improve ocular motor ability in patients with nystagmus and eccentric fixation. Goldrich (60) used a technique called emergent textual contour training to provide visual biofeedback regarding eye position and was successful in improving fixational ability. Other investigators have used auditory biofeedback to treat nystagmus. Ciuffreda, Goldrich, and Neary (70) and Abadi, Carden, and Simpson (61) achieved significant reduction in the amplitude and velocity of eye movements in congenital nystagmus. Flom, Kirschen, and Bedell (62) were able to improve fixational skills in amblyopes with eccentric fixation using auditory biofeedback.

Fayos and Ciuffreda (63) studied the effectiveness of vision therapy for improvement of reading eye movements in adults. They studied 12 young adult subjects (aged 18 to 38 years) using oculomotor auditory biofeedback training; 12 subjects read with auditory biofeedback during four half-hour training sessions over a 2-week period. Their eye movements were recorded during the first and last sessions. In addition, three control subjects followed the same protocol but did not receive any auditory feedback; 11 of the 12 subjects who received auditory feedback exhibited varying degrees of improvement in overall reading eye-movement efficiency (decreased number of fixations and regressions and increased reading rate). The training effect was most evident in subjects who initially read at a low-normal reading level on the Visagraph apparatus. There was no consistent trend in the control subjects. The authors concluded that oculomotor auditory biofeedback can be an effective training tool, particularly in low-normal readers.

The basic research and clinical studies reviewed demonstrate that eye movement skills can be modified in children and adults. Additional research is necessary to study larger numbers of subjects and subjects who only have eye movement disorders. It would also be important to clarify which vision therapy techniques are most efficacious.

Overview of General Management Principles for Ocular Motor Dysfunction

The sequential management considerations for ocular motor dysfunction are

- Optical correction of ametropia
- Added lens power
- Vision therapy

Prescribing for any significant refractive error should be the first management consideration. As discussed, it is unusual for eye movement problems to be present in isolation of other refractive, accommodative, or binocular vision disorders. If these other conditions are present, it is important to also follow the guidelines recommended in Chapter 3 with regard to correction of refractive error. In the presence of uncorrected significant refractive error, fixational skills, saccades, and pursuits may be less than optimal. Accurate fixation, saccades, and pursuits depend on adequate acuity. The strategy of first prescribing for significant refractive error is therefore based on the assumption that there may be a cause-and-effect relationship between refractive error and eye movement anomalies.

If an eye movement disorder is present in isolation of other problems, vision therapy is the treatment of choice. Prism and surgery have no role in the treatment of eye movement disorders, except for some patients with nystagmus (Chapter 18). Added lenses may be helpful if there is an associated accommodative or binocular problem. Sohrab-Jam (64) studied the effect of added plus lenses on the eye movement skills of 38 elementary schoolchildren. Book retinoscopy was used to determine whether an add would be appropriate. The sample was then divided into one group that would benefit from added lenses (positive response group) and another that would not be expected to benefit (negative response group). The eye movements of the subjects were then tested using the Eye Trac instrument, first with no added lenses and then with a +0.50 add. The results showed significant improvement in reading speed, fewer regressions, and higher relative efficiency with the +0.50 add in the positive response group. In the negative response group, the use of added plus lenses actually caused a deterioration in eye movement skills. This study underscores the value of prescribing added plus lenses if there is an associated accommodative or binocular vision problem along with the eye movement disorder. It also suggests, however, that it is inappropriate to prescribe added plus lenses if the data do not support such a prescription.

Vision therapy for eye movement skills generally involves more than mere treatment techniques for saccades and pursuits. As a general rule, accommodative and binocular vision techniques are incorporated into the therapy program because eye movement anomalies are usually associated with accommodative, binocular, or visual perceptual disorders. Even if the eye movement problem is present in isolation, there are two reasons for incorporating other techniques into the therapy program. First, one objective of eye movement therapy is to improve fixational skills and attention. All accommodative and binocular vision procedures require precise fixation and attention. The second reason is that in everyday life, patients make saccadic and pursuit eye movements together with vergence changes and alteration of accommodative level. It is therefore important to simulate natural seeing conditions in therapy by combining eye movements with changes in accommodative response and vergence eye movements.

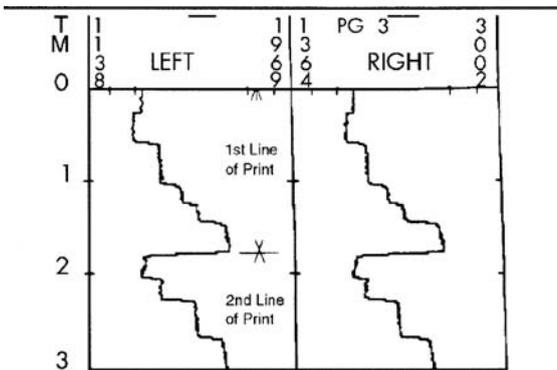
Ocular Motor Dysfunction

BACKGROUND INFORMATION

Saccades are eye movements that enable us to rapidly redirect our line of sight so that the point of interest stimulates the fovea. Saccades are the fastest eye movement, with velocities as high as 700 degrees per second (65). The saccadic peak velocity of normal observers is related to the size of the saccade. This relationship, known as the main sequence, is so consistent between people that a 10% slower velocity is considered pathologic. The normal latency for saccadic eye movements is about 200 ms, although the reaction time can vary depending on the luminance, size, and contrast of the target, motivation, and attention (65). The ideal saccade is a single eye movement that rapidly reaches and abruptly stops at the target of interest. Saccades may be inaccurate, however, in two ways. The most common inaccuracy is a slight undershoot. In most cases, the saccade is slightly short of the target and the eye “glides” to alignment; in more extreme cases, however, a second, smaller saccade is made to reach the target. A less common inaccuracy is an overshoot of the target.

As discussed, eye movements and, in particular, saccades have been a diagnostic and management concern of optometrists because of their importance in the act of reading. Figure 13.1 is an illustration of the output from the Visagraph instrument described in Chapter 1. The staircase-like plot displays the series of saccades and fixations that occur during reading. Accurate saccades are important in almost any visual activity, including other aspects of school performance such as copying from the board or a book, sports, and many job-related activities.

Pursuit eye movements enable continuous clear vision of moving objects. This visual following reflex ideally produces eye movements that ensure continuous foveal fixation of objects moving in space. The maximum pursuit predictive velocities are approximately 60 degrees per second. Smooth pursuit movements have a



■ **Figure 13.1** Output from a Visagraph instrument.

shorter average latency than saccades. Their normal latency is about 130 ms (65). Pursuit movements are affected by age, attention, and motivation. Because pursuit eye movements are only involved when a target is moving, they are more difficult to relate to reading and school performance than saccades. Pursuits may play a more significant role in activities such as driving and sports.

CHARACTERISTICS

Symptoms

Most symptoms related to saccadic dysfunction (Table 13.1) are associated with reading. These include head movement, frequent loss of place, omission of words, skipping lines, slow reading speed, and poor comprehension. Another common symptom is a short attention span. Teachers and parents often comment that children who do not perform well in school do not pay attention. A child with inadequate fixation and saccadic ability may look away from the task more often than other children. This “off-task” behavior may give the impression that the child is inattentive or impulsive. Richman (33) was able to demonstrate that “off-task looking time” during a sustained visual attention test is significantly related to a classroom teacher’s observation of a child’s personal or social behavior.

Saccadic dysfunction may also lead to symptoms related to other school tasks, such as copying from the chalkboard, solving arithmetic problems with columns of numbers, and taking standardized psychological or educational tests with computer scan sheets (66).

Although pursuit difficulties have been reported in children who have reading problems (67), pursuit dysfunction is probably more likely to interfere with activities such as sports. Any sport that involves, for instance, following the flight of a ball will place significant demand on the pursuit eye movement system. Symptoms such as trouble catching and hitting a baseball and difficulty with other sports involving timing and following a moving object may be related to pursuit dysfunction.

Signs

Chapter 1 described the three available methods for assessing saccadic ability: objective eye movement recording devices such as the Visagraph or the Readalyzer, standardized tests such as the DEM, and direct observations by the clinician using the Northeastern State University College of Optometry (NSUCO) oculomotor test. Signs indicating saccadic difficulty include poor performance on one or more of these tests (Table 13.1). A score below the 15th percentile on the DEM (in either the ratio or error scores) or below age-expected-level performance on the NSUCO oculomotor test, the Visagraph, or the Readalyzer is suggestive of saccadic dysfunction.

Because saccadic eye movements are believed to play a significant role in reading, school performance, and the workplace, a great emphasis has been placed on diagnostic testing for saccades. Fewer clinical assessment techniques are available for evaluating pursuit function. The most common method, direct observation, is described in Chapter 1. Another method that has been available for quite some time is the Groffman tracing procedure (68). This test is designed to evaluate pursuits in children. A shortcoming of the procedure, however, is that there has been no study of its reliability and validity.

TABLE 13.1 SYMPTOMS AND SIGNS OF OCULAR MOTOR DYSFUNCTION

Saccades
<i>Symptoms</i>
These symptoms are generally related to the use of the eyes for reading:
Excessive head movement
Frequent loss of place
Omission of words
Skipping lines
Slow reading speed
Poor comprehension
Short attention span
Difficulty copying from the chalkboard
Difficulty solving arithmetic problems with columns of numbers
Difficulty taking standardized psychological or educational tests with computer scan sheets
<i>Signs</i>
Below age-level performance on the Visagraph
Score below 15% on the developmental eye movement test
Score below age-expected norms on NSUCO oculomotor test
Pursuits
<i>Symptoms</i>
Excessive head movement
Poor performance in sports
Reading difficulty
<i>Signs</i>
Score below age-expected norms on NSUCO oculomotor test

NSUCO, Northeastern State University College of Optometry.

DIFFERENTIAL DIAGNOSIS

The mild form of ocular motor dysfunction discussed here is a functional disorder with no significant underlying pathology. It must always be differentiated, however, from other eye movement anomalies that may be related to more serious etiologies. Saccadic and pursuit anomalies can be caused by abnormalities in the supranuclear control centers for these two functions and their connections to the extraocular muscles. The saccadic and pursuit systems have separate and distinct neurologic pathways. With the exception of saccades to visual stimuli, all saccades probably originate in the contralateral frontal eye fields (Brodmann area 8) (69). Stimulation from area 8, in the right frontal lobe, results in conjugate movement of the eyes to the left side. The pathway is from the frontal eye fields to the conjugate gaze centers in the midbrain pons and then to the nuclei of the third, fourth, and sixth cranial nerves. Saccades to visual stimuli are probably initiated in the general area of the occipitoparietal junction.

The control center for pursuit eye movements is believed to be the occipitoparietal junction (69). In contrast to saccadic control, supranuclear control of pursuits is ipsilateral. The right occipitoparietal junction controls smooth pursuit to the right, and the left junction controls smooth pursuit to the left. The pathway is from the occipitoparietal junction to the midbrain and to the nuclei of the extraocular muscles.

Because the pathways are distinct for saccades and pursuits, underlying neurologic disease can affect one system, leaving the other intact. Thus, if a patient has abnormal pursuit movements with normal saccadic function, a problem in the occipitoparietal–supranuclear center should be suspected. Conversely, an abnormality is likely in the frontal eye fields if pursuits are normal while saccades are abnormal.

Pathologic Causes of Saccadic Dysfunction

Pathology of saccades can be divided into four categories: disorders of velocity, accuracy, initiation, and inappropriate saccades (Table 13.2) (65). Disorders of velocity include saccades that appear to be either too fast or too slow. Saccades that appear too fast usually occur when the saccade is interrupted in midflight and its intended target is never reached. These truncated saccades are common in myasthenia gravis. Slow saccades are commonly associated with ocular motor nerve paresis or abnormalities in the medial longitudinal fasciculus.

TABLE 13.2 DIFFERENTIAL DIAGNOSIS OF SACCADIC DYSFUNCTION

Serious Underlying Disease to Rule Out	Possible Etiology
Disorders of velocity	
1. Saccades that appear too slow	Ocular motor nerve paresis
2. Saccades that appear too fast	Internuclear ophthalmoplegia
3. Truncated saccades	Myasthenia gravis
Disorders of accuracy	
1. Dysmetria	Cerebellar disease
	Wallenberg syndrome
2. Hypometria	Alzheimer disease
	Most basal ganglia degenerations
	Visual field defects
3. Hypermetria	Visual field defects
Disorders of initiation	
1. Congenital ocular motor apraxia	
2. Acquired ocular motor apraxia	Parietal lesions
	Parkinson disease
Inappropriate saccades	
1. Square wave jerks	Cerebellar disease
2. Macrosquare wave jerks	Cerebellar disease
3. Flutter	Cerebellar disease
4. Opsoclonus	Cerebellar disease

For instance, when a patient is requested to produce a saccade under binocular conditions to one side or the other, the adducting eye will either not follow or will lag behind in latency. This is referred to as *internuclear ophthalmoplegia* and suggests a lesion in the medial longitudinal fasciculus in the brainstem.

Disorders of accuracy are referred to as *dysmetria* and can involve either undershooting (hypometria) or overshooting (hypermetria) the target. Dysmetria is characterized by a series of small saccades necessary to attain fixation. Clinically it appears as a to-and-fro saccadic oscillation around the fixation target before foveation is attained (69). It usually occurs at the end of a refixation. It is the hallmark of cerebellar disease, but can also be caused by brainstem lesions, such as in the Wallenberg syndrome. Hesitant long-latency hypometric saccades are common in Alzheimer disease and most basal ganglia degenerations. Visual field defects can also cause both hypermetric and hypometric saccades to keep the target within an intact part of the visual field.

Disorders of saccadic initiation can vary from slight increases in saccadic reaction time, which are difficult to perceive clinically, to latencies greater than several seconds (70). In some conditions, there is a difference in saccadic performance between random saccades and voluntary saccades. For instance, ocular motor apraxia is a condition in which a patient has nearly normal random saccades, but delayed initiation of voluntary saccades. Ocular motor apraxia can be congenital or acquired. When acquired, it is usually associated with parietal lesions. Patients with Parkinson disease show a characteristic disorder of initiation. When asked to make voluntary saccades between two targets, they undershoot, and the intersaccadic latencies gradually increase (71).

The last category is inappropriate saccades. Saccades are called inappropriate if they tend to interfere with foveal fixation. A variety of conditions are included in this category: square wave jerks, macrosquare wave jerks, flutter, and opsoclonus. Square wave and macrosquare wave jerks are relatively rare disorders and can be confused with nystagmus. They are unwanted saccades that occur at random, and they interrupt fixation, followed by a corrective saccade to bring the eye back to the target. There is usually a just-perceptible latency between the saccade away from and back to the target. The disorder is called a *square wave jerk* when the amplitude is 1 to 5 degrees, and a *macrosquare wave jerk* when the movement is large (10 to 40 degrees). In either case, these eye movement disorders give the patient a shifty-eyed or noncooperative appearance because of the inability to sustain gaze with concentrated effort and are clearly abnormal (72).

An *ocular flutter* is a burst of springlike decreasing horizontal oscillations that may either accompany small saccades or occur spontaneously during fixation (72). Cerebellar disease is usually the underlying cause of ocular flutter. A more advanced form of ocular flutter is called *opsoclonus* or *saccadomania*, where the clinician

observes a more pronounced, almost constant, chaotic series of saccades in all directions. This disorder is also generally caused by cerebellar disease and is easily recognized as abnormal.

Pathologic Causes of Pursuit Dysfunction

Disorders of pursuits (Table 13.3) may be caused by lesions that involve the occipitoparietal junction, the pathways to the brainstem, and the brainstem itself. The most common neurologic abnormality affecting pursuits is cogwheeling. This refers to steplike eye movements that are used instead of smooth pursuits to follow an object. This problem may be caused by basal ganglia disease, such as Parkinsonism or cerebellar disease. It is also possible for cogwheeling to be asymmetrical, occurring, for instance, on rightward but not leftward pursuits. Asymmetrical cogwheeling is also associated with nystagmus in primary gaze (69). The other common pursuit abnormality is low pursuit gain (eye velocity/target velocity). This disorder is commonly associated with aging or a variety of medications, particularly tranquilizers and anticonvulsants. After medications, disease of the cerebellum or its brainstem connections is the most common cause of slow pursuit gain (69).

In most cases, saccadic and pursuit disorders that have a serious underlying etiology can be readily differentiated from functional eye movement dysfunction. Medically significant eye movement disorders are often dramatic in presentation, and the patient presents with a shifty-eyed or noncooperative appearance. The history regarding onset and performance is important. As you can see from Tables 13.2 and 13.3, patients presenting with these serious saccadic and pursuit disorders are often sick and present with other signs of neurologic disease. It is always important to question the patient about use of medications, particularly the types listed in Table 13.4. Pursuits, in particular, are susceptible to a large variety of medications. The history regarding onset will also be suggestive of a nonfunctional disorder. Children with functional ocular motor dysfunction usually have a history of school-related problems—trouble with skipping lines, words, and loss of place—for several years. A history of a child with strong academic performance in previous years and a sudden onset of tracking problems is more suspect.

TABLE 13.3 DIFFERENTIAL DIAGNOSIS OF PURSUIT DYSFUNCTION

Serious Underlying Disease to Rule Out	Possible Causes
Cogwheeling	Basal ganglia disease Parkinsonism Cerebellar disease
Slow pursuit gain	Aging Tranquilizers Anticonvulsants

TABLE 13.4 DRUGS AND TOXINS THAT AFFECT EYE MOVEMENT FUNCTION

Drug	Possible Effects
Diazepam	Impaired saccadic velocity Impaired smooth pursuits Poor fixation
Phenytoin	Impaired smooth pursuits Poor fixation
Phenobarbital and other barbiturates	Impaired smooth pursuits Poor fixation
Methadone	Saccadic hypometria Impaired smooth pursuits
Alcohol and marijuana	Impaired smooth pursuits Poor fixation
Chloral hydrate	Impaired smooth pursuit
Chlordecone, lithium, thallium	Opsoclonus

TREATMENT

As discussed, saccadic, pursuit, and fixational disorders generally occur together, and we use the term *ocular motor dysfunction* to refer to the condition in which problems are present in all three areas. The treatment approach described is based on the assumption that problems are present in all areas. If this is not the case with a particular patient, it is easy enough to leave out the inappropriate part of the treatment plan. We recommend the management sequence listed on page 371.

After correction of any significant refractive error and consideration of added lenses to manage an associated accommodative or binocular problem, the best treatment approach is vision therapy.

Vision Therapy

A vision therapy program for ocular motor dysfunction generally requires from 12 to 24 in-office visits if vision therapy is office based. If home vision therapy can be effectively administered, the total number of office visits can be reduced. As stated in previous chapters, the key concept is that a given amount of vision therapy is necessary. Whether it takes place in the office or at home is less important, as long as the therapy can be effectively administered. The total number of therapy sessions also depends on the age of the patient and his or her motivation and compliance.

Specific Vision Therapy Program

All the vision therapy techniques recommended here are described in detail in Chapters 6 to 8.

Phase 1

This first phase of therapy is designed to accomplish the objectives listed in Table 13.5 under Phase 1. After establishing a working relationship with the patient, the primary goal of this first phase of therapy is to improve large or gross saccadic ability and small excursion pursuit ability. It is important to note that the training progression is from large to small movements for saccades and from small to large excursions for pursuits (67,73).

One of the important changes in vision therapy equipment has been the introduction of the computer. Computers are ideally suited for creating the stimuli and variability necessary for vision therapy techniques. This is particularly true for eye movement training. Several excellent programs are available for this purpose. The two primary systems available are the software from Computer Aided Vision Therapy^a and Computer Orthoptics,^b both of which have many programs designed for saccadic or pursuit training.

TABLE 13.5 OBJECTIVES OF VISION THERAPY FOR OCULOMOTOR DYSFUNCTION

Phase 1
<ul style="list-style-type: none"> • Develop a working relationship with the patient • Develop an awareness of the various feedback mechanisms that will be used throughout therapy • Develop more accurate gross saccades and fine pursuits • Equalize gross saccadic and pursuit ability in the two eyes • Normalize positive fusional vergence (PFV) and negative fusional vergence (NFV) amplitudes (smooth or tonic vergence demand) • Normalize accommodative amplitude and ability to stimulate and relax accommodation
Phase 2
<ul style="list-style-type: none"> • Develop more accurate fine saccades and large excursion pursuits • Equalize fine saccadic and pursuit ability in both the eyes • Normalize PFV and NFV amplitudes (smooth or tonic vergence demand) • Normalize PFV and NFV facility (jump or phasic vergence demand)
Phase 3
<ul style="list-style-type: none"> • Integrate accurate saccades and pursuits with changes in vergence and accommodation • Develop ability to change from a convergence to a divergence demand

All of these programs allow the practitioner to vary a wide range of parameters and accurately monitor progress. This ability to vary the stimuli in a controlled fashion allows one to begin therapy at a level at which the patient can succeed and to gradually increase the demand. We highly recommend incorporation of computerized vision therapy equipment. During this first phase of therapy, we recommend using random eye movements and large-angle eye movements from the Computer Aided Vision Therapy software or pursuits and saccades from the Computer Orthoptics vision therapy software. Several comprehensive reviews are available in the literature that provide detailed information about these programs (74–76). In addition, two new programs (Vision Builder^c and ADR iNet Dynamic Reader^b) designed to be used for home-based therapy are available. Both programs utilize a guided reader therapy format in which the print moves from left to right and top to bottom. The speed varies and is determined by the patient's reading rate and comprehension level.

Other common procedures that can be used include wall fixations with afterimages for feedback, Hart chart saccades, the pegboard rotator, and Groffman tracings.

In almost all cases, an accommodative or convergence problem will be present in addition to the eye movement disorder. Therefore, we have also included accommodative and binocular therapy procedures in the treatment plan. Even if accommodative and binocular function is normal, we suggest incorporation of these techniques, because adequate performance on accommodative and binocular therapy procedures is dependent on good fixation and attention.

Endpoint. Phase 1 of therapy ends when the patient can:

- Complete the Hart chart procedure in 15 seconds with no errors
- Complete five sets of Groffman tracings without error
- Fuse with a convergence demand of 30 base-out and a divergence demand of 15 base-in
- Complete 12 cpm of accommodative facility with +2.00/–2.00 lenses using a 20/30 target.

A sample vision therapy program is summarized in Table 13.6. This program includes several techniques that can be used by the patient at home to supplement the in-office therapy.

TABLE 13.6 SAMPLE VISION THERAPY PROGRAM FOR OCULOMOTOR DYSFUNCTION

Phase 1
<p><i>Sessions 1 and 2</i> IN-OFFICE</p> <ul style="list-style-type: none"> • Discuss nature of vision problem, goals of vision therapy, various feedback cues, importance of practice • Wall fixations with afterimages • Computer Orthoptics saccades • Computer Aided Vision Therapy: random eye movements • Lens sorting • Loose lens rock (begin with plus if accommodative excess, with minus if accommodative insufficiency) • Tranaglyphs or vectograms: base-out <ul style="list-style-type: none"> • Begin with a peripheral target, such as tranaglyph 515 or the Quoit vectogram • Computer Orthoptics Random Dot program: base-out
<p>HOME THERAPY Home Therapy System (HTS): saccades and pursuits</p>
<p><i>Sessions 3 and 4</i> IN-OFFICE</p> <ul style="list-style-type: none"> • Hart chart saccades • Computer Orthoptics saccades • Computer Aided Vision Therapy: large-angle eye movements • Computer Aided Vision Therapy: random eye movements • Groffman tracings • Loose lens rock • Tranaglyphs or vectograms: base-out <ul style="list-style-type: none"> • Use targets with more central demand (Clown, Bunny tranaglyphs; Clown, Topper vectograms) • Computer Orthoptics Random Dot program: base-out

(Continued)

TABLE 13.6 CONTINUED

HOME THERAPY <ul style="list-style-type: none"> • HTS: saccades and pursuits
<i>Sessions 5 through 8</i>
IN-OFFICE <ul style="list-style-type: none"> • Symbol tracking • Hart chart saccades • Computer Orthoptics saccades • Computer Aided Vision Therapy: large-angle eye movements • Computer Aided Vision Therapy: random eye movements • Groffman tracings • Loose lens rock • Tranaglyphs or vectograms: base-out <ul style="list-style-type: none"> • Use even more detailed targets, such as tranaglyph Sports Slide and Faces targets and the Spirangle vectogram • Computer Orthoptics Random Dot program: base-out
HOME THERAPY <ul style="list-style-type: none"> • HTS: saccades and pursuits
Phase 2
<i>Sessions 9 and 10</i>
IN-OFFICE <ul style="list-style-type: none"> • Letter tracking • Computer Orthoptics scan • Computer Orthoptics pursuits • Computer Aided Vision Therapy: large-angle eye movements • Computer Aided Vision Therapy: random eye movements • Tranaglyph 515 or the Quoit vectogram: base-in • Binocular accommodative therapy techniques: use any of the binocular techniques listed above with \pm lenses
HOME THERAPY <ul style="list-style-type: none"> • Letter tracking • ADR iNet Dynamic Reader
<i>Sessions 11 and 12</i>
IN-OFFICE <ul style="list-style-type: none"> • Letter tracking • Computer Orthoptics search • Computer Orthoptics scan • Computer Orthoptics pursuits • Computer Aided Vision Therapy: tracking numbers/sequences • Tranaglyphs or vectograms with modifications to create jump vergence demand: base-out • Aperture rule: base-out • Binocular accommodative therapy techniques: use any of the binocular techniques listed above with \pm lenses
HOME THERAPY <ul style="list-style-type: none"> • Letter tracking • ADR iNet Dynamic Reader • HTS: Vergence program
<i>Sessions 13 through 16</i>
IN-OFFICE <ul style="list-style-type: none"> • Letter tracking • Computer Orthoptics search • Computer Orthoptics scan • Computer Orthoptics tracings • Computer Aided Vision Therapy: tracking numbers/sequences • Aperture rule: convergence and divergence • Eccentric Circles or Free Space Fusion cards • Computer Orthoptics Random Dot Vergence program: both base-in and base-out • Binocular accommodative therapy techniques: use any of the binocular techniques listed above with \pm lenses

(Continued)

TABLE 13.6 CONTINUED

HOME THERAPY <ul style="list-style-type: none"> • Letter tracking • ADR iNet Dynamic Reader • HTS: Vergence program
Phase 3
<i>Sessions 17 through 20</i>
IN-OFFICE <ul style="list-style-type: none"> • Letter tracking; timed • Computer Orthoptics search; work on speed • Computer Orthoptics scan; work on speed • Computer Orthoptics pursuits • Computer Aided Vision Therapy: tracking numbers/sequences • Eccentric Circles or Free Space Fusion cards
HOME THERAPY <ul style="list-style-type: none"> • HTS: Vergence program • ADR iNet Dynamic Reader
<i>Sessions 21 and 22</i>
IN-OFFICE <ul style="list-style-type: none"> • Multiple Brock strings • Multiple sets of Eccentric Circles, Free Space Fusion cards, or Lifesaver cards
HOME THERAPY <ul style="list-style-type: none"> • HTS: Vergence program <ul style="list-style-type: none"> • ADR iNet Dynamic Reader
<i>Sessions 23 and 24</i>
IN-OFFICE <ul style="list-style-type: none"> • Multiple Brock strings • Multiple sets of Eccentric Circles, Free Space Fusion cards, or Lifesaver cards
HOME THERAPY <ul style="list-style-type: none"> • HTS: Vergence program • ADR iNet Dynamic Reader

Phase 2

This second phase of therapy is designed to accomplish the objectives listed in Table 13.5 under Phase 2. The objective of this phase is to develop more accurate saccades using finer, more detailed targets and to develop more accurate pursuits using larger excursions. Commonly used saccadic techniques include Ann Arbor letter tracking and loose prism jumps (monocular). For pursuits, continue working with the pegboard rotator and add flashlight pursuit techniques. We also suggest incorporating computer vision therapy techniques for both saccades and pursuits. Some of the programs we have found to be most helpful include saccades, pursuits, visual memory, visual search, visual scan, and tachistoscope from Computer Orthoptics, and random eye movements, large-angle eye movements, tracking numbers, tracking sequences, and tracking words from Computer Aided Vision Therapy. It is also important to work monocularly until performance is equalized for fine saccadic and pursuit ability in both the eyes.

Goals during this second phase of therapy also include normalization of both positive fusional vergence (PFV) and negative fusional vergence (NFV) amplitudes using smooth or tonic vergence demand and jump or phasic vergence demand.

Endpoint. The endpoint of phase 2 is reached when the patient can:

- Successfully complete a paragraph from letter tracking in less than 1 minute
- Successfully complete the outside circle of the pegboard rotator at a setting of 33 cpm
- Fuse card 12 using convergence and card 6 using divergence on the aperture rule.

A sample vision therapy program for phase 2 is summarized in Table 13.6. This program includes several techniques that can be used by the patient at home to supplement the in-office therapy.

Phase 3

The third phase of therapy is designed to accomplish the objectives listed in Table 13.5 under Phase 3. By this stage in therapy, the patient should have developed excellent accommodative and fusional vergence amplitude and facility as well as normal fixational skills and monocular saccadic and pursuit ability. This last phase of therapy is primarily designed to integrate saccadic and pursuit eye movements with changes in accommodative and vergence demand. Thus, during this stage, the patient should be working binocularly during all procedures.

The use of two or more Brock strings is a simple task that combines all of the necessary elements desired at this point. The patient simply holds two or three strings at the bridge of his or her nose, rather than one. The origin of the Brock strings can be placed to the patient's right, left, and directly in front. With two beads on each string, the patient has multiple targets in various positions of gaze. Instruct the patient to change fixation in a given pattern and use a metronome to provide an auditory stimulus to control the speed of change of fixation. To accomplish this task, the patient must make accurate saccades and accommodate and converge accurately.

The Brock string can also be used to integrate pursuits with accommodation and convergence. Tie the end of the Brock string to a pencil. Have the patient hold one end of the string against the bridge of his or her nose, while holding the other end (tied to the pencil) with his or her arm outstretched. Instruct the patient to slowly move his or her arm in a circular fashion, while also changing fixation every 5 seconds from the far to the near bead. If a rotating pegboard device is available, one end of the Brock string can be attached to the rotator to accomplish the same effect.

Another common procedure is to use two or more tranaglyphs, vectograms, or Eccentric Circles. The patient is already familiar with and has succeeded with all of these procedures. The objective, at this stage, is to have the patient fixate from one target to another and quickly achieve clear single binocular vision. Finally, the Eccentric Circles and Lifesaver cards can be handheld by the patient and rotated in a circular or any other pattern. This is another excellent method of integrating pursuits with changes in vergence and accommodative stimulus levels.

Endpoint. The endpoint for this phase of therapy is reached when the patient is able to make accurate saccades and pursuits while fusing the Eccentric Circles.

Using the approach suggested above should lead to the elimination of the patient's symptoms and improved fixation and saccadic and pursuit function.

CASE STUDIES

The following case studies (Cases 13.1 and 13.2) are representative of the types of eye movement disorders that clinicians will encounter in practice.

Case 13.1

History

Kevin, an 8-year-old third grader, was referred for a vision evaluation by his reading tutor. The tutor was concerned because she had observed frequent loss of place, skipping of lines, inability to sustain at the reading task, and poor comprehension. She wanted to rule out a vision problem as a possible cause of these behaviors. Kevin had not had a previous full vision examination, although he had passed all of the previous school screenings. He did not report any symptoms of eyestrain, blur, or diplopia. Academically he was experiencing difficulty, primarily in the area of reading. The reading

problems had been present to some degree since the first grade, although the problems appeared worse this year. Although his sight vocabulary and phonic skills were average to above average, he consistently scored poorly on comprehension tests. In addition, his reading speed was significantly less than expected. Because of these difficulties, his parents had initiated work with the reading tutor. After several weeks of working with Kevin, the tutor suggested the vision evaluation because of the observations described above. A recent medical evaluation revealed normal health, and he was not on any medication.

Examination Results

VA (distance, uncorrected):	OD: 20/20 OS: 20/20
VA (near, uncorrected):	OD: 20/20 OS: 20/20
Near point of convergence	
Accommodative target:	1 to 2 in.
Penlight:	2 to 3 in.
Cover test (distance):	Orthophoria
Cover test (near):	2 exophoria
Subjective:	OD: +0.25 OS: plano
Distance lateral phoria:	Orthophoria
Base-in vergence (distance):	X/6/5
Base-out vergence (distance):	X/16/12
Near lateral phoria:	3 exophoria
–1.00 gradient:	2 esophoria
Gradient AC/A ratio:	5:1
Calculated AC/A ratio:	4.8:1
Base-in vergence (near):	8/16/10
Base-out vergence (near):	10/15/9
Vergence facility	14 cpm
Negative relative accommodation (NRA):	+2.50
Positive relative accommodation (PRA):	–1.00
Accommodative amplitude (push-up):	OD: 9 D; OS: 9 D
Monocular accommodative facility (MAF):	OD: 0 cpm, fails –2.00 OS: 0 cpm, fails –2.00
Binocular accommodative facility (BAF):	0 cpm, fails –2.00
Monocular method estimation (MEM) retinoscopy:	+1.25 OU
NSUCO saccades:	Head movement 3, ability 4, accuracy 2
DEM:	Ratio score: below the fifth percentile Error score: below the first percentile
NSUCO pursuits:	Head movement 2, ability 4, accuracy 3

Pupils were normal, all external and internal health tests were negative, the deviation was comitant, and color vision testing revealed normal function.

Case Analysis

In this case, the history of frequent loss of place, skipping of lines, and poor comprehension strongly suggests that there may be an ocular motor problem. Analysis of the data from the ocular motor

group confirms a diagnosis of ocular motor dysfunction. Kevin experienced difficulty on the DEM, scoring poorly in speed and accuracy. Direct observation of saccades and pursuits using the NSUCO oculomotor test also revealed poor eye movement skills.

In addition, analysis of the accommodative system group data clearly indicates difficulty with all tests assessing the ability to stimulate accommodation. The low amplitude of accommodation, high MEM, low PRA, and difficulty with MAF suggest a diagnosis of accommodative insufficiency.

Management

This is a typical presentation of ocular motor dysfunction. As we have emphasized throughout this chapter, there is often an associated accommodative or convergence disorder. In this case, we prescribed added plus lenses to manage the accommodative insufficiency. Both the MEM finding and the NRA/PRA relationship suggested an add of about +0.75. We prescribed OD = +0.25 and OS = plano with an add of +0.75 OU. We instructed Kevin to wear these glasses in school and for all near work. In addition, we prescribed a program of vision therapy to treat the ocular motor dysfunction and accommodative problems.

We followed the therapy sequence outlined in Table 13.6, and 18 therapy visits were required. A reevaluation after visit 18 revealed the following results:

Cover test (distance):	Orthophoria
Cover test (near):	2 exophoria
Subjective:	OD: +0.25 OS: plano
Near lateral phoria:	3 base-in
Base-in vergence (near):	12/24/12
Base-out vergence (near):	20/30/22
NRA:	+2.50
PRA:	-2.25
Accommodative amplitude (push-up):	OD: 13 D; OS: 13 D
MAF:	OD: 10 cpm OS: 10 cpm
BAF:	8 cpm
MEM retinoscopy:	+0.75 OU
NSUCO saccades:	Head movement 5, ability 5, accuracy 4
DEM:	Ratio score: 45th percentile Error score: 65th percentile
NSUCO pursuits:	Head movement 5, ability 4, accuracy 5

His parents and tutor reported a significant decrease in loss of place and skipping lines. In addition, his tutor found increased reading speed and comprehension and felt that she was now able to work with him more productively over the course of the 1-hour tutoring session. We discontinued therapy and instructed the patient to continue wearing his glasses for school and all reading.

This case demonstrates how ocular motor, accommodative, and convergence disorders can interfere with reading. These vision problems may cause inefficient, slow reading with comprehension problems in children who have the basic reading abilities such as decoding and sight vocabulary skills. Treatment of these conditions can lead to increased reading speed and comprehension. Of course, children with such problems also may have other reading problems or lags and will generally require additional tutoring in reading to solve these problems.

Case 13.2

History

Bernadette, a 14-year-old ninth grader, was referred by another optometrist for vision therapy. The other optometrist had been treating Bernadette for about 1.5 years for increasing myopia. In addition, over the past 9 months, Bernadette had been complaining of difficulty reading music, with frequent loss of place. She also complained of eyestrain and discomfort associated with reading and other deskwork. The other optometrist had prescribed bifocals about 3 months previously to try to relieve her symptoms. This approach was not successful, however.

Her current prescription was as follows:

OD: $-1.75 - 0.75 \times 15$

OS: $-2.25 - 0.75 \times 165$

+1.00 add OU

Examination Results

VA (distance, corrected):	OD: 20/20 – 2 OS: 20/20 – 2
VA (near, uncorrected):	OD: 20/25 OS: 20/25
Near point of convergence	
Accommodative target:	3 to 4 in.
Penlight:	3 to 5 in.
Cover test (distance):	Orthophoria
Cover test (near):	2 esophoria, with a 2 Δ right hyperphoria

In downgaze, the deviation was 10 esophoria. There was also a 2 Δ right hyperphoria in left gaze and a 2 Δ left hyperphoria in right gaze. Saccadic testing revealed great difficulty initiating saccades. The patient almost had to make a head movement to help initiate the saccade. The saccades were also inaccurate, with significant undershoots.

Subjective:	OD: $-1.75 - 0.75 \times 15$ OS: $-2.25 - 0.75 \times 165$
Distance lateral phoria:	Orthophoria
Distance vertical phoria:	Isophoria
Base-in vergence (distance):	X/6/2
Base-out vergence (distance):	8/17/12
Near lateral phoria:	3 esophoria
–1.00 gradient:	9 esophoria
Gradient AC/A ratio:	6:1
Calculated AC/A ratio:	7.2:1
Near vertical phoria:	1 base-down OD
Base-in vergence (near):	X/8/4
Base-out vergence (near):	x /12/6
NRA:	+1.75
PRA:	–1.75

Accommodative amplitude (push-up):	OD: 10 D; OS: 10 D
MAF:	OD: 3 cpm; OS: 3 cpm
BAF:	2 cpm
MEM retinoscopy:	+0.25 OU

Pupils were normal, and all external and internal health tests were negative.

Case Analysis

Unless one looks carefully at the cover test in different positions of gaze or eye movement testing, it is easy to conclude, as did the first optometrist, that this patient should receive vision therapy. Analysis of the accommodative and binocular data suggests problems with fusional vergence at near and accommodative infacility. Although the data do not suggest a specific diagnosis, there are certainly signs of fusional vergence dysfunction and accommodative infacility.

Of course, the results of saccadic testing and the vertical deviation and variation of the hyperphoria in different positions of gaze cannot be ignored. These are significant findings and suggest a possible serious underlying etiology. Based on these findings, we referred Bernadette for a neurologic evaluation. As part of the evaluation, the neurologist referred her for magnetic resonance imaging. The results of this testing revealed the presence of an arachnoid cyst in the brainstem area. Based on this result, it was clear that the visual findings were secondary to the pressure on the brainstem due to the cyst. Neurosurgery was recommended.

Management

Two weeks later, Bernadette woke up at night vomiting and required neurosurgery to relieve the elevated intracranial pressure caused by the cyst. The surgical procedure was successful, and a follow-up 4 weeks later revealed almost normal saccades. Although the esophoria continued to be slightly larger in downgaze, the hyperdeviation was no longer present.

This case underscores the importance of carefully evaluating eye movement skills and always being cognizant of the differential diagnosis of eye movement disorders, as well as accommodative and binocular vision disorders.

Summary

Assessing and treating ocular motility disorders has been a concern for clinicians because of the effect such problems may have on the functional capability of an individual. Although saccadic and pursuit anomalies can be entirely functional in etiology, it is always important to first rule out the serious causes of ocular motor dysfunction in the differential diagnosis. Once it is clear that a functional ocular motor dysfunction is present, following the sequential management sequence suggested in this chapter should lead to elimination of these problems in most cases.

SOURCES OF EQUIPMENT

- (a) Bernell Corporation: 4016 North Home Street, Mishawaka, IN 46545; 800-348-2225.
- (b) Computer Orthoptics: 6788 Kings Ranch Rd, Ste 4, Gold Canyon, AZ 85218; 800-346-4925; www.visiontherapysolutions.net.
- (c) Optometric Extension Program Foundation: 1921 E. Carnegie Ave., Suite 3-L, Santa Ana, CA 92705-5510; 949-250-8070; www.oep.org.

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Cyclovertical Heterophoria

Uncorrected cyclovertical heterophorias frequently cause symptoms that prompt patients to seek visual care; yet, many practitioners are uncomfortable managing such deviations. Some reasons for the reluctance to prescribe treatment for cyclovertical heterophorias include a perception that these conditions are more difficult to understand, the occasional difficulty of making an accurate assessment of the direction and magnitude using conventional measurement techniques, and a mistaken belief that treatment is not very successful. This chapter represents a review of the major clinical aspects of cyclovertical heterophoria. It includes definitions, a brief historical review, a description of the expected frequency and diagnosis of cyclovertical deviations, and a discussion of applicable clinical management techniques.

Background

DEFINITIONS AND TERMINOLOGY

Vertical deviations, which are upward or downward misalignments of the visual axis of one eye from the object of regard (1), are typically measured in prism diopters (Δ) of vertical misalignment. *Cyclovertical deviations* are rotations or rotary displacements of the eye about an anteroposterior axis that are measured in degrees of rotation (2). Both lateral and cyclovertical deviations are classified as follows:

- *Phorias* are latent deviations from the relative positions necessary to maintain single binocular vision (3). Latent deviations are held in check by fusional vergence (4).
- *Tropias* are manifest deviations from the position of single binocular vision (5).

The terminology for recording vertical deviations is *hyper* for upward deviations and *hypo* for downward deviations (6). Generally, vertical heterophorias are designated according to the eye that misaligns higher vertically. As a result of this convention, it is customary to speak of hyperphoria, rather than hypophoria. In general, this convention should be followed unless there is a diagnosed pathology causing the vertical deviation. For example, in thyroid eye disease, a hypophoria often results from inferior rectus muscle involvement, and it is more clinically correct to call this deviation a hypophoria of the eye with the involved muscle (because that is the actual deviation) than a hyperphoria of the other eye. In addition, when there is a strabismus, the strabismic eye is recorded, and thus there are also either hyper- or hypotropias.

Current preferred terminology for torsional deviations is *excyclophoria* and *encyclophoria*. Excyclophoria is temporalward rotation (outturning) of the top of the vertical meridian of the cornea during dissociation, whereas encyclophoria is latent nasalward rotation (inturning) of the top of the vertical meridian of the cornea (7).

HISTORICAL PERSPECTIVE

The clinical importance of considering cyclovertical deviations when managing patients with binocular vision dysfunction has been recognized for many years. For example, the existence of latent hyperphoria has been debated since the early 1930s, and the role of prism adaptation in determining vertical prism corrections has been important in the clinical literature since the 1950s (8). Evaluation of cyclovertical deviations has a similar history. In 1891, Savage reported “insufficiency of the oblique muscles” (9) and described detailed treatment for over 300 cases of cyclovertical deviations. Jackson (10) agreed with Maddox (11) that “in nearly all cases, nonparalytic cyclovertical deviations causes no symptoms and requires no treatment.” Howe (12) implied that the small near excyclovertical deviations that he found in about 25% of normal patients was probably not clinically significant. The contrasting

TABLE 14.1 NEAR ASTIGMATIC AXIS SHIFT

Patients tested: 247
Near axis shift: 189 (77%)
No shift: 58 (23%)
Patients with axis shift: 189 of 247
Monocular: 104 (55%)
Right eye: 75 (72%)
Left eye: 29 (28%)
Binocular: 85 (45%)

opinions of Stevens (13) and Savage (9) (that cyclophoria plays a large role in binocular visual problems) and Maddox (11) (that cyclophoria is of no consequence) suggest that an intermediate view is probably correct.

INCIDENCE

Hyperphoria

Estimates of the incidence of vertical deviations range from 7% (14) to 52% (15). Because of the wide range reported in the literature, it is difficult to be certain of the exact incidence; however, based on an average of the results reported in studies over the last 100 years (16), a reasonable estimate of the incidence of vertical deviations in a clinical population is approximately 20%. Probably only about 10% of these (1–2 patients per 100) have a type of latent vertical heterophoria that requires prolonged occlusion for diagnosis.

Cyclophoria

Measurement and analysis of cyclophoria include differentiation between real and apparent torsion (rotation) of the eye(s) about the line of sight. In evaluation of cyclophoria, the important torsion is associated with fusional movements (cyclovergence). Average excyclophoria tested with horizontal Maddox rods at 6 m (20 ft) is about 0.752 degrees \pm 1.15 degrees (17). The excyclophoria that is usually present at distance increases as convergence increases, but it does not usually change for lateral version movements. Excyclophorias increase on upgaze and decrease on down gaze (18).

The significance of an increase in excyclophoria with convergence is a potential change in the astigmatic axis when fixation shifts from distance to near (18). Scobee (19) studied 247 patients and found that 77% had a shift in astigmatic axis during near fixation (Table 14.1) and that this shift in axis could be up to 10 degrees. Although a significant percentage of patients have a measurable change in near astigmatic axis, only a small portion will have the combination of sufficient astigmatism along with a large enough change in axis to cause symptoms that justify treatment.

Characteristics

CAUSE

Significant cyclovertical deviations can be caused by optical (anisometropia), orbital, neuromuscular, or innervational factors. Generally, little is known about the exact cause of either vertical phorias or cyclophorias, although a vertical deviation in down gaze often accompanies significant anisometropia and a small amount of excyclophoria is physiologically normal. Increases in excyclophoria on convergence and upgaze (20) are probably due to increased inferior oblique innervation through the third nerve nucleus associated with convergence (in the same way that accommodation, convergence, and pupil size are related). Cyclophoria also results from uncorrected oblique astigmatism. “Astigmatic” cyclophoria is due to perceived inclination of the images of vertical and horizontal lines that are inclined toward the corneal meridians of greatest curvature. Symptoms generally disappear after properly prescribed optical correction.

MOTOR AND SENSORY FUSION

Integration of similar ocular images into a single percept involves separate components of motor and sensory fusion (21). Because vertical heterophorias typically remain the same at distance and near (in the absence of a paretic muscle etiology or anisometropia, either of which can cause a significant change in the vertical deviation in down gaze), the average vertical motor fusion ranges of about 3 degrees are also the same for distance and near (22). Cyclovergence ranges are greater for encyclovergence. For example, Sen, Singh, and Mathur (23) found average encyclovergence in the primary position of 5.25 ± 2.73 degrees and average excyclovergence of 4.15 ± 1.86 degrees measured with vertical lines. However, cyclovertical vergence ranges are variable between subjects and for the same subject at different times, depending on the speed of disparity introduction (24), the targets used (25), and the attention of the subject (26).

Subjective measurements of fusion have sensory as well as motor components. The primary difference between cyclofusion and horizontal/vertical fusion is that the sensory component of cyclofusion is large, whereas it is small for horizontal/vertical fusion (27). For example, the motor component to cyclofusion is probably 50% to 60% of the total fusional response required (2.8 to 3.4 degrees for a 5.75-degree torsional disparity) (28), depending on the size of the retinal area covered by the test used. Indeed, it is possible to produce solely sensory cyclofusion without motor cyclovergence (29).

SYMPTOMS

As with other ocular conditions, eye-related symptoms of cyclovertical heterophorias can be categorized as ocular, visual, and referred (30). Symptoms are variable, affected by the patient's mental and general physical state, and are often similar to symptoms of other types of binocular dysfunction. Therefore, in addition to evaluating cyclovertical deviations, we suggest that a thorough examination of the lateral vergence and accommodative systems be carried out.

SYMPTOMS OF CYCLOVERTICAL HETEROPHORIAS

- Lose place when reading
- Eyes tire easily
- Skip lines/read same line
- Slow reading
- Burning sensations
- “Eyestrain”
- Headaches
- Blurring of reading material

Ocular (asthenopic) symptoms are those directly associated with the use of the eyes. “Pulling” sensations, itching, “gritty” feelings, and burning are some of the ocular symptoms related to cyclovertical heterophoria. An asthenopic symptom particular to hyperphoria is motion sickness (31), which most frequently manifests as car sickness although it may even manifest as a “dizziness” when walking (e.g., through a department store aisle). Visual symptoms—subjective observations such as blurred or double vision—may or may not be associated with ocular symptoms. Visual symptoms particular to cyclovertical heterophoria include loss of place while reading (hyperphoria), tilting or slanting of objects (cyclophoria), and problems when changing fixation from distance to near. Referred symptoms include headaches, nausea, dizziness, and nervousness.

In clinical practice, perhaps 15% to 20% of all patients have symptoms related to cyclovertical deviation. Patients with cyclovertical deviations may not be diagnosed early and may be anxious and apprehensive. This is not unusual, since a psychoneurotic factor has been found in 75% of ophthalmic patients, as compared to 50% in general medical practice (32).

SIGNS

An observable head tilt is a frequent sign exhibited by patients with cyclovertical deviations. Another sign that may be observed is a change in astigmatic axis from distance to near refraction, which can indicate uncompensated cyclophoria associated with convergence. Corrective measures will be needed if excessive blur or near discomfort is noticed.

Another frequent manifestation of cyclovertical deviations is seen when patients appear to have normal muscle balance but have multiple pairs of eyewear, stating that none are “right.” Careful diagnostic testing may reveal cyclovertical deviations or aniseikonia. When no binocular anomaly is found on conventional testing and symptoms are still present even after correction of refractive error, diagnostic monocular occlusion can be useful for determining a management strategy for the symptomatic patient who might otherwise be told that “nothing is wrong with your eyes.”

Diagnostic Testing

DISSOCIATED TESTING

The principle of dissociated testing is to measure the direction and magnitude of the cyclovertical phoria under conditions where fusion is prevented. Cyclovertical deviations are frequently noncomitant where the hyper deviation is larger or smaller depending on the direction of gaze. Thus, when examining a patient with a cyclovertical deviation, it is important to assess the vertical component in the primary position, in all fields of gaze (especially down gaze at near—the reading position), and with the patient’s head tilted to the right and left. This will often allow a determination of the muscle involved in causing the vertical phoria and assist in determining management options.

Assessing Vertical Deviation

The three commonly used techniques to assess the vertical deviation are the cover test, Maddox rods, and prism dissociation. It is important that these tests always be done at least in the primary position and down gaze (reading position).

Cover Test

The cover test, which is used routinely in the diagnosis of lateral heterophorias and cyclovertical strabismus, is often of less value for diagnosis of small cyclovertical heterotropias. Because of the often very small nature of cyclovertical eye movements present in patients with heterophorias, even the most experienced observers may not always obtain a valid measure of cyclovertical heterophorias. As a result, Maddox rods are probably the most clinically used test for cyclovertical heterophorias.

Maddox Rod Evaluation for Vertical Phoria and Cyclophoria

Vertical Heterophoria: Single Maddox Rod. When testing for vertical phoria, a vertically aligned Maddox rod is placed before one eye, and the amount of vertical misalignment between the horizontal line (seen by the eye behind the rod) and a light (seen by the fixing eye) is neutralized using a Risley prism. Figure 14.1 shows the technique needed to evaluate a hyperphoria. Because noncomitancy is frequent in cyclovertical deviations, assessment should be made in all fields of gaze (see the three-step test results in Table 14.2).

Cyclophoria: Double Maddox Rod. When testing for cyclophoria, a Maddox rod is placed in front of each eye, a prism is used to dissociate the rods, and the streaks are compared for parallelism. When cyclophoria is present, one image appears rotated. The corresponding Maddox rod can be rotated until the lines are parallel, and the amount and kind of cyclophoria can be read directly from the indicators. For patients with unilateral superior oblique weakness, the excyclophoria is generally between 3 and 7 degrees, whereas in bilateral superior oblique weakness the excyclophoria is typically greater than 10 degrees. Care must be taken that the patient’s gaze is in the primary position with no head tilt. Borish (26) suggests that the Maddox rod test for cyclophoria be incorporated into the examination between the “delayed subjective” and “ductions at far.”

Maddox Double Prism for Cyclophoria

Another useful clinical test for cyclophoria is the Maddox double prism, which is formed by placing two low-power (3 or 4 Δ) prisms base to base. Monocular diplopia results when an eye fixates with the horizontally oriented bases bisecting the pupillary axis. Thus, if a dot target is used, the eye with the double prism sees two dots,



■ **Figure 14.1** Vertical eye alignment can be assessed with a single vertically oriented red Maddox rod and a penlight. With the patient observing the penlight with one eye and the horizontal red streak with the other, vertical prism power is slowly increased using base-down prism over one eye until the streak is reported to be aligned with the light. Changes in prism power should be at a slow, steady rate.

the other eye sees one, and three dots appear with both eyes open. The eye not behind the double prism is the eye being tested, so the subject's attention is directed to the center dot. Figure 14.2 shows the use of a trial frame for a patient with left exocyclophoria. Provided the dots are not fused, the amount of cyclophoria can be quantified by rotating the prism until the dots are vertically aligned. Patient responses (especially those of children) are not extremely accurate on this test.

Prism Dissociation

Prism dissociation, an alternative to Maddox rods that is often used for clinical detection and quantification of vertical deviations, is used less often for cyclophorias. When using this technique for assessment of vertical heterophoria, nonfusible targets are dissociated (usually using horizontal prism) and the patient is required to respond when they are aligned vertically. Figure 14.3 shows the technique for prism dissociation evaluation of a patient with a left hyperphoria.

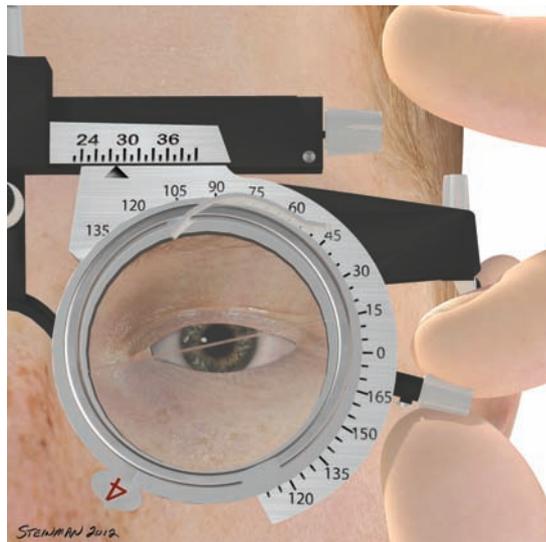
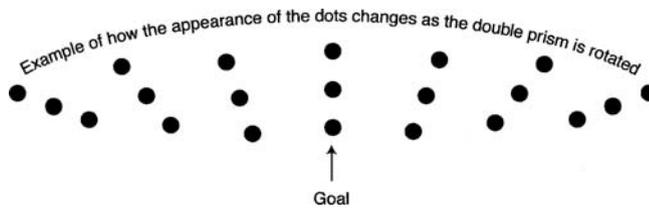
FIXATION DISPARITY TESTING

The principle of fixation disparity testing is to measure the direction and magnitude of the cyclovertical phoria under conditions where fusion is present. Because the deviation is measured while the patient is fusing,

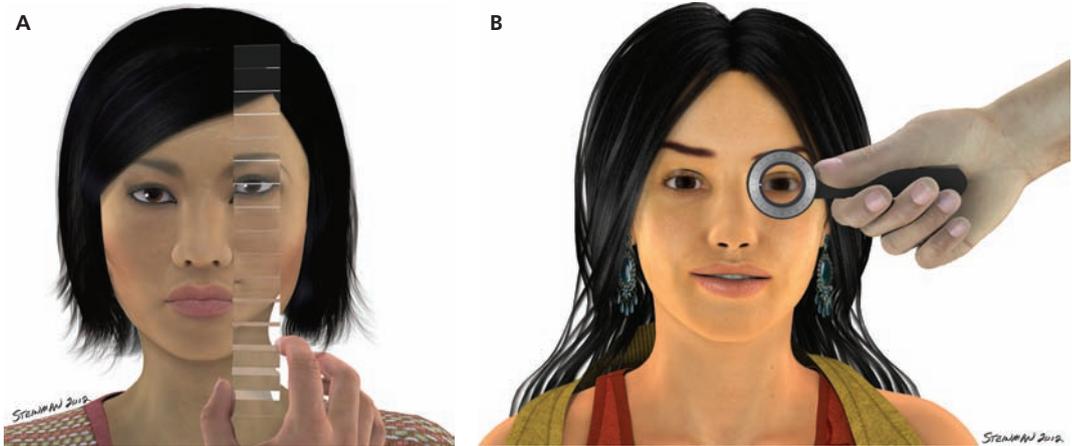
TABLE 14.2 THREE-STEP TEST

Hyper	Increase on Gaze	Increase on Head Tilt	Affected Muscle
R	R	R	LIO
R	R	L	RIR
R	L	R	RSO
R	L	L	LSR
L	R	R	RSR
L	R	L	LSO
L	L	R	LIR
L	L	L	RIO

R, right; L, left; LIO, left inferior oblique; RIR, right inferior rectus; RSO, right superior oblique; LSR, left superior rectus; RSR, right superior rectus; LSO, left superior oblique; RIO, right inferior oblique; LIR, left inferior rectus.



■ **Figure 14.2** **Top:** Assessment of cyclophoria with the double 4 Δ prism test can be done using a single dot as a target. **Middle:** When using the double 4 Δ prism, the patient will see three dots—two seen by the eye observing through the double prism and one by the other eye. **Bottom:** The double 4 Δ prism can be used to measure the amount of cyclophoria. With the prism mounted in a trial frame, the patient rotates the prism until the dots are seen aligned; the amount of rotation indicates the amount of cyclophoria.



■ **Figure 14.3** Vertical eye alignment can be assessed with a vertical prism bar (A) or a Risley prism (B). The patient observes a short horizontal line or a diamond, and vertical diplopia is achieved using about 8Δ of vertical prism. One eye is occluded, and the target is briefly shown at intervals (flashed). The vertical prism power is slowly decreased until the two targets are reported to be in horizontal alignment. Changes in prism power should be at a slow, steady rate. Small amounts of lateral prism (typically 6 to 10Δ base-in) may be needed to be sure that the targets are not fused as the vertical prism power is reduced.

fixation disparity tests probably correlate best with symptoms of cyclovertical heterophorias, just as they do for horizontal heterophoria (33,34). Both the horizontal and vertical associated phorias should be assessed. Additionally, the effects of small amounts of horizontal prism on the vertical associated phoria should be determined. Typically, the amount of prism required to reduce the perceived vertical misalignment to zero (vertical associated phoria) can be prescribed with confidence that it will resolve the patient's symptoms; these patients seldom require vision therapy programs after prism prescription. Just as with dissociated measures (e.g., cover test or Maddox rod), fixation disparity testing should be done at distance, near, and in down gaze at near (reading position).

Horizontal Testing

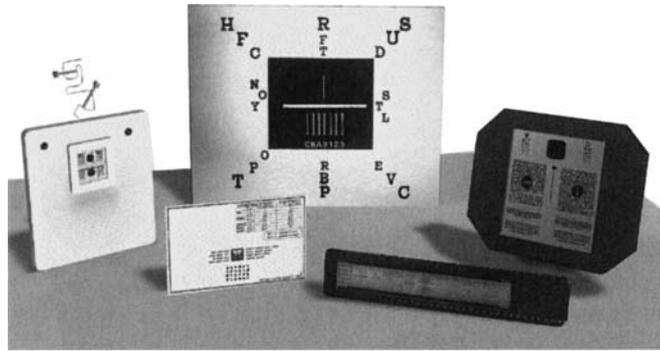
It has been observed in some patients that small amounts of lateral prism can assist fusion to such an extent that a vertical associated phoria is reduced to zero (35); in these patients, no vertical prism is needed. The reason these small lateral corrections affect the vertical deviation is not precisely known. However, it is prudent to evaluate this effect when there are small vertical associated phorias, generally less than 1.25Δ . As a rule patients with vertical deviations that respond to horizontal prism are candidates for horizontal fusional vergence therapy. They rarely require any prism after vision therapy programs are completed.

Vertical Testing

Vertical Associated Phoria

In general, the amount of prism to reduce the fixation disparity to zero can be prescribed with confidence that it will dramatically relieve the patient's symptoms. Because this measure is so easy to make, this form of fixation disparity testing has become the test of choice for vertical heterophoria and, when used properly, is also useful for diagnosis of patients with symptomatic cyclophoria. Associated phoria measures can be made using the American Optical (AO) vectographic slide, Turville testing, and the Mallett near unit (Fig. 14.4).

A valuable addition to vertical associated phoria evaluation can be used to be certain that the endpoint has been reached. The principle is to align the eyes vertically so that no alteration in ocular alignment is required when the patient blinks. This can be achieved by interposing vertical prism until the nonius lines seem to be stable through the prism. Then have the patient close both eyes for 1 to 2 seconds. When the eyes are again opened, the patient's task is to notice whether the nonius lines remain exactly aligned or whether one line or the other had to move up or down to become aligned. Repeat the open–close eyes procedure and modify the prism



■ **Figure 14.4** Instruments for clinical measurement of fixation disparity curve parameters include the Disparometer (**left**), the Woolf (**center**) and Wesson cards (**bottom left**), the American Optical vectographic adult slide (**bottom right**), Turville testing, and the Mallett near unit (**right**). During each of these tests, the majority of the visual field is visible to both eyes and, thus, can be fused. However, a portion of the central field is only visible to one eye or the other, either because of polarized filters or a septum (Turville test).

prescription in 0.5Δ steps until the lines appear stable and aligned at all times. Frequently, small increases in vertical prism from that seen in standard eyes-open associated phoria measurement is required to reach the stable endpoint of alignment of the lines immediately after opening the eyes. When the lines remain aligned immediately after the eyes have been opened again, the amount of prism that is in place can be prescribed.

Forced Vergence Fixation Disparity Curves

Forced vergence fixation disparity curves can be generated by measuring the fixation disparity through various amounts of vertical prism. When there is a vertical phoria, these measures are typically not curves, but rather are very frequently linear. As a result, the associated phoria measure described above is the clinically used assessment for the majority of patients. Forced vergence curves are useful primarily when contemplating and monitoring a vision therapy program. See Chapter 15 for a complete description of fixation disparity testing and interpretation.

Cyclofixation Disparity

Turville tests show cyclofixation disparity when the letters make an oblique line as the test is done (36). Fixation disparity tests such as the AO vectographic adult slide and the Mallett distance and near tests show horizontal and vertical fixation disparity and indicate cyclofixation disparity by a tilt of the test targets (37). These tests do not measure the amount of cyclophoria; the amount has to be measured directly by one of the previously described tests. However, a manifest cyclofixation disparity indicates uncompensated cyclophoria; these patients should be questioned closely for symptoms of cyclophoria and treatment instituted as necessary.

OUT OF PHOROPTER TESTING

Probably, the most frequent challenge that clinicians incur when treating patients with cyclovertical deviations comes as a result of the fusion difficulties that many anisometropic patients have. Patients with anisometropic prescriptions of significant power experience induced prism between the two eyes that increases when looking away from the optical center of the lens. This induced prism impedes binocular alignment and becomes especially significant when the anisometropic patient is presbyopic and looks down to use a bifocal. Many times significant binocular stress occurs in down gaze and failure to account for these anisometropia-induced complications frequently thwarts successful management. Even patients without anisometropia may have a cyclovertical component that manifests more in down gaze, as is common with patients having unilateral or bilateral superior oblique palsies as well as many with thyroid and myasthenic myopathies.

TABLE 14.3 WHEN AND HOW TO USE DIAGNOSTIC OCCLUSION

When:
Patient has symptoms of vertical heterophoria but <ol style="list-style-type: none"> No vertical on clinical testing with <ul style="list-style-type: none"> Maddox rod Cover test Fixation disparity measures Apparently good compensation for a small existing cyclovertical deviation
How:
Occlude the hyperphoric eye for 24 hours based on <ol style="list-style-type: none"> Cover testing (including patient reports of phi phenomena movement) Vertical fixation disparity curves Reports of vertical instability of the horizontal nonius lines on fixation disparity testing

Patients with significant cyclovertical heterophoria in the primary position (through the phoropter) frequently tend to tilt or turn their heads to a position that allows more comfortable binocular vision. Trial frame evaluation in the primary position and in down gaze (reading position) using the best correction will provide essential information about the patient's habitual binocular status and head position(s). Correction of a coexisting or induced vertical phoria in down gaze often provides considerable symptom relief.

DIAGNOSTIC OCCLUSION

When occlusion relieves the complaint of the patient, the cause of the complaint is usually some handicap to binocular vision (38). Thus, in cases where a definitive diagnosis cannot be determined using the conventional techniques described above, a trial period of 24 hours of occlusion of the hyperphoric eye should be used diagnostically to determine the effect on the patient's symptoms (38). Table 14.3 lists the considerations for determining when to utilize diagnostic occlusion. The occasionally difficult decision concerning which is the hyperphoric eye is based on cover testing (including patient reports of phi phenomena movement), vertical fixation disparity curves, and reports of vertical instability of the horizontal nonius lines on fixation disparity testing. Following occlusion, vertical prism that neutralizes the vertical fixation disparity (associated phoria) can be prescribed, and vertical vergence therapy may also be considered.

Differential Diagnosis

The primary issue in determining the indicated treatment is the etiology of the cyclovertical condition. Newly acquired cyclovertical deviations should be considered to have a serious etiology until proven otherwise. Generally, the newly acquired cyclovertical deviation will be noncomitant and it is important to determine which muscle is involved in causing the vertical deviation.

DETERMINING THE MUSCLE INVOLVED IN NONCOMITANCE—THE THREE-STEP TEST

The primary approach to determining what muscle might be involved in a noncomitant cyclovertical deviation is to make measures in all fields of gaze using one or more of the tests described previously. Diagnostic analysis of the findings in all fields of gaze is called the *three-step test*—named for the three measures that are made. First, determine which eye is misaligned vertically (the “hyper” eye), then determine whether the hyper increases in right or left gaze, and finally assess whether the hyper increases on right or left head tilt. Table 14.2 indicates expected findings in various fields of gaze for patients with vertical muscle weakness. For example, if there is right inferior rectus involvement, there will be a right hyper that increases on right gaze and on left head tilt (see bold row in Table 14.2).

Superior oblique palsies are relatively common causes of hyperdeviations because it is moderately easy to injure the trochlear nerve (Cranial Nerve IV). The findings on the three-step test for superior oblique palsies are easy to remember, because they follow a marching cadence: RSO = right, left, right (*right* hyper increases

on left gaze and on right head tilt); LSO = left, right, left (left hyper increases on right gaze and on left head tilt); see Table 14.2 rows 3 and 6. However, instead of memorizing the different findings in Table 14.2, the results of the three step test can also be graphed, which simplifies the diagnosis by eliminating the need to remember the actions of the extraocular muscles.

A GRAPHICAL METHOD OF REPRESENTING THE THREE-STEP TEST

The results of the three-step test can be represented graphically with a diagrammatic representation of the three-step method (Fig. 14.5A), which signifies the examiner's view of the patient (thus, the image on the left is the patient's right eye, while the image on the right represents the patient's left eye). The eight cyclovertical muscles are listed on Figure 14.5A in the action field of each respective muscle. To use the graphical method, follow the steps below:

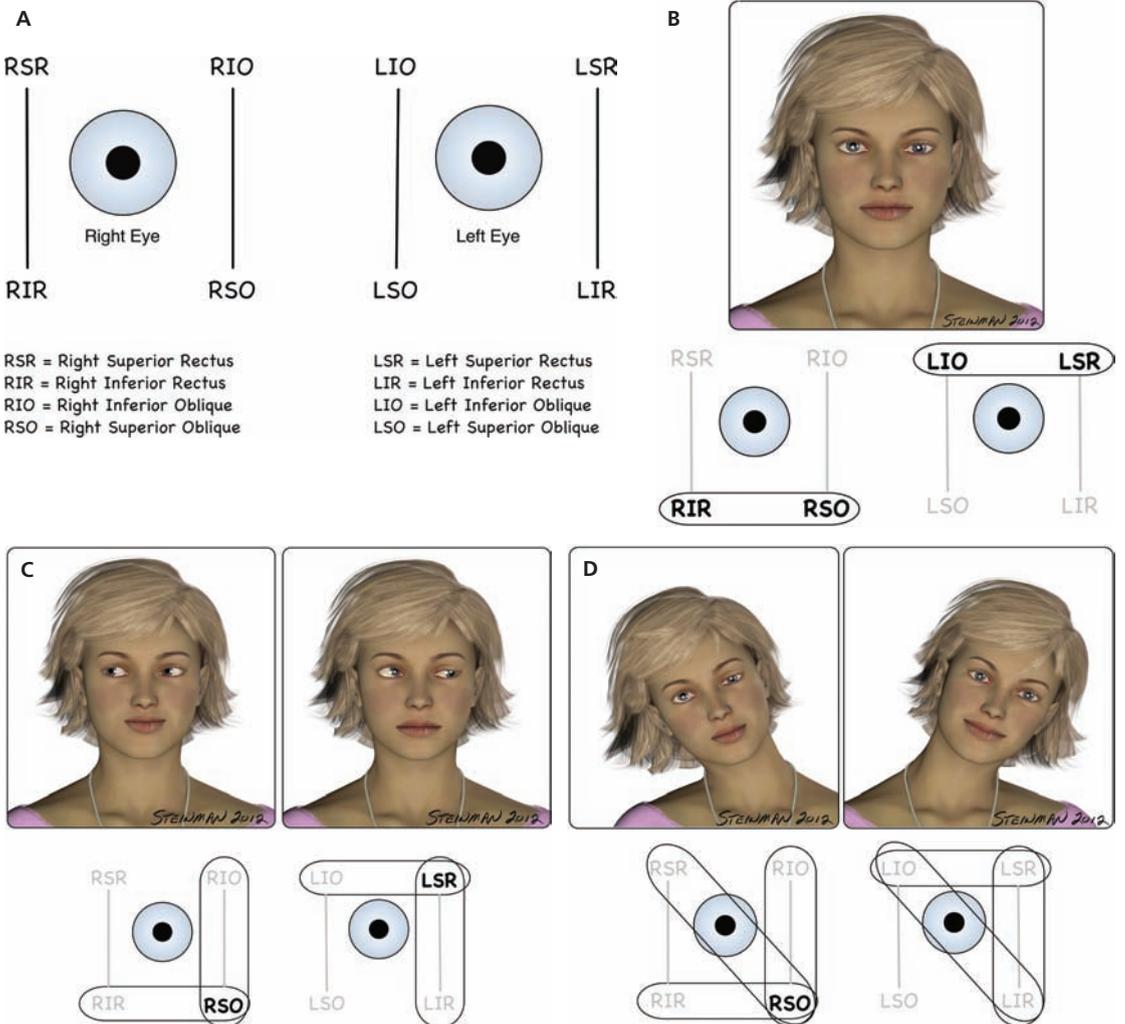


Figure 14.5 A–D: Perform the cover test with the patient fixating in primary gaze (straight ahead) and if there is a right hyper, circle the depressors of the right eye (RIR, RSO) and the elevators of the left eye (LIO, LSR) (Fig. 14.5B). Perform the cover test determining if the hyperdeviation increases in right or left gaze. If the hyper increases in left gaze, circle the muscles on the *patients'* left in each eye (RIO, RSO, LSR, LIR) (Fig. 14.5C). Determine whether the hyper increases with head tilt to the patient's right or left shoulder. If the hyper increases with head tilt to the right shoulder, circle the muscles that correspond to head tilt to the *patients'* right in each eye (RSR, RSO, LIO, LIR) (Fig. 14.5D). The muscle that is circled three times is the affected muscle. In this case, where there is a right hyper in primary gaze that increases on left gaze and right head tilt, the diagnosis is a hyperdeviation caused by a right superior oblique weakness.

- Step 1.** Perform the cover test with the patient fixating straight ahead (in primary gaze) and determine if there is a right or left hyperdeviation. If there is a right hyper, circle the depressors of the right eye (RIR, RSO) and the elevators of the left eye (LIO, LSR) (Fig. 14.5B).
- Step 2.** Perform the cover test again in right and left gaze, determining if the hyperdeviation increases in right or left gaze. If the hyper increases in left gaze, circle the muscles on the *patient's* left in each eye (RIO, RSO, LSR, LIR) (Fig. 14.5C).
- Step 3.** Determine whether the hyper increases with head tilt to the patient's right or left shoulder by performing the cover test with the patient's head tilted to the right and then to the left. If the hyper increases with head tilt to the right shoulder, circle the muscles that correspond to head tilt to the *patient's* right in each eye (RSR, RSO, LIO, LIR) (Fig. 14.5D).
- Diagnosis:** The muscle that is circled three times is the affected muscle (Fig. 14.5D). In this case, where there is a right hyper in primary gaze that increases on left gaze and right head tilt, the diagnosis is that the hyperdeviation is caused by a right superior oblique weakness because the RSO is circled three times. This is expected as findings on the three-step test for superior oblique palsies follow a marching cadence: RSO weakness = right, left, right (*right* hyper increases on *left* gaze and on *right* head tilt); refer again to Table 14.2, row 3.

Differential diagnosis of acquired conditions is based on reports of recent-onset diplopia, noncomitancy in which the deviation changes in various fields of gaze, visual field defects, and recent onset of coexisting ocular health conditions such as papilledema or retinal disease (Case 14.1). Patients with such symptoms or findings should be referred for appropriate systemic, endocrine, or neurologic evaluation. Management of the vertical deviation can continue concurrently.

Case 14.1 Recent-Onset Vertical Diplopia

An 18-year-old man complained of recent diplopia while reading. The diplopia had developed over the previous 2 months and seemed to be increasing in frequency. At the time of the examination, he also reported occasional diplopia on upgaze. There was an increase in the magnitude and frequency of the diplopia with strenuous exercise. He had been involved in an automobile accident 4 months previously, but denied any dizziness, ataxia, or systemic illness. He also denied taking any medication. He wore no lens correction at the time of the examination.

Examination revealed emmetropia, with 20/15 acuity in each eye. There was no nystagmus. The cover test revealed a 2 Δ left hyperphoria in primary gaze that increased to a 25 Δ left hypertropia in down gaze. Pupillary reactions were normal; there was no afferent pupillary defect. He had 100 seconds of arc of stereopsis at 40 cm (Randot stereograms). Monocular muscle fields were normal, and binocular fields indicated increasing diplopia in down gaze to the right.

Because of the recent development of vertical strabismus, the patient was referred for neurologic evaluation. Examination findings were consistent with those described above, and the patient was scheduled for an evaluation of the posterior fossa by magnetic resonance imaging. The study revealed the presence of an Arnold-Chiari type I malformation. Surgery was deferred until the summer, between school years. No lens correction was prescribed.

Patients with long-standing congenital deviations generally do not complain of recent-onset diplopia; reports of diplopia in patients with congenital cyclovertical deviations have typically been present with varying frequency for a number of years. Further, in contrast to the noncomitancies frequently seen in patients with acquired cyclovertical deviations, many patients with congenital cyclovertical heterophorias have comitant deviations. Patients with congenital deviations are treated using the techniques below.

Treatment

Management of cyclovertical heterophorias follows the same logical sequence as the treatment for lateral heterophorias outlined in Chapter 3 of this book (Table 14.4). The initial management step is to provide clear retinal images by prescribing the optimum lens correction. This is followed by additional optical

TABLE 14.4 SEQUENCE OF CONSIDERATIONS FOR MANAGEMENT OF CYCLOVERTICAL HETEROPHORIAS

Occlusion (diagnostic)
Refractive correction
Optical management (usually vertical prism, occasionally near additions if accommodative problems or high AC/A ratio)
Occlusion (therapeutic)
Vision therapy
Surgery

management, which, for cyclovertical deviations, primarily consists of vertical or horizontal prism or both. At times, added plus lenses also play a role if better fusion is gained at near through a change in alignment or clearer images in the presence of a coexisting accommodative deficiency. Therapeutic occlusion to eliminate diplopia, by blocking one retinal image, is seldom needed for cyclovertical heterophoria. Usually, fusion is well established and only needs to be enhanced. Vision therapy, which can substantially improve alignment and fusion, can be considered when a cooperative patient will comply with the prescribed procedures and prism correction does not totally eliminate the symptoms.

Surgery, an important part of management of cyclovertical heterotropias, is needed less often by patients with cyclovertical heterophorias. Consider surgical referral for patients with cyclovertical heterophoria when the vertical angle is larger than 15 Δ or there is a significant noncomitancy.

REFRACTIVE CORRECTION

Clear retinal images assist fusion in cyclovertical deviations. As a result, in the presence of hyperphoria, the best lens correction should be determined by retinoscopy and maximum-plus binocular refraction. Refractive treatment for cyclophoria depends on the type of cyclophoria. When there is uncorrected oblique astigmatism, lens correction found by binocular refractive techniques will frequently eliminate symptoms. Compensatory cyclofusional movements to the natural uncorrected image tilt are made to enhance fusion without spectacle lenses; when the proper correction is in place, the image tilt disappears, there is no need for cyclofusional movements, and the symptoms resolve.

However, there are some patients who are more comfortable without correction of oblique astigmatism. These patients may have aniseikonia caused by the correcting cylinder (32), they may be unable to adjust to vertical prism differences on lateral gaze from the new correction (39), or they may have cyclophoria opposite to the cyclophoria created by fusion of the uncorrected images. For these patients, correction of astigmatism forces them to compensate for the cyclophoria, often unsuccessfully (40).

Cyclophoria associated with convergence may cause a change in the near astigmatism axis (Case 14.2). This can cause clinically significant symptoms if the power of the correcting cylinder is large or there is

Case 14.2 Symptomatic Cyclophoria

A 35-year-old man had long-standing complaints of headaches over the left eye, eyestrain, and intermittent blurred vision while reading with his glasses. He wore a moderate astigmatic correction. External and internal ocular health was within normal limits. Visual acuity and refraction with cycloplegia were the same as his current correction:

OD: 1.00 – 3.50 \times 95 20/15–
 OS: 0.75 – 4.00 \times 105 20/20+
 OU 20/15

There was comitant 3 Δ exophoria at 6 m and 40 cm. There was occasional intermittent suppression of the left eye on Worth dot testing, and stereopsis was 40 seconds at 40 cm with Randot circles. Accommodative findings were normal (amplitude = 8 D, lag = +0.25 D, and facility = 10 cpm with ± 2.00). There was no fixation disparity at 6 m, but the patient reported a torsional disparity of the left eye's target at 40 cm. Near refraction revealed the following cylinder axes:

OD: 96

OS: 112

Although distance vision was blurred, reading with near axes findings allowed comfortable vision with no blurring. Maddox rod testing revealed a 1-degree excyclophoria at 6 m and an 8-degree excyclophoria at 40 cm.

Two pairs of glasses were prescribed—one with the distance axes and the other with the near axes. The patient returned for reevaluation in 2 weeks, with no further symptoms.

a substantial axis shift. Binocular refraction at distance will give the best refractive correction. If the near cylinder axis shift, as determined by binocular refraction at near, is enough to cause symptoms, separate lens corrections for distance and near may be needed. Careful attention should also be given to correction of associated vertical deviations.

PRISM

After prescription of the best lens correction, the next logical consideration in management of patients with a cyclovertical deviation is prism. Decisions concerning prescription of prism for a patient with a cyclovertical heterophoria are often complicated by the different combinations of symptoms and heterophorias that exist. As illustrated in Table 14.5, when a hyperphoric patient is truly asymptomatic, management is frequently deferred (Table 14.5, row 2). On the other hand, treatment may be indicated if the patient is asymptomatic because of avoidance of symptom-causing tasks.

Patients who have symptoms and a manifest cyclovertical heterophoria or a vertical fixation disparity (Table 14.5, rows 3 and 4) are generally more easily managed by prescribing prism than by vision therapy. In general, the prism correction that is considered is a vertical prism correction of sufficient amount to relieve the symptoms. However, for certain patients, a horizontal prism prescription will eliminate the vertical associated phoria (35). This type of horizontal correction of vertical deviation is described more completely in the section on fixation disparity.

TABLE 14.5 CLINICAL MANAGEMENT OF VERTICAL HETEROPHORIA

Vertical	Symptoms	Diagnostic Occlusion	Treatment	Estimated Patient %
None present	None	No	None	80
Phoria or fixation disparity	None	No	None unless avoiding tasks	3
Phoria and fixation disparity	Yes	No	Prism based on fixation disparity	12
Fixation disparity only	Yes	No	Prism based on fixation disparity	3
None on routine testing	Yes	Yes (1 day over the eye that has the hyperphoria)	Prism based on fixation disparity after diagnostic occlusion	2

Patients Needing Different Vertical Prism at Distance and Near

Presbyopic patients with anisometropia often have difficulty with induced vertical deviation; a non-presbyopic patient typically learns to tilt the chin downwards (or raise the reading material), keeping vision close to the optical center of the lens and minimizing the amount of prismatic effect while presbyopic patients are required to view much further down the lens to use the reading segment. Because of these factors, the process of bicentric grinding (slab-off), which *can* be done on single-vision lenses, is much more commonly prescribed for patients needing multifocals, including trifocals and even progressive lenses. Slab-off or bicentric grinding is typically used more commonly on lined multifocals; when using a slab-off design in the case of lined trifocals, the visible line that bisects the lens horizontally should line up at the top of *intermediate section* of the segment rather than at the top line of the segment as it does in lined bifocals.

Although anisometropic patients often benefit from slab-off prism corrections, it is important to consider the need for slab-off prism as well as reasons to avoid such correction. Table 14.6 indicates reasons that slab-off prism should generally not be used, along with case examples. Patients who fall into one of the five categories in Table 14.6 typically do not require consideration for slab-off lens correction (to develop skill in determining whether a patient might be considered for slab-off correction, consider the examples in Table 14.6). In general, it is useful to first estimate the amount (if any) of vertical imbalance present when the patient reads 10 mm below the optical center of the lenses. After determining, by calculation, that slab-off prism might be needed, make vertical fixation disparity measurements at near in down gaze (reading position) to determine whether the patient will actually benefit from a slab-off to correct the imbalance and the proper amount of prescription required.

Criteria for Prescribing

Several techniques have been described that may be used to determine a prism correction for patients having a vertical heterophoria. However, the precise methods used for prescribing the correct amount of prism for vertical heterophoria have not been well defined. In clinical practice, most clinicians base prism prescription decisions on one or more of the following factors: the magnitude of the heterophoria, the vertical or cyclovergence ranges, flip prism tests, or fixation disparity measurements.

Magnitude of the Heterophoria

Clinicians who prescribe based on the magnitude of the vertical heterophoria follow the lead of clinical researchers of the early 20th century. Unfortunately, the techniques that have been recommended can cause considerable variation in the amount of prism that might be prescribed. For example, Hansell and Reber (41) felt that when a hyperphoria remains after refractive correction, prism power should be prescribed that corrects one-third of the hyperphoria. Emsley (42) and Maddox (43) suggested prescribing vertical prism equal to two-thirds of the vertical heterophoria. Giles (44) advised correcting three-fourths of the vertical heterophoria found at near. Duke-Elder (45) and Peter (46) felt that when the refractive correction had been worn and over 1 Δ remained, a nearly full correction (or perhaps 0.5 Δ less) should be given for the hyperphoria. Hugonnier, Clayette-Hugonnier, and Veronneau-Troutman (47) recommend complete prismatic correction when the deviation is small.

Thus, many clinicians have relied on rough guidelines or rules of thumb when prescribing prism. For example, Krinsky (48) did not even suggest an amount, but stated that each case should be considered individually and that the weakest prism that would relieve symptoms and restore binocularity should be used. An anecdotal method that has been recommended to determine the weakest prism is to place a prism with its base in the appropriate direction in the trial frame with the refractive correction and evaluate the patient's visual acuity or comfort. This lack of standardization and the variety of suggestions imply that other techniques may be superior to use of vertical heterophoria measures and that a more definitive management regimen should be sought.

Prism Vergence Ranges

Prism vergence measurement has probably been the method of choice in the management of vertical heterophoria for a majority of optometrists. Methods of determining the amount of prism to prescribe based

TABLE 14.6 CONTRAINDICATIONS FOR CORRECTING VERTICAL IMBALANCE**Single-vision lens wearers.**

Example 14-6a: A 22-year-old asymptomatic woman whose prescription is unchanged but who wants new single-vision glasses. Her prescription is:

OD: -0.75 sphere = 20/20

OS: $+2.00$ sphere = 20/20

Calculated Vertical Imbalance: 2.75

Slab-off: No

Rationale: It is a single-vision correction in a patient without symptoms.

Contact lens wearers.

Example 14-6b: A 34-year-old asymptomatic myopic anisometropic woman wants contact lenses. Her spectacle prescription is:

OD: -0.75 sphere = 20/20

OS: -5.75 sphere = 20/20-

Calculated Vertical Imbalance: 5.00

Slab-off: No

Rationale: There is no need for slab-off correction in a contact-lens-wearing patient without symptoms.

Monocular patients (one eye or good acuity in only one eye).

Example 14-6c: A 54-year-old male patient who has lost his old eyeglasses. He has had shadow vision in left eye since a racket ball injury when he was a teenager. On examination he has a large macular scar in the left eye with a pale optic nerve on that side as well. His prescription is:

OD: $+2.50$ c -1.00×090 = 20/20-1

OS: -1.00 sphere = 20/200

Add: $+2.00$ OU

Calculated Vertical Imbalance: 3.5

Slab-off: No

Rationale: The poor visual acuity in the left eye suggests the calculated vertical imbalance will not need to be treated.

Asymptomatic patients who have tolerated high degrees of uncorrected vertical imbalance in the past without special correction.

Example 14-6d: A 47-year-old stock broker who has been comfortably wearing FT-28 bifocal lenses with no slab-off for several years. He has decided to try progressive lenses for the first time. His old Rx is:

OD: -4.00 sphere

OS: -0.25 c -1.00×180

Add: $+1.25$ OU

His new Rx:

OD: -3.75 sphere

OS: $+0.50 -0.75 \times 005$

Add: $+1.75$ OU

Calculated Vertical Imbalance: 3.50

Slab-off: No

Rationale: Despite the calculated vertical imbalance, the patient has comfortably worn glasses for many years that do not correct a similar imbalance.

Patients with small amount of vertical imbalance (less than 1.0 to 1.5 diopters).

Example 14-6e: A 66-year-old woman who is getting a first prescription, post IOL surgery in each eye. Her prescription is:

OD: PL c -0.50×090 = 20/15

OS: -0.50 sphere = 20/20+2

Add: $+2.75$ OU

Calculated Vertical Imbalance: 0.50

Slab-off: No

Rationale: Calculated imbalance is less than 1.0 diopter.

on prism vergence ranges vary from that of Tait (49), who recommended prescribing the amount of vertical prism that requires the patient to use one-fifth of the vertical fusional amplitude to oppose the deviation, to that of balancing the vertical vergences (described below). Another recommendation for prescribing vertical prism is to balance the recovery values when they closely agree with the direction of the heterophoria. Use of the recovery values may yield a prism correction that is more readily accepted subjectively (26).

When prescribing prism based on vertical vergence ranges, the clinician measures vertical vergence reserves after having assessed the vertical heterophoria. Vertical vergence reserves are usually determined using the rotary prisms of the phoropter. The prism vergence test involves increasing the vertical prism power first base-down and then base-up, over one eye, until fusion is interrupted and then recovered. With this technique, patients without a vertical heterophoria will have supravergence and infravergence that are basically equal to each other for each eye. For example, the left infravergence value will equal the right supravergence value. Thus, vergences often need to be measured over only one eye.

The technique of balancing the vertical vergence ranges has probably been used most widely for prescribing vertical prism, particularly before the advent of fixation disparity measurement. The prescribed prism is used to balance the vertical vergence break values; its amount is usually one-half to two-thirds the actual vertical heterophoria. In the presence of a vertical heterophoria and unequal vertical vergence measurements, the vertical fusional vergence (VFV) break or recovery values can be used to determine the prism power to prescribe. Prism may be determined by the following formula:

$$\begin{aligned} &(\text{Base-down to break minus base-up to break})/2 = \text{correcting prism} \\ &(\text{If resultant is plus, prism is base-down; if minus, base-up.}) \end{aligned}$$

For example, if there is 3 Δ right hyperphoria and 6 $\Delta/3 \Delta$ right supravergence and 4 $\Delta/2 \Delta$ right infravergence, then 2 Δ base-down OD would equalize the break values: $(6 \Delta - 4 \Delta)/2 = 2 \Delta$.

A potential problem with prescribing based on vertical vergence ranges is that vergence ranges are not always useful in determining an appropriate prism amount. There can be substantial variability in the vertical vergence measurements depending on factors such as the speed at which the prism disparity is introduced (24), the distance at which the measurement is taken (25), and the actual vertical deviation (26). Numerous researchers have reported that vertical heterophorias and fusional amplitudes are also affected by residual tonicity. For some patients with vertical heterophoria, the vertical vergence values also can be affected by the muscles stimulated first. For example, if the left supravergence is measured first, then the left infravergence value is reduced by tonicity of the first vergence stimulation.

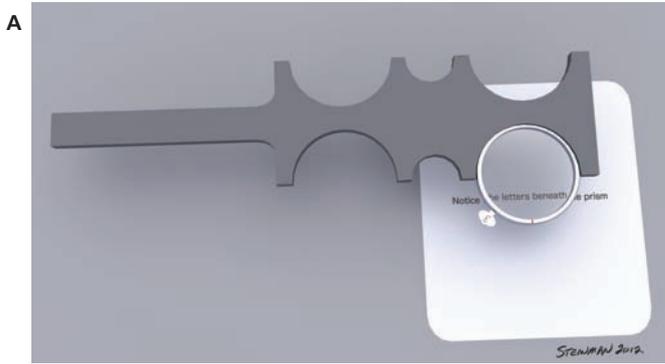
Clinically, the problem of altering tonicity is easily circumvented by measuring the compensating fusional reserve and then measuring the opposing fusional vergence on the fellow eye. For example, if a right hyperphoria is present, the right infravergence should be measured first and compared to the left infravergence (i.e., right supravergence). This avoids the effect of residual tonicity on the fusional vergence reserves. Alternatively, assessment of the opposing vergence can be postponed to the end of the examination to allow residual tonic innervation to subside. This will allow measurement of the opposing fusional vergence after some time has elapsed.

Flip Prism Tests

Eskridge (50) suggested that a 3 Δ prism in a handheld lens mount could be used for determining the type of hyperphoria and the amount of vertical prism (Fig. 14.6). The prism is flipped from base-down to base-up, and the patient observes the vertical separation of the images in each presentation. The direction of the prism base for which the images are closer documents the type of heterophoria. Thus, there is a right hyperphoria if the images are closer when the flip prism is base-up before the left eye. The prism power to be prescribed can be determined by placing the prism base-down in front of the right eye until the images are equidistant for successive presentations of the flip prism. The sensitivity of the test is high, because bisection tasks are easily done by most patients and the testing procedure approximately doubles small existing vertical heterophorias. The flip prism test measures the deviation while the patient is diplopic. Because fusion causes changes in the vergence adaptive position (51), using the flip prism may overestimate the prism prescription for some patients.

Fixation Disparity Measurements

Horizontal Prism Corrections. Small amounts of horizontal prism have been shown to reduce a vertical associated phoria to zero in some patients (35). The number of patients with vertical associated phoria who respond



C

Condition	Patient's Percept with BU Prism over Right Eye	Patient's Percept with BD Prism over Right Eye
Right Hyper (Left Hypo) Deviation		
Right Hypo (Left Hyper) Deviation		
Normal (No Deviation)		

■ **Figure 14.6** **A:** A 3 Δ prism mounted in a handheld rotatable mount can be used to test for vertical deviation and determine the amount of prism to prescribe. **B:** As the patient observes a horizontal row of 0.75 M print, the prism is flipped from base-down to base-up. **C:** The patient observes the vertical separation of the images in each presentation of the prism; the prism to be prescribed is the amount at which the vertical separation of the images in each presentation is equal.

in this manner to lateral prism is unknown since most practitioners prescribe vertical prism for these patients and do not even investigate the effect of horizontal prism. However, when there are small vertical associated phorias (less than 1.5 Δ), the effects of both vertical prism and small amounts of lateral prism should be investigated. When small amounts of horizontal prism (less than 2.5 Δ) are successful in eliminating a vertical associated phoria, the patient is usually better managed by a brief vision therapy program emphasizing horizontal vergence and antisuppression therapy. Such a vision therapy program is almost invariably effective and eliminates the need for any type of prism.

Vertical Associated Phoria: Fixation Disparity Curves. Although there are four types of horizontal fixation disparity curves (Chapter 15), patients with a vertical heterophoria typically have a linear fixation disparity curve because their fixation disparity is reduced by a similar amount for each prism diopter of prism added. This linear response pattern was originally reported by Ogle (21), and Rutstein and Eskridge (52) suggested that all vertical fixation disparities are linear for patients with normal binocular vision. Petito and Wick (53) confirm the linearity of most vertical fixation disparity curves, but suggest that about 10% of subjects have a clinically significant nonlinearity. Generally, vertical fixation disparity curves are linear enough so that vertical prism may be prescribed in an amount that reduces the disparity to zero (associated phoria). Testing should be done at distance, near, and at near in down gaze (reading position).

Forced Vergence Curves

In the case of vertical deviations, the reduction to zero of the vertical misalignment of the targets under binocular viewing conditions (vertical associated phoria) is the most accurate and readily accepted method of precise prism prescribing. It also results in the prescription of the least amount of prism that relieves symptoms. The primary clinical value of the forced vergence fixation disparity curve is to monitor vision therapy programs (see later section in this chapter).

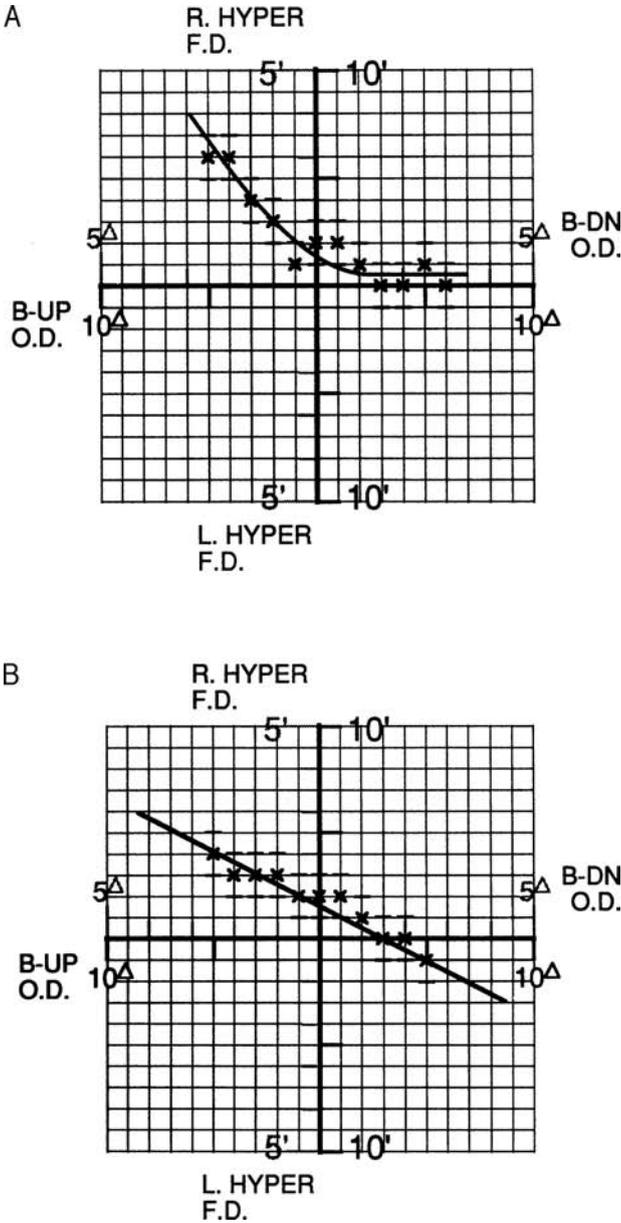
Measurement of vertical fixation disparity with the appropriate instrumentation will allow graphing of the data that generates a straight line, although some subjects manifest nonlinear findings (Fig. 14.7A). Figure 14.7B illustrates the linear relationship that is characteristic of most vertical fixation disparities. As increasing amounts of prism are placed over an eye, the fixation disparity is decreased by a similar amount for each prism power increase. This linear relationship occasionally varies in such a way that the associated phoria does not equal the dissociated phoria. Such a difference is easily noted on simple comparison and suggests that vertical vergence therapy will be useful, since there is established prism adaptation evidenced by the nonlinearity. See the prism adaptation discussion in Chapter 16.

Prism Adaptation

When vertical prism is placed before one eye of a patient with normal binocular vision and no cyclovertical heterophoria, remeasurement of the induced vertical deviation after 15 minutes will indicate that the resultant deviation is less than the amount of prism placed before the eye. This adaptation to vertical prism has been shown by Rutstein and Eskridge (54) and others (55,56), and individual differences in the rate and amount of prism adaptation have been observed (57). Nearly 80% of patients adapt to vertical prism (58). However, symptoms generally are not reported by subjects who completely adapt to vertical prism (59). In addition, Schor (60) has demonstrated that patients who do not adapt adequately to prism are most likely to be symptomatic. These factors suggest that patients who have a reduced ability to adapt to prism are those who manifest symptoms.

Lie and Opheim (61) used prism to correct heterophoric patients with long-standing severe visual symptoms. They reported that a small vertical deviation was present in most of these cases. Furthermore, in 80% of their cases, prism corrections needed to be increased over a period of time before the full deviation that eliminated symptoms was determined. Clinical reports by Surdacki and Wick (62) also suggest that patients may require multiple prism corrections before a latent vertical deviation is completely compensated.

Based on basic and clinical research, we suggest that the prescription of vertical prism for symptomatic patients generally does not lead to adaptation to the prisms. Increases in the prism required are probably not adaptation in the classic sense, but rather are similar to that seen in latent hyperopia, where the increase in plus is not adaptation but rather occurs because the entire correction was not prescribed initially.



■ **Figure 14.7 A:** Although the vertical fixation disparity graph is nonlinear for 15% of patients, only about 5% have a clinically significant nonlinearity. **B:** The vertical fixation disparity graph is typically linear for about 85% of patients tested. As a result, the prism indicated by the associated phoria measure (prism to reduce fixation disparity to zero) can be prescribed in virtually all cases.

Prism Prescriptions for Latent Hyperphoria

Some of the most difficult management decisions in clinical binocular vision practice arise when the patient has symptoms suggestive of a vertical deviation (Table 14.5), but no vertical heterophoria is evident on routine clinical testing. Small latent vertical phorias can cause patients to be symptomatic. And, just as with some deviations of larger amounts, these vertical deviations only become manifest with prolonged occlusion. We suggest that the patient with latent hyperphoria can be managed successfully by following the procedures listed in the last row of Table 14.5. See Case 14.3 for an example.

Case 14.3 Latent Hyperphoria

An 11-year-old boy had difficulty reading. He complained of slow reading, loss of place while reading, reading the same line when going back to the beginning of a line, headaches (eyelid/brow area) after approximately 30 minutes of reading, and blurring of material after the onset of headaches. He stated that blinking cleared the near blur. The current spectacle prescription was essentially the same as the refractive findings:

OD: -2.50 DS 20/15
 OS: -2.25 DS 20/15

All further testing was performed through the habitual spectacle lenses. Cover test and Maddox rod testing revealed 1 Δ of exophoria in all fields of gaze at distance and near. The associated phoria findings were orthophoria/isophoria at distance and an unstable 0.75 Δ left hyper associated phoria at near that increased with time. There were no changes in associated phoria response as the patient shifted vision into lateral gaze. Accommodative findings were normal (lag = 0.75 D, amplitude = 14 D, binocular facility = 6 cpm with ± 2.00 D flippers at near). Vertical vergence ranges were symmetrical at distance and near.

Based on the examination findings, the habitual spectacle correction was judged to be adequate, as were accommodative and fusional abilities. Instability and variability of the vertical associated phoria measurement suggested a latent left hyperphoria, and it was decided that diagnostic occlusion would be useful for further assessment. The patient was instructed to patch the left eye constantly 24 hours before a follow-up examination. During the follow-up examination, the patch was removed and fusion was prevented until associated phoria measurements were taken. Cover test at distance revealed 2 Δ left hyperphoria. Associated phoria testing at distance revealed 2.75 Δ left hyperphoria.

The myopic correction alone and then with the addition of 2.75 Δ base-down before the left eye was placed into a trial frame, and the patient was allowed to read for 10 to 15 minutes under both conditions. He expressed a feeling of less eyestrain and more accurate eye movements (easier returning to the next line of letters) with the additional 2.75 Δ base-down, which was then prescribed. With the new prescription, the patient initially experienced mild discomfort that subsided in less than 30 minutes. At this visit and for at least 5 years (the latest follow-up), the patient reported a decrease in the frequency of losing his place while reading, and he has experienced no symptoms while reading. Associated phoria measurements continued to indicate that approximately 3 Δ base-down was required before the left eye to reduce the left hyperfixation disparity to zero. All other findings remained within normal limits.

Prism corrections can be determined by clinical judgment based on associated phoria, severity of symptoms, and monocular occlusion. Monocular occlusion is used to unmask the vertical correction by first determining from the fixation disparity curves and dissociated phoria measurements which eye has a tendency to be hyperphoric and then occluding that eye for 24 hours. When the patient returns the next day (still occluded), dissociated phoria measurements are taken at distance and near immediately after removal of the patch and only allowing fusion to occur briefly during the dissociated phoria measurements. Using the prism amount determined during the dissociated phoria testing as the starting prism, vertical fixation disparity measurements are taken in the manner described previously. Thus, prism prescriptions are determined from the prism required to reduce the associated phoria to zero after 24 hours of occlusion.

Prism Prescriptions for Anisometropia Induced Vertical Deviations

How to Determine Slab-off Prism

Calculation

To determine the amount of slab-off prism that might be required, it is necessary to know the vertical power in each lens in the 90° meridian (which is determined by the sphere power of the lens and the astigmatism power in the 90° meridian) and the reading depth (which is determined by the frame size and the bifocal height).

When there is astigmatism, the amount of astigmatism in the vertical meridian needs to be added to the sphere power. There is a mathematical formula for determining power at every axis. For the vertical meridian the formula is:

$$\text{Power}^{90} = \text{Cyl Power} * [\sin(\theta - 90)]^2$$

(Remember, the axis of the cylindrical correction must be added to or subtracted from axis 90—the vertical meridian.)

This formula is easy enough to employ, but requires calculation with use of a sin table each time it is applied; generally, the percentages in Table 14.7 shown are sufficient to closely estimate power in the 90° meridian of a lens.

Consider the following example prescription:

$$\begin{aligned} \text{R } & -0.25 \text{ c } -2.00 \times 30 \\ \text{L } & -5.00 \text{ c } -1.00 \times 150 \end{aligned}$$

Power in 90° Meridian Calculation

For the right eye, the axis is 60° away from the 90° axis (90–30 = 60) and, thus, from Table 14.7 there is 75% of the cylinder power in this meridian—giving us a cylinder power of 1.4 diopters (2.00 × .75). Adding this cylinder power to the sphere power provides a resulting total power of –1.65 diopter in the 90° meridian (–0.25 + –1.4). For the left eye, the left axis is 40° away from the 90° (90–50 = 40), and from Table 14.7 there is 44% of the cylinder power in this meridian—giving a cylinder power of 0.44 diopters (1.00 × .44). Adding this to the sphere power gives a total power of –5.44 diopters at the 90 axis (–5.00 + –0.44).

To determine the total prismatic effect, subtract the right from the left: (–1.65) – (–5.44) = 3.79 diopters of vertical anisometropia.

This rough number is still not the true calculated slab-off correction. To determine the true slab-off correction, the reading depth must be determined.

Reading Depth Calculation

Once the power in the 90° meridian has been determined, calculate the reading depth. This is done by adding 5 mm to the segment drop. To determine the segment drop, divide the frame B measurement

TABLE 14.7 THE POWER IN THE 90 DEGREES MERIDIAN FOR CYLINDER POWERS AT VARIOUS AXIS

Degrees from Axis		% of Cylinder Power
0	180	0.00
5	175	0.01
10	170	0.03
15	165	0.07
20	160	0.12
25	155	0.18
30	150	0.25
35	145	0.33
40	140	0.44
45	135	0.50
50	130	0.59
55	125	0.67
60	120	0.75
65	115	0.82
70	110	0.88
75	105	0.93
80	100	0.97
85	95	0.99
90	90	1.00

(vertical dimension) by 2 and subtract the segment height. For example, a frame with a B measurement of 45 and a segment height of 15 will have a reading depth of:

1. $45 \div 2 = 22.55$
2. $22.5 - 15 = 7.5$
3. $7.5 + 5 = 12.5$ (this is the reading depth in mm)

Slab-off Prism Calculation

After determining the power and the reading depth, multiply the power by the reading depth, and divide by 10 (Prentice's Rule) to determine the amount of prism for each eye, and then subtract the two: this difference is the calculated slab-off correction.

From above, the power in the vertical meridian of the right and left eye are:

$$\text{O.D. } -1.65$$

$$\text{O.S. } -5.44$$

Multiply the power by the reading depth

$$-1.65 \times 12.5 = -20.63$$

$$-5.44 \times 12.5 = -68.00$$

Divide by 10 (Prentice's Rule) to determine the amount of prism for each eye

$$-20.63 \div 10 = -2.06 \text{ Total} = -2.06 \Delta$$

$$-68.00 \div 10 = -6.80 \text{ Total} = -6.80 \Delta$$

For the total prismatic effect subtract the right from the left: $(-6.80) - (-2.06) = -4.74 \Delta$ of calculated slab-off correction needed.

Measurement

After it has been determined by calculation that there is sufficient vertical anisometropia (more than 1 Δ to 1.25 Δ) to possibly require a different prism correction for distance and near, testing should be completed to determine how much prism to prescribe. The hallmark of determining whether different prism correction is needed at distance and near for anisometropic patients is to *prescribe what you measure*, NOT what you calculate.

Thus for anisometropic patients we suggest:

- 1) Estimate the amount of vertical anisometropia by rough calculation to determine whether the patient might need correction; it is seldom necessary to completely calculate the anisometropic imbalance in down gaze as described above. After calculation:
- 2) The cover test, a Maddox Rod test, and vertical fixation disparity measures, all in down gaze, will typically provide the desired information to determine the amount of prism to *prescribe* in virtually all instances for heterophoric patients.

Trial frame evaluation using the best correction (or testing over their previous glasses if the power is similar) will often give a better evaluation of the patient's habitual binocular status in down gaze than tests through the phoropter. Consider Cases 14.4A through 14.4D which are examples of patients requiring vertical

Case 14.4A–D Considerations for Slab-Off Prism Correction

Case 14.4A: A first spectacle prescription post IOL surgery for a 70-year-old female patient. She has had an implant in the right eye and will have the left eye done in 4 months. Her new prescription is:

OD: Plano = 20/20+

OS: +2.50 c-0.75 \times 90 = 20/30-

Add: +2.50 OU

His new prescription:

OD: -2.75 sphere 20/20+
 OS: -4.00 -3.00 × 178 20/20-
 Add: +2.00 OU

Calculated Vertical Imbalance: 4.25

Slab-off: Yes

Rationale: He currently has long-standing symptoms that are probably a result of uncorrected vertical imbalance. The new prescription improves his visual acuity but increases the calculated imbalance. Without slab-off correction, his previous problems will only be increased. Vertical associated phoria measures with the Mallett near unit at near in down gaze gave a measured amount of 2.0 Δ BD before the right eye—less than calculated—to give best near fusion. Slab-off correction of 2.0 Δ left him symptom-free.

prism by slab-off calculation and the amounts needed after measurement. These cases demonstrate how the measured prescription is often less than the calculated amount of prism.

Bicentric Grind or Slab-OFF—What Lens to Slab-off

“Bicentric grind” can be broken down as: “bi-” means two, “center” refers to the optical centers, “grind” refers to surfacing the lens. So, bicentric grind signifies that two optical centers are surfaced on the lens. Slab-off refers to the traditional method of attaching a slab of material to the front surface and grinding only part of it off, leaving a prism in that area.

Glass Lenses

Glass lenses are typically processed by adding material and then grinding base-up prism on the front of the lens. Because the actual reading segment is inside the lens, the grinding has no effect on the segment shape or power. The result is a line that looks and feels like a crease in a piece of paper on the front side of the lens (not a ledge as on executive bifocals). It takes considerable skill to end up with the line exactly where the top of the segment is. These methods are time consuming and many labs do not have personnel trained to accurately process such lenses. For glass lenses the most minus or least plus lens is slabbed off.

Plastic Lenses

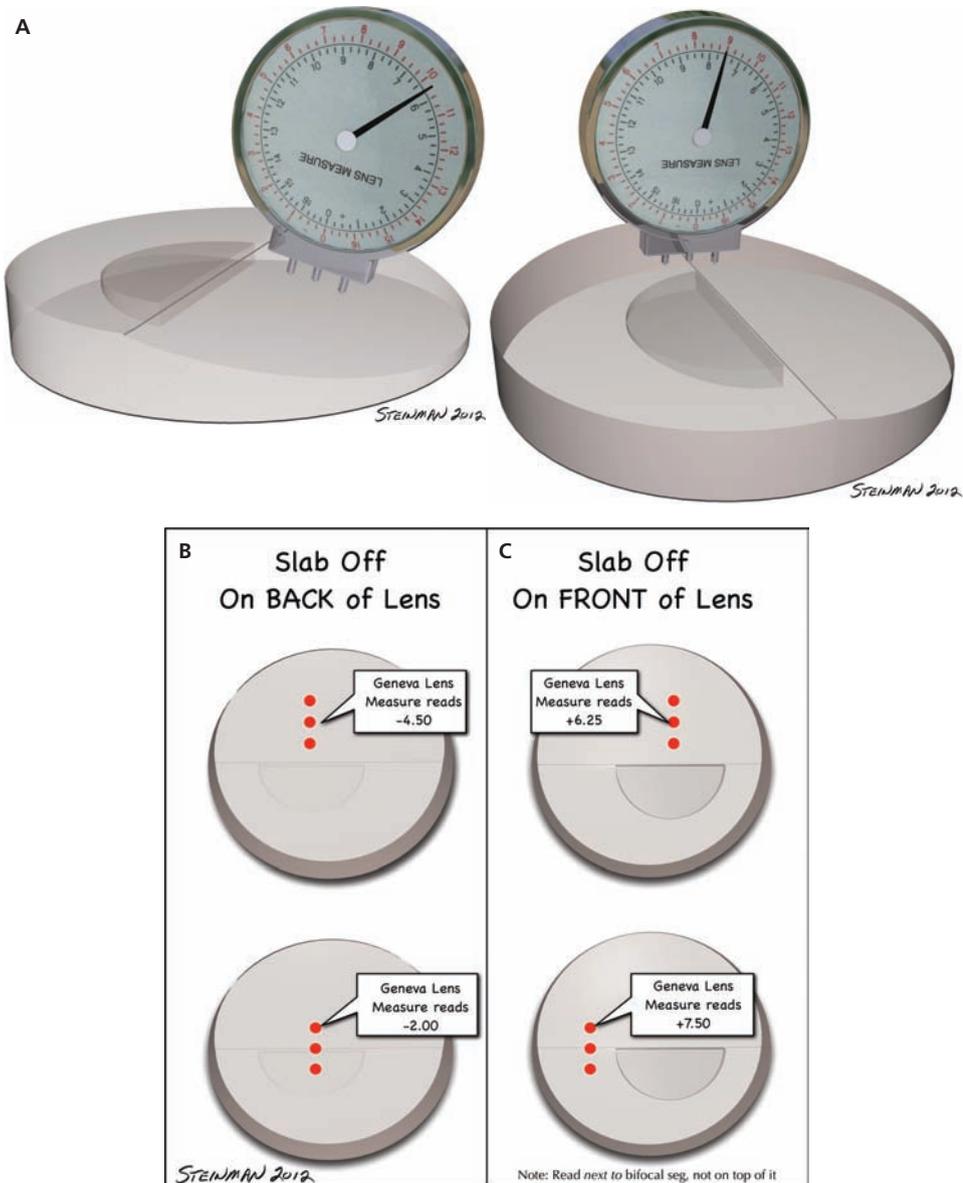
In 1983, Younger Optics developed the “reverse” slab-off lens. The reverse slab-off employs base-down prism molded on the front of the plastic lens where the segment is. The surfacing lab can order the blank with the reverse slab-off and surface and edge it normally; as a result, it is easier to make since the surfacing is part of the normal lab procedures and the molded lens is prefabricated. The reverse slab-off is available only in plastic and because it employs base-down prism, it is used for the most plus or least minus lens.

Verification of Slab-off

When glasses with slab-off prism are received from the lab, it is important that they be verified before contacting the patient. Verification can be done with a lensometer using the special prism rings built in. However, this is sometimes difficult and the challenge may be increased by the fact that the bifocal segment often contains some prism right under the line that is not there above the line. Fortunately, the technique described below using the lens clock (Geneva Lens Measure) is accurate and simple.

Using the Geneva Lens Clock

On the side of the lens with the bicentric grind use the lens clock to determine the lens curve twice, first in the distance portion and then **bisecting** the distance and near portion of the lens (see Fig. 14.8A). Always



■ **Figure 14.8 A–C:** Slab-off Verification Using The Geneva Lens Clock. Use the lens clock on the side of the lens with the bicentric grind to determine the lens curve twice; first in the distance portion (Fig. 14.8A top) and then **bisecting** the distance and near portion of the lens (Fig. 14.8A bottom), making sure to hold the pins vertically on the 90th meridian. The amount of slab off is the difference between the curve above and the curve bisecting the slab off. For example, if the bicentric grind is on the back of the lens and the Geneva Lens Measure reads -4.50 at the top and -2.00 at the bisection (Fig. 14.8B), the slab off is 2.5Δ ($[-2.00] - [-4.50] = 2.5$). If the bicentric grind is on the front of the lens and the Geneva Lens Measure reads $+6.25$ at the top and $+7.50$ at the bisection beside the segment (Fig. 14.8C), the slab off is 1.25Δ ($7.50 - 6.25 = 1.25$).

make sure to hold the lens clock with the pins oriented vertically on the 90th meridian. For example, if the bicentric grind is on the back of the lens (and if the prescription has some cylinder power):

- 1) Record the first reading made vertically on the 90th meridian.
- 2) Next place the lens clock on the lens so that the middle pin is exactly on the line between the distance and the near portion. Again, when making this measurement make sure to be on the 90th meridian.

- 3) Record this second reading and then,
- 4) Take the difference between the two readings. The difference between the two readings is equal to the amount of slab-off prism (Fig. 14.8B).

When verifying a reverse slab-off (plastic lens), where the difference in prism is on the front of the lens,

- 1) Make sure to measure first above, and then beside the segment (not on it, to be sure that the measurement is made where the curve is still creating the distance prescription) but on the line between the distance and the near portion.
- 2) Record the two readings, and
- 3) Take the difference, which is the amount of slab-off prism (Fig. 14.8C).

Vertical Prism Corrections: How Little Prism Should Be Prescribed?

Assessment of the vertical associated phoria has become the standard method for the prescribing of prism for vertical heterophorias over the past 30 years (Case 14.5). Morgan (63) measured the vertical associated phoria by assessing the patient's ability to detect alignment differences of a line of 20/30 letters interrupted by a septum. Over 98% of the 215 patients tested noticed the difference created by a 0.5 Δ prism. Prism was prescribed for 15% of Morgan's patients based on the perceived vertical misalignment, and over 90% successfully wore the prism. Morgan's results are supported by Elvin (64) and Tubis (65). In a small case study series, Wick (66) found that as little as 0.5 Δ vertical prism prescription successfully relieved symptoms related to vertical heterophoria; Jackson and Bedell (31) found that 0.75 Δ prism reduced symptoms of motion sickness in 50% of their small nonclinical patient sample. Based on these results we suggest that patients having symptoms consistent with vertical heterophoria (e.g., motion sickness, loss of place when reading, etc.) with more than 0.75 Δ vertical associated phoria be considered for treatment, via either prism correction or vision therapy. And, there may even be some very symptomatic patients with as little as 0.5 Δ vertical associated phoria who will benefit from treatment. In general, slab-off corrections should be considered for presbyopic anisometropic patients having associated phoria measures greater than 1.0 Δ at near in down gaze (reading position).

Case 14.5 Prescribing Vertical Prism Based on Associated Phoria

A 17-year-old myopic boy complained of slow reading, loss of place while reading, reading the same line when going back to the beginning of a line, and headaches (eyelid/brow area) after approximately 30 minutes of reading. He stated that blinking cleared the near blur. The current spectacle prescription was essentially the same as the refractive findings:

OD: -1.50 diopter sphere (DS) 20/15
 OS: -1.75 DS 20/15

All further testing was performed through the habitual spectacle lenses. Cover test and Maddox rod testing revealed 2 Δ of left hyperphoria in all fields of gaze at distance and near. The associated phoria findings were 1.75 Δ left hyper associated phoria at distance and near. There were no changes in associated phoria response as the patient shifted vision into lateral gaze. Accommodative findings were normal (lag = 0.75 D, amplitude = 14 D, binocular facility = 6 cpm with ± 2.00 D flippers at near).

Based on the examination findings, the habitual spectacle correction was judged to be adequate, as were accommodative and fusional abilities. The myopic correction alone and then with the addition of 1.75 Δ base-down before the left eye was placed into a trial frame, and the patient was allowed to read for 10 to 15 minutes under both conditions. He expressed a feeling of less eyestrain and more accurate eye movements (easier returning to the next line of letters) with the additional prism, which was then prescribed. With the new prescription, the patient reported a decrease in the frequency of losing his place while reading, and he experienced no symptoms while reading.

Patient Counseling

Frequently, symptoms associated with cyclovertical heterophorias can be minimized by proper patient counseling. It is important, when discussing the patient's problem and treatment, to avoid technical language and jargon like "bicentric grinding," "prismatic effect," and "anisometropia." Describe the problem and its possible solutions in simple, easy-to-understand, laymen's terms. After prescription of the best refractive correction and any necessary prism, patients who have increased cyclovertical heterophoria in a certain direction of gaze can be shown the advantage of head turns or tilts, which place their eyes in the position that gives the most comfortable binocularity. This is particularly important for those whose eyes are frequently in upgaze and convergence during their jobs (carpenters, painters, cabinetmakers, some mechanics) or hobbies (especially pool or billiards, basketball, and occasionally archery or shooting). Proper placement of reading or working material away from the eyes can enhance eye comfort for certain patients. Care taken in advising the patient regarding eye use during work and hobbies can often minimize the requirements for other, more elaborate and costly, forms of treatment.

Types of Correction When Different Prism Powers Are Needed at Distance and Near

When the vertical deviation increases in down gaze, there are a variety of correction considerations available; all of them are designed to reduce or eliminate the fusion difficulty. It is important to involve the patient in the decision and sometimes, as a clinician, some creativity is required to come up with a joint solution that satisfies the patient's needs and is economically acceptable and optically feasible.

1. Contact lenses often correct the problem when there is anisometropia. The contact lens centers on the eye and moves with eye movement, effectively eliminating any induced prism.
 - a) Single-vision contact lenses for distance with reading glasses (single vision or bifocals with no distance correction) will eliminate the imbalance because the wearer will be able to look through the optical centers of the contacts and the reading glasses will be equal power in each eye.
 - b) Bifocal contact lenses will typically correct the problem.

Unfortunately, these solutions require successful contact lens fitting and may be problematic if the patient does not want to, or cannot, wear contact lenses for a sufficient portion of the day.

2. Two pair of single-vision glasses, one for distance and one for reading, can be prescribed. With single-vision lenses, it may be necessary to teach the patient how to make the proper head movements (look through the centers of the reading lenses, rather than looking down).
3. In borderline cases where there is not much difference between the two eyes, it is sometimes possible to lower the optical center a little at distance and raise the bifocal height a little at near. This effectively splits the imbalance between the distance and the reading positions. Unfortunately, this treatment is usually only successful when there is not much anisometropia, because in patients with significant anisometropia it creates a problem in both the distance and the near portion of the lens. Also, many patients are unable to tolerate the higher bifocal placement.
 - a. Compu Specs® (<http://www.uniqueoptical.com>) provides an attractive alternative to altering the optical centers or using separate pairs of spectacles. The Compu Specs® has two magnets located in each nose pad; these provide normal positioning of the distance and near add, but they allow lenses to be elevated so that the bifocal segment can be utilized in primary gaze. These frames are very helpful for patients with a gaze palsy affecting down gaze.
4. Create prism in the bifocal area that is different from that in the distance. There are several ways to do this.
 - a. Slab-off or bicentric grind glasses. This is a common solution without much cosmetic effect. However, there is a faintly visible line on one lens that goes from one edge to the other. Because the line is located at the top of the bifocal segment, and since the most popular traditional bifocal has a flat straight top, the line is typically not very obvious.
 - b. Different segments for each lens. This has the advantage of lower cost and more rapid turnaround, since the lenses are commonly used styles. It has the disadvantage of being cosmetically noticeable. This technique is successful because different types of bifocal segments have different amounts of prism present at the top (and therefore a few mm into) of the segment. The challenge is to choose segments where this add-induced prism provides the desired prism at near.
 - c. Special segments, which look like straight-top segments with the bottom cut off, can be used that have prism of varying amounts. Because they are a less-common option, they may take more time to receive. Fortunately, they only cost a little more money than conventional flat-top bifocals, they work well, and look relatively normal.

5. Prism Segments and Franklin Bifocals

- a. Laminated prism segments are one option for presbyopic patients who need prism only in the bifocal portion of their glasses. For example, if the patient needs no prism at distance and 7 Δ base-up before the right eye at near, the lab can grind a single-vision lens to the patient's distance prescription in the right eye. Then, another single-vision lens is ground with the desired prism amount and add power and cut to look like a bifocal. These two lenses are then laminated together (the bifocal component to the original single vision) to form a right lens that has no prism in the distance, 7 Δ base-up at near, and a +2.00D add power. Because these lenses are custom-made, they can be made in all flat-top sizes, round segments as well as trifocals.
- b. An alternate technique to achieve different prism amounts between distance and near viewing zones uses a Franklin Segment (also referred to as a Franklin Split or a Stacked Segment). In this procedure separate "top" and "bottom" lenses are ground to the appropriate distance and near prescriptions and these are stacked together. Because the two lenses are independent prescriptions, prism and/or power can vary between distance and near portions of the lens; when the lenses are completed, the two single-vision lenses are stacked and the result mimics an Executive bifocal.

6. Prism Wedges and Multi-Prism Lenses

In addition to the laminated lenses listed above, some laboratories can create multi-prism lenses. Conceptually, these involve a similar laboratory process to the Franklin segment design above. The prism wedge design utilizes a vertical cut so that the prism can be present in multiple prism powers and locations. The lab can work with the doctor to assemble a lens that creates prism in desired amount locations and appropriate amounts.

7. Fresnel press-on prism. These lightweight, inexpensive thin sheets of plastic come in many different prism powers, can be cut to any shape and size, and can be oriented in any direction on the lens. They can easily be applied on a trial basis before a final slab-off lens is ordered. In the most commonly used low powers, the Fresnel press-on prism causes a slight decrease in visual acuity.

THERAPEUTIC OCCLUSION

Occlusion to eliminate a diplopic image is not usually necessary in the management of cyclovertical heterophoria. Generally these deviations are small, and enhancement of fusion will suffice to eliminate the patient's symptoms. However, diplopia associated with significant noncomitancy can be very distressing. Occlusion can be used as a treatment technique for cyclovertical diplopia when other techniques fail or are not possible.

Total occlusion of the entire field, or a sector of the field, of the nonpreferred eye will eliminate diplopia, although a patch on the spectacle lenses or patient's eye is often unacceptable cosmetically. Firm or soft occlusion contact lenses can be used when necessary (67). For patients who need or wish to continue with spectacle correction, graduated central or sector occlusion using Magic Tape (68) often gives diplopia relief that is cosmetically acceptable (Case 14.6).

Case 14.6 Vertical Diplopia Treated with Sector Occlusion and Counseling

A 29-year-old man received a blow with a baseball bat to the right forehead above the eye. Constant vertical diplopia resulted from the restricted superior oblique function as a sequela to the broken frontal bone and trochlear pulley. Facial reconstructive surgery resulted in a normal appearance and single vision in straight-ahead and down gaze. Diplopia remained in upgaze, because the right eye was unable to elevate in up-left gaze.

At the time of the examination, the patient wore no lens correction. Examination revealed emmetropia with 20/15 acuity in each eye. The cover test revealed a 2 Δ exophoria in primary gaze, with a noncomitant hyperdeviation that increased to a 25 Δ right hypotropia in up-left gaze. Pupillary reactions were normal; there was no afferent pupillary defect. He had 40 seconds arc of stereopsis

at 40 cm (Randot stereograms). Monocular muscle fields were normal, and binocular fields indicated increasing diplopia in upgaze to the left.

The patient was managed with counseling concerning the condition and instructed about the need to place objects in straight-ahead and down gaze when possible. Glasses were prescribed with sector occlusion of the upper nasal portion of the right lens, so that he could play pool without diplopia.

VISION THERAPY

Because the angles of deviation are invariably small in patients with cyclovertical heterophorias, the foundation of management is prescription of refractive and optical (prism) correction. The small prisms that are generally needed are not visible in spectacle corrections; as a result, prism provides a rapid and efficient correction. However, vision training is also an important management consideration, because large vertical and cyclovergence ranges can often be trained (69). This section discusses the various vision therapy protocols and considers the types of vision therapy procedures that can be used for treatment of patients with cyclovertical heterophorias. We recommend including vision therapy in management when vertical prism prescriptions are unsuccessful or small prism prescriptions are required by patients who prefer to wear no correction or are uncomfortable with vertical prism in a contact lens correction. In addition, vertical vergence therapy can improve comfort for some patients even when vertical prism is worn successfully.

The fact that vision training is not used more frequently in treatment of patients with cyclovertical deviations probably has, as its basis, the perceived difficulty in designing training protocols and the lack of defined goals by most practitioners. Before beginning any vision therapy program, the ultimate goals must be determined. For example, when dealing with a patient having a cyclovertical heterophoria, if more comfortable binocular fusion is the ultimate goal, then vision therapy is often a useful management consideration. However, if reduction of prism to zero is the goal, then the patient's initial prism requirements must be considered. When the initial prism prescription required is smaller than 4 Δ , a supplementary prism prescription will often not be required if vision therapy is successful. However, a combination of prism contact lenses (with up to 4 Δ) and vision therapy can often be successful with up to 9 Δ vertical deviation. These factors are important when the clinician advises a patient about therapy.

Horizontal versus Vertical Vergence Therapy

The underlying premise of vision therapy programs is that fusion ability can be enhanced with a concomitant reduction of symptoms. Fusion is enhanced by lessening suppression, increasing fusional vergence ranges, and reestablishing normal vergence adaptation via properly designed vision therapy programs. Consideration of vision therapy in this manner helps explain the thrust of the two currently accepted therapy modes used for management of patients having cyclovertical deviations.

In one therapy protocol, the goal is to maximally increase horizontal fusional vergence with the concurrent achievement of normal vertical vergence adaptation. In this approach, minimum amounts of vertical prism are used to assist fusion. The small vertical prism corrections, which are usually worn full time, are subsequently reduced as fusional abilities are increased—primarily via horizontal vergence therapy. The logic of why vertical vergence adaptation would normalize with horizontal vergence therapy is not clearly given by proponents of this mode of therapy, and for many patients elimination of vertical prism is not possible. Indeed, increases in prism are often needed to eliminate symptoms, even though horizontal vergence abilities are dramatically improved. In the second protocol, larger amounts of vertical prism are prescribed and vertical fusional abilities are increased via vertical vergence therapy, usually emphasizing expansion of vertical smooth vergence ranges. This approach often suffers from a difficulty in reducing the vertical prism to a reasonable amount. Because neither procedure is always successful, many practitioners tend to use only prism corrections for patients having cyclovertical deviations and disregard vision therapy entirely.

Because neither of the above approaches is uniformly successful, our approach to vision therapy for cyclovertical deviations has been to develop a protocol, based on fixation disparity assessment, that allows the two methods to be combined. Our protocol is uniformly successful in developing comfortable binocular

TABLE 14.8 HOW ASSOCIATED AND DISSOCIATED PHORIA COMBINATIONS DICTATE MANAGEMENT

	Associated Phoria		
	Small	Medium	Large
Dissociated phoria			
Small	Vertical VT or small vertical prism	Vertical VT or vertical prism	N/A
Medium	Horizontal and vertical VT	Vertical prism or vertical VT	Vertical prism and vertical VT
Large	Horizontal VT and vertical prism	Horizontal or vertical VT	Vertical moderate vertical prism

VT, vision therapy; N/A, not applicable.

vision, although many patients still require small to moderate amounts of vertical or horizontal prism for maintenance of reduced symptoms.

Therapy protocols are determined by considering both the associated and the dissociated phorias. This technique accounts for the vertical vergence adaptation abilities of the patient when designing the therapy program, thereby improving the results of vision therapy for cyclovertical heterophorias over the current therapy protocols. Table 14.8 lists the various combinations and therapy protocols for each. In general, the more normal the vertical adaptation is initially, the more likely vision therapy is to be successful; patients with less normal vertical vergence adaptation typically respond better to prism correction.

When there is a mismatch between the associated and the dissociated phoria (evidenced by a large dissociated phoria and a small associated phoria), the patient has relatively normal vertical vergence adaptation or a well-compensated vertical deviation. For this patient, small amounts of (or even no) vertical prism can be used in combination with horizontal fusional vergence and antisuppression therapy. Emphasis can be on horizontal vergences, since the vertical deviation is well compensated (as evidenced by the much smaller associated than dissociated phoria) or vertical vergence adaptation is already nearly normal (as evidenced by a nonlinear vertical fixation disparity curve) (Table 14.8, column 1). Small amounts of vertical vergence therapy can be included. When there is a large dissociated and associated phoria, vertical prism is the treatment of choice, since there is a large dissociated heterophoria and vertical vergence adaptation is not present. If vision therapy is used, vertical vergence therapy (as described below) can be considered. As Table 14.8 indicates, intermediate combinations of associated and dissociated phoria require combinations of horizontal and vertical vision therapy, along with prism.

Antisuppression Therapy

An interesting clinical observation is that vergence abilities are often significantly improved as a result of successful treatment of suppression. Thus, an important initial step in therapy for cyclovertical deviations is treatment of suppression. Suppression training uses active therapy, such as red/green anaglyphic stereograms (tranaglyphs), either in the office or at home. Polaroid materials are usually not used because a tilt of the head, which is frequently present for patients with cyclovertical heterophorias, allows both targets to be seen by one eye.

During antisuppression therapy, attention is drawn to simultaneous perception of suppression clues and clearness of the clues seen by each eye. Active treatment involves binocular (dichoptic) stimulation of peripheral retinal areas, followed by gradual encroachment upon central areas. If office therapy is contemplated, therapy is structured using dissimilar targets (first degree, such as the soldier and house in the Bernell Variable Prismatic Stereoscope) initially, and then similar flat fusion targets (second degree). Other valuable techniques that can be used include anaglyphic TV trainers, anaglyphic coloring activities, and tranaglyphs. Finally, physiologic and pathologic diplopia therapy is added.

Sensory fusion should be maximally developed before motor fusion therapy begins. Qualitative aspects are more important than quantitative aspects (i.e., development of increased facility is more important than training large vergence magnitudes). The importance of transference to free space situations must be recognized by designing programs that utilize the most natural environment possible, consistent with controlling the therapy, so that an improvement in binocularity is achieved. This can be done by using red/green or Polaroid procedures (i.e., tranaglyphs or vectograms) as soon as possible in the therapy program.

Horizontal Vergence Therapy

Horizontal vergence therapy is considered when there is a large dissociated heterophoria and a small associated phoria. The initially normal vertical vergence adaptation, or good compensation for the vertical heterophoria by such a patient, suggests that horizontal fusional vergence and antisuppression therapy can be combined with the small amount of vertical prism required to reduce the fixation disparity to zero (associated phoria).

The ultimate goal of horizontal vergence and accommodative therapy is to increase the patient's vergence responses so that he or she can maintain comfortable binocular alignment for longer periods of time. Ideally, the small amounts of vertical prism that might have been required initially can subsequently be reduced to zero. The specific goals of horizontal vergence therapy depend on the type of horizontal anomaly present. For example, if there is convergence insufficiency, the goals in Chapter 9 should be followed. If horizontal vergence therapy is not progressing as expected, it is important to reevaluate the need for vertical prism and, if fusion is improved with a vertical prism correction, to prescribe the prism so that the vision therapy can be more successful (Case 14.7).

Case 14.7 Secondary Vertical Deviation

A 31-year-old man with an intermittent exotropia of the right eye presented for a routine yearly examination. He had been told that he needed surgery for his eye turn, but had never had any treatment and currently wore no lens correction. External and internal ocular health was within normal limits. Visual acuity and refraction with cycloplegia were as follows:

OD: $-1.00 - 1.50 \times 005$ 20/20+
 OS: $+0.25 - 0.75 \times 165$ 20/15
 OU 20/15

There was a comitant intermittent 21Δ right exotropia combined with a 6Δ right hyperdeviation at 6 m and 40 cm. The right eye was exotropic approximately 45% of the time. Fixation was central with both eyes. There was occasional intermittent suppression of the right eye on Worth dot testing, and stereopsis was 40 seconds at 40 cm with Random Dot circles. Fixation disparity testing at 40 cm revealed no vertical fixation disparity, and a cover test at 40 cm, through -4.00 lenses, revealed 4Δ exophoria and no hyperdeviation.

The refractive finding was prescribed, but vertical prism was not given because both the cover test (through minus lenses) and the fixation disparity assessment indicated that the vertical deviation was secondary to the exodeviation, since the vertical deviation decreased to zero with the eyes in the primary position. The patient returned for reevaluation in 2 weeks with acuity unchanged from above, but the proportion of time of his eye turn had decreased to about 25%. Binocular antisuppression therapy using a TV trainer, reading bar, and Brock string was prescribed. After 3 weeks, accommodative/vergence interaction therapy was instituted, using lens and prism flippers. Over the next 8 weeks, the patient's binocular status improved, as summarized in the following table.

Week	Management	Proportion of Time of Exotropia	Stereopsis (sec)
1	Exam	45%	40
2	Best prescription (spectacles) Progress visit (binocular antisuppression vision therapy)	25%	40
4	Lens/prism flipper	20%	30
6	With suppression	10%	30
8	Monitoring	0%	20
10	15Δ loose prism fusion	0%	20

After vision therapy, the secondary vertical deviation was still present on alternating cover test (18Δ exophoria with 5Δ right hyper), but vertical prism correction was not needed.

Sensory motor therapy involves programs designed to affect vergence or accommodation and then to utilize procedures that affect their interactions. Many vision therapy procedures can be used to improve vergence ability; as different as they may seem initially, their similarities are striking. The primary emphasis is on the improvement of the magnitude and especially the facility of vergence responses. To this end, many of the following techniques can be used.

In-office Therapy

Bernell Variable Prismatic Stereoscope. Use targets that have second-degree fusion or stereopsis. The parameters of the target can be varied by changing the brightness or flashing the target to eliminate suppression and reduce anomalous responses. Other instruments, discussed below, can be used for therapy in the office or at home.

In-office or Home Therapy

Stereoscope and Cheiroscope. Use targets that have second-degree fusion or stereopsis. With a stereoscope, the parameters of the target can be varied in the same manner as with the Bernell Variable Prismatic Stereoscope. Vergence can be varied using split stereograms or by tromboning the targets in stereoscopes or by moving the targets as a fusion response is maintained. To eliminate suppression, have the patient point at details of the target and vary the parameters of the target by altering the brightness, flashing, or changing the size.

Convergence and Accommodative Facility Procedures

Vergence Therapy

See Chapters 6 through 8 for the techniques needed for vergence therapy. The following equipment is useful for horizontal vergence therapy when there is a concurrent cyclovertical deviation. Tranaglyphs can be used to develop convergence ability and accommodative facility. The single or double Aperture Rule trainer is an excellent instrument for home and office, although young children often have difficulty learning the required responses. Free fusion stereo rings (opaque or transparent Eccentric Circle cards) or red/green circles are also useful vergence therapy techniques. Fusion, step, and jump vergences can be trained depending on the techniques used or by using a prism bar (70) or loose prisms.

Accommodative Therapy

Clearness and singleness are stressed, so that the accommodative response is appropriate to the stimulus and not an overcompensation to induce convergence. The total convergence response includes tonic, accommodative, fusional, and proximal vergence. Accommodative convergence may be poor in quantity or facility, adding to the total ocular problem. Thus, specific accommodative therapy may be as important to the successful treatment of horizontal deviations as vergence therapy. Accommodative therapy should be done by combining red/green or Polaroid techniques (i.e., tranaglyphs or vectograms) with lenses as soon as possible in the therapy program. Use plus and minus lenses or prism to modify the accommodative or vergence demand.

Vertical Vergence Therapy

Vertical vergence therapy is a management consideration when there is a moderate dissociated phoria and a slightly smaller associated phoria and, occasionally, when there is a small but equal associated and dissociated phoria. The vertical vergence adaptation of these patients is somewhat (or completely) abnormal, which suggests a need for vertical fusion vergence therapy to extend vertical vergence ranges and redevelop more normal vergence adaptation. Moderate amounts of vertical prism are generally required initially to give comfortable fusion (Case 14.8).

Case 14.8 Well-Compensated Vertical Deviation

An 18-year-old woman who wore no lens correction had complaints of eyestrain and difficulty staying on the correct line while reading. External and internal ocular health was within normal limits. Visual acuity and refraction with cycloplegia were as follows:

OD: +0.00 – 0.50 × 15 20/15
 OS: +0.25 – 0.25 × 160 20/20+
 OU 20/15

There was a comitant 6 Δ exophoria combined with a 4 Δ left hyperphoria at 6 m and 40 cm. There was occasional intermittent suppression of the left eye on Worth dot testing, and stereopsis was 50 seconds at 40 cm with Randot circles. Fixation disparity testing at 40 cm revealed a vertical associated phoria of 0.75 Δ base-down left at 40 cm.

The refractive finding was prescribed with 0.75 Δ base-down left. The patient returned for reevaluation in 2 weeks with substantial reduction of symptoms, but she still had some difficulty maintaining her place when reading for prolonged periods. Binocular antisuppression and horizontal vergence therapy was prescribed using a TV trainer, reading bar, and Aperture Rule trainer. After 3 weeks, accommodative/vergence interaction therapy was instituted using lens and prism flippers. Vertical vergence therapy was instituted about week 8 (see below). Over the course of therapy, the patient's binocular status and symptoms improved (as summarized in the following table). The vertical prism correction was retained, but worn only during prolonged reading.

Week	Management	Symptoms	Stereopsis (sec)
1	Exam	Loses place when reading, headaches	50
	Best prescription (spectacles) with 0.75 Δ base-down left		
2	Progress visit (binocular antisuppression vision therapy)	Occasionally loses place when reading, fewer headaches	40
4	Lens/prism flipper		30
6	With suppression		30
8	Monitoring	A few headaches	20
10	Vertical vergence therapy	None	20

The ultimate goal of vertical vergence therapy is to increase the patient's vergence responses and enhance vertical vergence adaptation until comfortable binocular alignment can be maintained for longer periods of time (Case 14.9). When vision therapy is successful, the amount of vertical prism is reduced as appropriate, with an ultimate goal of only a small amount of vertical prism being required. Ideally, comfortable binocular vision can be achieved with a minimum amount of vertical prism—for example, an amount that permits wearing of prism contact lens correction.

Case 14.9 Vertical Vergence Therapy

A 25-year-old woman had endured many years of headaches, eyestrain, and difficulty staying on the correct line while reading. She was interested in contact lenses and currently wore a small myopic lens correction with 1.5 Δ base-down left that gave only partial relief of her symptoms. External and

internal ocular health was within normal limits. Visual acuity and refraction with cycloplegia were the same as her current prescription:

OD: $-1.50 - 0.50 \times 165$ 20/15-
 OS: $-1.75 - 0.25 \times 5$ 20/15-
 OU 20/15

There was a comitant 3 Δ exophoria combined with a 7.5 Δ left hyperphoria at 6 m and 40 cm. There was occasional intermittent suppression of the left eye on Worth dot testing, and stereopsis was 40 seconds at 40 cm with Randot circles. Fixation disparity testing at 40 cm revealed a vertical associated phoria of 6.5 Δ base-down left at 6 m and 40 cm.

After treatment options were explained, the patient decided to continue to wear her current refractive correction and begin a vision therapy program. Vertical vergence therapy was instituted using a 0.5 Δ prism for 30 minutes per day, in a ratio of two times base-down and one time base-up before the left eye. A TV trainer and reading bar were used concurrently for suppression therapy. The amount of vertical prism used in the flip prism therapy was gradually increased to 2.5 Δ . After 3 weeks, a 1 Δ stress prism (base-up left) was incorporated and the flip prism continued. At the same time, accommodative/vergence interaction therapy was instituted using lens and prism flippers. The stress prism was gradually increased to 4 Δ over a 1-month period. Over the course of therapy, the patient's binocular status and symptoms improved, as summarized in the following table. Because she became symptom-free with vision therapy, contact lenses were fit without prism.

Week	Management	Symptoms	Stereopsis (sec)
1	Exam Current prescription: spectacles with 1.5 Δ base-down left; vertical jump vergence therapy with 0.5 Δ and antisuppression therapy	Loses place when reading, headaches	40
2	Progress Increase vertical jumps to 2.5 Δ by week 3	Occasionally loses place when reading; fewer headaches	40
4	Lens/prism flipper		30
6	With suppression		30
8	Monitoring; stress therapy	A few headaches	20
10	Vertical prism (start with 1 Δ and increase to 4 Δ base-up)	None	20 seconds
12	Contact lens fitting without prism	None	

Smooth Vertical Vergence Therapy

Smooth training of vertical vergence can generally be done quite easily using tranaglyphs with a vertical holder (Fig. 14.9). Unfortunately, such therapy does not usually relieve the existing symptoms and, as a result, should be done sparingly. Rather, the therapeutic emphasis should be on jump vergence therapy.

Jump Vertical Vergence Therapy

When vertical vergence programs are designed based on our philosophy, therapy is directed at making abrupt changes, emphasizing speed and quality of response in preference to stressing maximum amplitudes



■ **Figure 14.9** **A:** Vectograms or tranaglyphs can be used for vertical vergence therapy. **B, C:** When a handheld vertical holder is used, the patient simply vertically separates the two vectogram halves to the appropriate separation.

of response. Thus, step vergence changes are best achieved using loose prisms. Start with 0.5Δ and have the patient fuse as it is interposed base-up and base-down. Usually, both vergence directions should be trained with a 2:1 ratio of procedures—that is, when there is a 4Δ left hyperphoria, train using two base-up procedures to one base-down procedure. Increase the prism in 0.5Δ steps until the patient reaches a maximum goal of about 2.5Δ .

Stress Vertical Vergence Therapy

When the flip prism goal of 2.5Δ is reached, then stress (isometric) training is begun. The patient fuses the vectogram or tranaglyph through a 1Δ prism oriented in the direction opposite to the phoria. The jump vergence procedure (described in the previous section) is repeated through the maximum amount of flip prism possible, even though it may be less than the previous amount. Gradually increase the power of the flip prism as the patient increases his or her fusion ability with the procedure. As an example, after the patient with a 4Δ left hyperphoria reaches the maximum flip prism goal of 2.5Δ , place a 1Δ prism base-up before the left eye and have him or her resume flip training using the maximum prism power possible. Usually this will be about 1Δ to 1.5Δ , substantially smaller than the previous amount. Again, use a ratio of two base-up procedures to one base-down procedure. Increase the prism in 0.5Δ steps until the 2.5Δ flip goal is reached and then increase the stress prism. The goal is to be able to fuse through a stress prism of three-fourths of the vertical phoria.

Cyclophoria Therapy

Cyclovergence therapy is a management consideration when there is an uncompensated cyclophoria and the best refractive correction, with any needed vertical prism or vision therapy, has not alleviated the symptoms (Case 14.10). Fortunately, cyclophorias are typically small in magnitude, and vision therapy has a better prognosis than for the cyclotropic patient, who often benefits from surgery as well as vision therapy. When vision therapy is successful, there is total elimination of symptoms; occasionally, however, vision therapy is only partially successful, and patient counseling concerning work habits and distance is then required to minimize symptoms.

Case 14.10 Cyclovergence Therapy

A 23-year-old woman had complaints of headaches over the left eye, eyestrain, and intermittent blurred vision while reading. She wore a moderate astigmatic correction. External and internal ocular health was within normal limits. Visual acuity and refraction with cycloplegia were the same as her current correction:

OD: +0.50 – 3.50 × 5 20/15–
 OS: +0.75 – 3.25 × 175 20/20+
 OU 20/15

There was a comitant 3 Δ exophoria at 6 m and 40 cm. There was occasional intermittent suppression of the left eye on Worth dot testing, and stereopsis was 40 seconds at 40 cm with Randot circles. Accommodative findings were normal (amplitude = 11 D, lag = +0.25 D, facility = 12 cpm with ±2.00). There was no fixation disparity at 6 m, but the patient reported a torsional disparity of the left eye's target at 40 cm. Near refraction revealed the following cylinder axes:

OD: 6
 OS: 165

Although distance vision was blurred, reading with near axes findings allowed comfortable vision with no blurring. Maddox rod testing revealed a 1 Δ excyclophoria at 6 m and a 9 Δ excyclophoria at 40 cm.

The patient did not want to have two pairs of glasses, and her allergies prevented satisfactory wearing of contact lenses. A cyclovergence therapy program was begun using Maddox rods and orthoptic (divergent) fusion cards with torsional disparity. The patient returned for reevaluation in 2 weeks with substantial reduction of symptoms, but she still reported some blurring when reading for prolonged periods. Binocular antisuppression therapy using a TV trainer and reading bar was added, and the cyclovergence therapy was increased in difficulty. Over the course of therapy, the patient's binocular status and symptoms improved, as summarized in the following table.

Week	Management	Symptoms	Stereopsis (sec)
1	Exam Cyclovergence therapy with Maddox rods and fusion cards	Blurs when reading; headaches	40
2	Progress visit Binocular antisuppression vision therapy; increase cyclovergence therapy	Occasionally blurs when reading; fewer headaches	30
4	Continue	None	20
6	Final visit	None	20

Training cyclofusion can be done by various techniques. Among the most useful clinically are Maddox rod therapy, stereoscopes or synoptophores, biofeedback, and the dove prism. The most successful clinical methods are probably (a) the afterimage technique and the stereoscope with rotatable cards for office training and (b) Maddox rods and rotating orthoptic fusion cards for home training. The dove prism also works well, but it is generally not clinically available.

Rotating Cylinder and Maddox Rod Therapy

Savage (71) used a home-training method consisting of a 2.00 D cylinder (axis 180) in front of each eye. The patient fixates a vertical line target, and the cylinder lenses are rotated in the direction to increase the action of the insufficient muscle while fusion is maintained. Savage reported cures of 300 patients using this technique.



■ **Figure 14.10** Cyclovergence therapy can be achieved using split targets in a stereoscope. The targets are fused and then slowly rotated to give the appropriate cyclovergence demand. As the patient's abilities increase, the amount and speed of rotation are increased.

Maddox rods can also be used. A point source is viewed through Maddox rods, and a fused line image is seen. The rods are rotated until diplopia occurs. Cyclofusion ranges are trained, concentrating on the opposing cyclovergence.

Stereoscopes

A stereoscope with rotatable targets can be used (Fig. 14.10). In a stereoscope, orthoptic (divergent) fusion cards with appropriate targets can be fused and rotated. Targets are rotated to increase fusion ranges, concentrating on the opposing cyclovergence.

Biofeedback

With biofeedback techniques using afterimages, cyclorotations (pursuits and saccades) have been developed up to 30 degrees (72). In a short time, large ranges of cycloverersion can be trained (73). Training procedures have been used, with success, for cyclotropia up to 7 degrees (17).

In this research-based technique, the patient's head is restrained by a mouth bite while a vertical afterimage is placed on one eye. The patient monocularly aligns this afterimage with a vertical line that is rotated more as his or her ability increases. This portion of the technique increases cycloverersion. Subsequently the lines are polarized. The lines are rotated and the patient's task is to maintain fusion using cyclovergence. This is achieved by maintaining alignment of the afterimage and line seen by the eye with the afterimage. Cyclofusion ranges are trained, concentrating on the opposing cyclovergence.

Dove Prism

The dove prism inverts the image seen by an eye. Rotating the prism will cause the inverted image to rotate. The patient fixates a vertical line target, and the dove prism is rotated in the direction to increase the action of the insufficient muscle while fusion is maintained.

SURGERY

Cyclovertical heterophorias are generally of small magnitude. As a result, they can usually be managed utilizing a combination of best lens correction, prism, and vision therapy. Patients with vertical heterophoria greater than 15 Δ are often candidates for surgery because it is difficult to manage them satisfactorily without substantial amounts of prism. However, the specialized, difficult surgery required is not generally recommended for cyclovertical heterophorias until other treatment techniques have been unsuccessfully attempted (74).

Cyclovertical heterotropias are usually associated with muscle paresis, and for cyclotropias over 5 degrees surgery has traditionally been the medically recommended treatment (47,75). When cyclotropia occurs in

association with a clinically significant hyperdeviation, surgical correction of the hyperdeviation usually corrects the cyclodeviation simultaneously (76). Cyclodeviations without significant vertical deviations are more difficult to manage surgically (77) because conventional muscle weakening or strengthening procedures can have an undesired vertical effect. An operation that has no effects on the vertical balance of the eye (78) involves surgical advancement of the anterior portion of the superior oblique insertion for excyclotropia and recession for encyclotropia (79). Similar partial advancements can be done on the inferior oblique insertion, with an expected quantitative effect of 3 Δ per millimeter of advancement and 2 Δ per millimeter of recession for either muscle (80).

Summary

Symptoms of uncompensated cyclovertical heterophoria may be present in about 20% of patients (62). Attention to case history combined with careful examination will usually reveal patients suffering from this condition. Binocular refraction at distance and near (if necessary) and fixation disparity testing in all fields of gaze are probably the most important factors in analyzing the role of cyclovertical heterophoria in everyday clinical practice. Special consideration should be given in occupational vision work and patient counseling for certain hobbies. Multiple prescriptions (usually incorporating vertical and/or slab-off prism correction) or vision therapy or both may be useful in alleviating symptoms of cyclovertical deviations.

Study Questions

1. Why is it medically important to identify both hypertropia and hypotropia when heterophorias are typically only labeled as hyper?
2. Describe why and how astigmatism might be a problem for patients with cyclophoria. What does this mean in relation to patient examinations (i.e., for which patients might you be concerned that a cyclophoria would cause astigmatism-related symptoms)?
3. List five symptoms that patients with hyperphoria typically report.
4. The double Maddox rod test is used to determine the amount of cyclophoria or tropia. How is the test done, what is the patient's perception, and how does the examiner determine the result?
5. Why is fixation disparity testing the test of choice to determine how much vertical prism to prescribe? Based on fixation disparity measures, how small a prism finding might be considered for prescription and on what criteria would you base your prescription decisions?
6. When might diagnostic (prolonged) occlusion be used?
7. What does the forced vergence fixation disparity curve typically look like for patients with vertical phoria? What does this mean regarding prescribing prism that is based on the associated phoria?
8. Describe how to calculate the amount of prism needed for an anisometric patient at near. Why might this calculated amount be different from amounts measured by associated phoria testing and what does this difference mean when deciding whether or not to prescribe slab-off prism?
9. Why is vision therapy not used as the first choice for patients with vertical phoria?
10. How do treatment considerations differ when there is a mismatch between the dissociated and associated phoria? Why are these distinctions made?
11. When is surgery for vertical phoria considered?

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Fixation Disparity

Fixation disparity tests are measures of changes in ocular alignment in response to binocular vergence stimulation or accommodative stress or both (1). With fixation disparity testing, it is not necessary to assume that a measured latent neuromuscular bias (heterophoria) also exists and causes symptoms noted during binocular viewing. Residual misalignment can be directly measured, concurrent with assessment of the ability to adjust to induced external vergence and accommodative demands. This chapter discusses the issues involved in fixation disparity assessment, with an emphasis on clinically useful methods.

Fixation Disparity or Fixation Misalignment

Clinical research has demonstrated that parameters of fixation disparity testing are related to symptoms for some patients (2), and there are clinical reports that prism prescriptions (3) or vision therapy (4) procedures based on these measures will reduce or eliminate many of these symptoms. However, basic science research suggests that clinical measures of fixation disparity are made up of at least two components—a change in visual direction and an actual motor change that together constitute the fixation disparity seen clinically (5). A sensory factor could, in part, explain why prescriptions based on fixation disparity measures are not successful for all patients and might further explain why the fixation disparities of some patients are smaller than expected from the heterophoria finding (6).

Given the clinical success (and improvement on previous techniques) that management based on fixation disparity measures enjoys, it seems imprudent to discount the clinical research concerning use of fixation disparity measures simply because fixation disparity tests measure the sum of separate sensory and motor components rather than simply assessing eye misalignment. However, thoughtful clinicians should remain aware of the fact that clinical fixation disparity measures probably represent sensory remapping as well as motor misalignment of the eyes. In the discussion that follows, fixation disparity will be deemed to include both the motor and perceptual components of eye alignment measured under binocular conditions, without differentiating between them.

Analysis Approach for fixation disparity

Three analysis approaches have traditionally been used to determine whether reported symptoms are likely to be related to vergence or accommodative deficiencies: graphical analysis (7), analytical analysis (8), and normative analysis (9). Chapter 2 discussed and presented integrative analysis—a new method of binocular analysis that combines these previous techniques and also incorporates features of fixation disparity measures. In this light, assessment of fixation disparity per se is not the key issue. Rather, clinical fixation disparity measures are looked at as part of a group of findings, and decisions are made using this residual perceptual/motor misalignment as a basis for prescription of added lenses, prism, or vision therapy.

The important reason for including fixation disparity measures in binocular vision diagnosis is that many important accommodation and vergence interactions can only be adequately tested under binocular conditions. Binocular testing also provides a more accurate and complete picture of the interactions between binocular components than traditional systems, which compare various monocular (dissociated) measures. Binocular analysis also eliminates the necessity of assuming that any one component is the cause of binocular dysfunction. Fixation disparity curves measured at distance as well as near fixation distances represent the only clinical assessment of vergence and accommodative interactions under binocular conditions. The fixation disparity curve allows the clinician to assess the therapeutic effect of lens and prism combinations and helps determine an intervention strategy that develops optimal binocular responses.

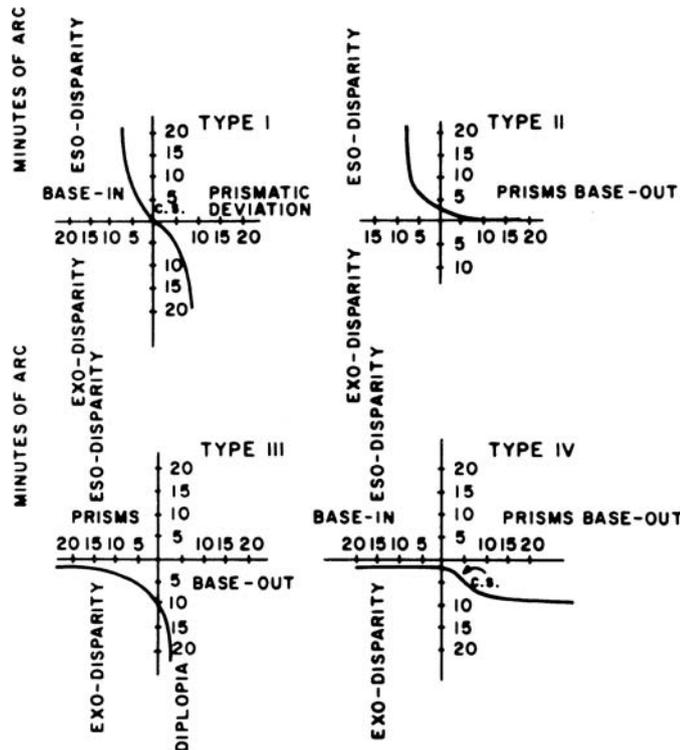
FUSIONAL VERGENCE

During patient examinations, fusional vergence measurements are often performed at distance and near, using loose or rotary prisms in free space or through a phoropter, or both. Because fixation disparity measures assess ocular alignment through an extended range of prism powers, rotary prism measurement of vergence ranges through the phoropter can frequently be eliminated from the test sequence when forced vergence fixation disparity curves are measured. Loose prism measurements, which are presented in discrete steps, provide a useful indication of fusional ranges as well as recovery ability.

Forced Vergence Curve Parameters

CURVE SHAPE

Increasing amounts of prism can be used to change fusional vergence demand while fixation disparity is monitored. Graphic representation of the results portrays what has come to be called the *forced vergence fixation disparity curve*. As vergence demand is altered, the amount of fixation disparity may change. Usually, an increase in base-out prism increases exofixation disparity and an increase in base-in prism increases esofixation disparity (10). Curves with steep slopes, large associated phorias, and substantial fixation disparities are found more frequently when testing symptomatic patients (11). Asymptomatic patients usually have type I curves. Other curve types are frequently associated with patients who have large dissociated heterophorias (type II eso, type III exo) or unstable binocularity (type IV) (6,12). Figure 15.1 illustrates distance and near-horizontal forced vergence fixation disparity curve types found in the examination of clinic populations (13).



■ **Figure 15.1** The four fixation disparity curve types, originally described by Ogle (1), are classified as types I through IV. Type I curves, which are present in about 55% of the population, are usually associated with asymptomatic patients. Other curve types are frequently associated with patients who have large dissociated heterophorias (type II eso, 30% of the population; type III exo, 10% of the population) or unstable binocularity (type IV).

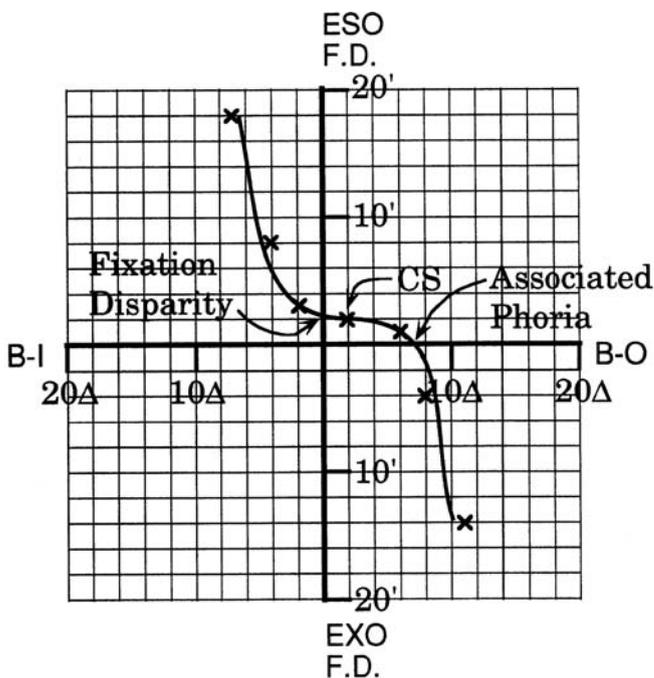
Most people adapt more to one type of lateral prism (base-in or base-out) than the other. These variations in adaptation determine the shape of the curve (14). Type I curves result from approximately equal adaptation to base-in and base-out prism stress. However, properly differentiating type I from type II curves often requires that the base-out end of the range be carried to the full extent of the disparity (fusional) vergence range (15), so that fusional (disparity) convergence and fixation disparity relationships are fully evaluated. Type II curves originate from more adaptation to base-out prism and less adaptation through base-in prism. Persons who adapt more completely to base-in than base-out prism have more fixation disparity with base-out prism, and have a type III curve.

CENTER OF SYMMETRY

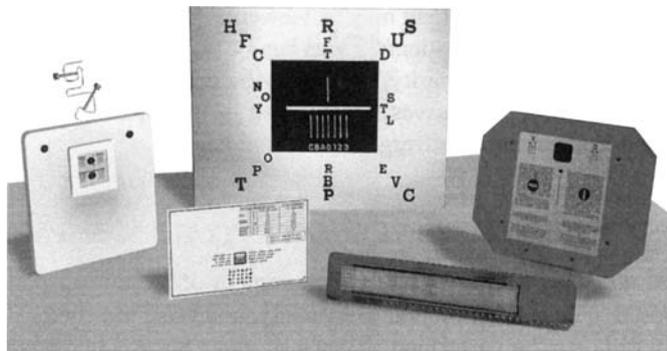
Center of symmetry refers to the area of the forced vergence fixation disparity curve where vergence adaptation occurs most readily to changes in disparity (fusional) vergence (6) (Fig. 15.2).

ASSOCIATED PHORIA: X-INTERCEPT

The *associated phoria* is defined as the amount of prism required to reduce fixation disparity to zero (6). The associated phoria (*x*-intercept, Fig. 15.2) is the point usually measured clinically. Figure 15.2 shows the location of the associated phoria plotted on a forced vergence fixation disparity graph. The magnitude of the associated phoria is generally significantly less than the dissociated phoria for exophoric patients and is often greater for esophoric patients (6). In addition, there are occasional patients who have paradoxical responses where, for example, an exophoric patient has an eso-associated phoria (see Chapter 16—Fig. 16.9) (6). Associated phoria magnitude is influenced by proximal vergence and vergence adaptation (16,17). In addition to vergence adaptation, factors such as suppression and reduced peripheral fusion (17) may influence the associated phoria magnitude by limiting responses to vergence stimuli in the peripheral retina (6,18).



■ **Figure 15.2** Center of symmetry refers to the area of the forced vergence fixation disparity curve where vergence adaptation occurs most readily to changes in disparity (fusional) vergence. The prism to reduce the fixation disparity to zero (associated phoria) is about 7 Δ base-out, and the actual fixation disparity is 2 minutes arc eso.



■ **Figure 15.3** Equipment used to test fixation disparity includes the Disparometer (**left**), the Woolf card (**back center**), the Mallett near unit (**right**), the Wesson card (**front left**), and the American Optical vectographic adult slide (**front right**).

The associated phoria is determined at distance using a Mallett unit, American Optical (AO) vectographic chart, or Bernell lantern and neutralizing any reported misalignment of the lines with appropriate prism. The same concept applies to near testing, where the associated phoria can be determined using the AO near vectographic card, Borish card, or near the Mallett unit (Fig. 15.3).

The associated phoria is only one aspect of the fixation disparity curve. Although measurement of the associated vertical phoria is the method of choice for determination of vertical prism corrections (Chapter 14), the lateral associated phoria is not as clinically useful. To utilize fixation disparity assessment for prescription of horizontal prism, it is necessary to consider the lateral associated phoria along with other forced vergence fixation disparity curve parameters (slope, curve type, and fixation disparity) (3). Use of only the lateral associated phoria is not adequate, because there is then a tendency to overestimate needed prism corrections for patients with esodeviations.

Indeed, for esophoric patients, it is often useful to start prism analysis through prism base-out equal to one-third of the distance esophoria. Thus, when there is distance esophoria of 6Δ , a prism of 2Δ base-out can be used as a starting prism, and the vergence ranges, distance associated phoria/fixation disparity, and stereopsis can be assessed to determine whether the prism is the appropriate amount. More normal vergence ranges, a zero-associated phoria, or improved stereopsis through the prism indicate that the chosen prism power is appropriate; often the patient will also report that distance visual acuity is more clear. Starting prism determination with one-third of the distance esophoria allows a more rapid clinical determination of the prism needed. The distance phoria is used because the near phoria is more influenced by the AC/A ratio, and added lenses are used to alter this relation, whereas the distance phoria can only be treated by prism or vision therapy.

FIXATION DISPARITY: Y-INTERCEPT

Fixation disparities are small misalignments of the visual axis (usually less than 6 seconds of arc) under binocular conditions (13). Fixation disparity exists when images of a bifixated object are not on exactly corresponding points, but remain within the Panum area. The retinal images are seen singly, even though the foveas may have a misalignment of up to 30 seconds (10). The amount of misalignment (fixation disparity) is dependent on the size of the Panum area. When lenses or prism or both are added and the eyes maintain binocular fixation, there is frequently increasing misalignment of the visual axis (still maintained within the Panum area) (6).

The forced vergence fixation disparity curve is graphically represented by plotting the change in fixation disparity with change in lens or prism (6). The actual fixation disparity measurement, which is not generally measured clinically except by instruments designed for the purpose (such as the Disparometer, Woolf card, or Wesson card), is the point where the curve crosses the y-axis (Fig. 15.2). Typically the fixation disparity is in the same direction as the heterophoria (1); however, there are patients (who are typically exophoric) who have paradoxical patterns where there is an eso-fixation disparity when fusing but an exo-dissociated phoria measured by cover test or Maddox rod (see Chapter 16, Fig. 16.8).

SLOPE

The slope, which can easily be determined using a forced vergence fixation disparity graph, can be estimated by calculating the change in fixation disparity between prism demands of 3 Δ base-out and 3 Δ base-in. When a patient has a flat fixation disparity curve, prism prescriptions based on shifting the center of symmetry (midpoint of the flattest portion) of the curve (Fig. 15.2) toward the y-axis are generally more successful in reducing symptoms, enhancing binocularity, and yielding lower prism prescriptions than those based on either dissociated or associated phoria measurements. These prescriptions optimize responses of vergence adaptation to convergence and divergence responses (14).

Patients with steep curves can often be treated using vision therapy. When the curves do not flatten with vision therapy, the patient may be viewed as being resistant to the development of vergence adaptation (14). For these patients, prism can be prescribed, based on the associated phoria (prism to reduce fixation disparity to zero). Measures of the center of symmetry of forced vergence fixation disparity curves, the fixation disparity, and the associated phoria allow analysis of tonic disturbances of vergence adaptation.

Generation of the Forced Vergence Fixation Disparity Curve

Generating forced vergence curves requires measurement of fixation disparity as prism or lenses are interposed. The results, plotted graphically, constitute the forced vergence curve. Fixation disparity tests can be performed at distance and near and in all positions of gaze. The basic technique is similar for distance or near measurements regardless of the instrument used.

AVAILABLE INSTRUMENTATION

Associated Phoria Measurement

Vertical and horizontal associated phoria can be measured at distance and near, neutralizing any reported misalignment of the lines with appropriate prism, using the instruments listed in Table 15.1.

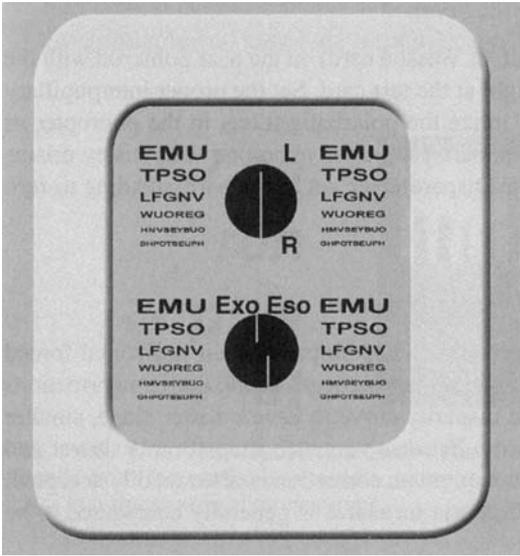
Fixation Disparity Curve and Associated Phoria Measurement

Vertical and horizontal fixation disparity curves and associated phoria can be measured at distance and near using several instruments. For distance, there is the Woolf card;^a for near, the Disparometer^b and the Wesson card.^c The Wesson card is the most commonly used instrument for clinical measurement of fixation disparity curve parameters. The most affordable readily available clinical instrument is the Wesson card.

The Disparometer consists of two 1.5-degree circular targets, each containing two oppositely polarized lines (Fig. 15.4). The circle provides the fusion lock. The upper circle is used for vertical fixation disparity measurement; the left line is seen by the left eye. The lower circle allows analysis of horizontal deviations; the lower line is seen by the left eye. The letters surrounding the circles help provide accurate, stable accommodation, and modification of the instrument using thin strips of black tape on the plastic protector over sections of the nonius lines (Fig. 15.5) further aids in keeping accommodation at the plane

TABLE 15.1 INSTRUMENTS FOR MEASURING ASSOCIATED PHORIA

Instrument	Available From
Distance	
Mallett unit	Bernell Corporation
American Optical vectographic chart	American Optical Company
Bernell lantern	Bernell Corporation
Near	
American Optical near vectographic cards	American Optical Company
Borish card	Stereo Optical Co., Inc.
Mallett near unit	Bernell Corporation



■ **Figure 15.4** The Disparometer consists of two 1.5-degree circular targets, each containing two oppositely polarized lines. The circle provides the fusion lock. The upper circle is used for vertical fixation disparity measurements; the left line is seen by the left eye. The lower circle allows analysis of horizontal deviations; the lower line is seen by the left eye. A wheel with a knob at the back can be rotated to present various vernier offsets. The patient's task is to judge which of the pairs of vernier lines is vertically aligned.



■ **Figure 15.5** The letters surrounding the circles help provide accurate stable accommodation and modification of the instrument. Using thin strips of black tape on the plastic protector (over sections of the nonius lines) further aids in keeping accommodation at the plane of regard. (From Schor CM. The influence of rapid prism adaptation upon fixation disparity. *Vision Res* 1979;19:757–765, with permission.)

of regard (14). Suppression is evident when there is disappearance of an entire line. To generate forced vergence fixation disparity curves at 40 cm using the Disparometer or Woolf or Wesson cards, use the following steps (pages 441–446) (3).

PHOROPTER SETUP

Place the test instrument (Disparometer, Woolf card, or Wesson card) on the near point rod with the target plane at 40 cm, and aim the overhead light at the test card. Set the proper interpupillary distance and desired lens correction. Utilize the polarizing filters in the phoropter or have the patient wear polarizers. Position the patient behind the phoropter with Risley prisms set at zero in front of each eye. When using the Disparometer, set the disparity reading to zero with the knob on the back of the instrument.

VERTICAL ASSOCIATED PHORIA

Patients with vertical vergence anomalies often show steep slopes of their horizontal forced vergence fixation disparity curves (19). For some of these patients, vertical prism corrections can cause the lateral forced vergence fixation disparity curve to have a flatter slope, smaller associated phoria, and smaller fixation disparity. Because vergence adaptation is slower and often incomplete for vertical vergence (20), vertical prism correction is often readily accepted. Prism correction based on vertical associated phoria measures is generally considered to be the treatment of choice (21). See Chapter 14 for a more complete description of the technique to assess the vertical associated phoria.

When vertical and lateral deviations are both present, we recommend evaluation and correction of any existing vertical deviation before corrective measures are instituted for the lateral deviation (19). When vertical prism is indicated, place it in front of the appropriate eye. When more than 2 Δ of vertical prism is needed, use equal amounts of prism in front of each eye. Loose vertical prisms may be taped on the phoropter at the front of the lens well, Fresnel prism can be used, or the patient can wear the correct prism in eyewear or a trial frame. It is often desirable to make lateral fixation disparity measurements with and without any indicated vertical prism correction to analyze the value of an indicated vertical correction (19).

HORIZONTAL FIXATION DISPARITY CURVE

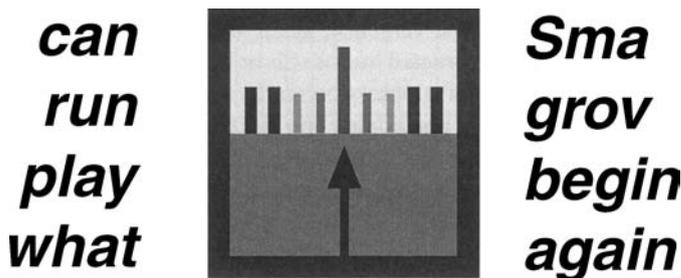
Measurement

Return the Risley prisms to the horizontal position and zero them in front of each eye. When using the Woolf or Wesson cards, the amount and direction of disparity is read directly from the card (Fig. 15.6). For example, when the patient reports that the top arrow is to the left, there is a right exofixation disparity.

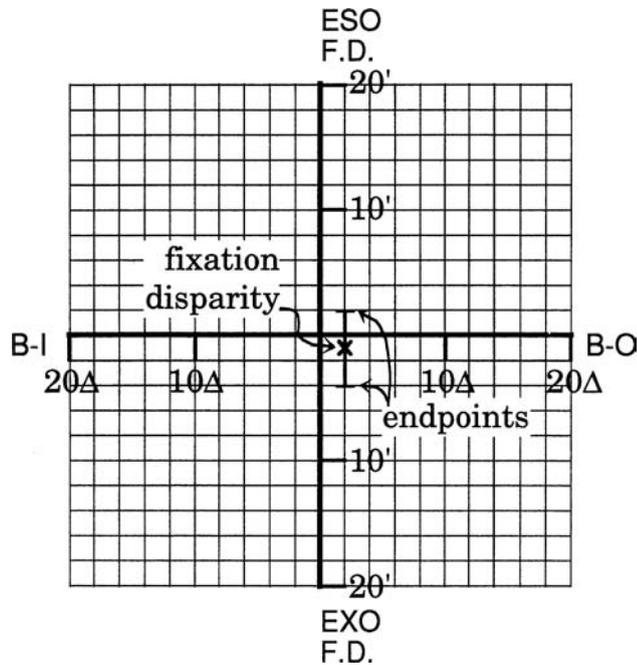
When using the Disparometer to measure fixation disparity parameters, use the knob at the rear of the Disparometer and offset the vertically oriented nonius lines to approximately 10 seconds exodisparity. Have the patient report the relative placement of the upper line. If it appears to the right, reduce the exodisparity in 2-second steps until alignment is reported. Note the disparity in the window and continue to reduce the exo (or increase eso) until misalignment is noted in the opposite direction. Measurements should be made within 15 seconds to minimize vergence (prism) adaptation (22). The actual fixation disparity measurement is the midpoint of the range between reported alignment in one direction and reported alignment in the other.

Example 15.1

The patient reports that the lines are misaligned to the left when the lines are set at 10 seconds exodisparity. When the exodisparity is reduced in 2-second steps, misalignment is still reported at 4 seconds, and the first reported alignment occurs at 2 seconds of exodisparity. The disparity is continually reduced in 2-second steps, and the first reported eso misalignment occurs at 4 seconds of esodisparity. This point represents the other end of the range. Figure 15.7 indicates these endpoints with horizontal lines. The midpoint of the limits (marked with an "X") is a 1-second esodisparity, which represents the actual fixation disparity.



■ **Figure 15.6** When the Wesson cards are used, the amount and direction of disparity are read directly from the card. For example, when the patient reports that the top arrow is to the left, there is a right exofixation disparity.



■ **Figure 15.7** If misalignment is still reported at 4 seconds and the first reported alignment occurs at 2 seconds of exodisparity, this point is marked on the graph as one end of the range. The disparity is reduced in 2-second steps, and the first reported eso misalignment occurs at 4 seconds of esodisparity. This point represents the other end of the range. These endpoints are plotted with horizontal lines, and the midpoint of the limits (marked with an "X") represents the actual fixation disparity.

Introduce prism with Risley prisms to measure binocular responses at other vergence demands. When the test is conducted at 40 cm, vergence demand is introduced in 3 Δ steps, first placing 3 Δ base-in before the dominant eye and subsequently alternating base-in and base-out. When testing at 6 m, the vergence demand is introduced in 2 Δ steps for base-in vergence and 3 Δ steps for base-out vergence, again alternating base-in and base-out prism demands. The patient should be instructed to close the eyes for approximately 15 seconds between measurements. Diplopia or suppression marks the endpoint of the curve. When there is instability, it often helps to cover one nonius line and briefly expose ("flash") it periodically during each setting until the patient reports alignment.

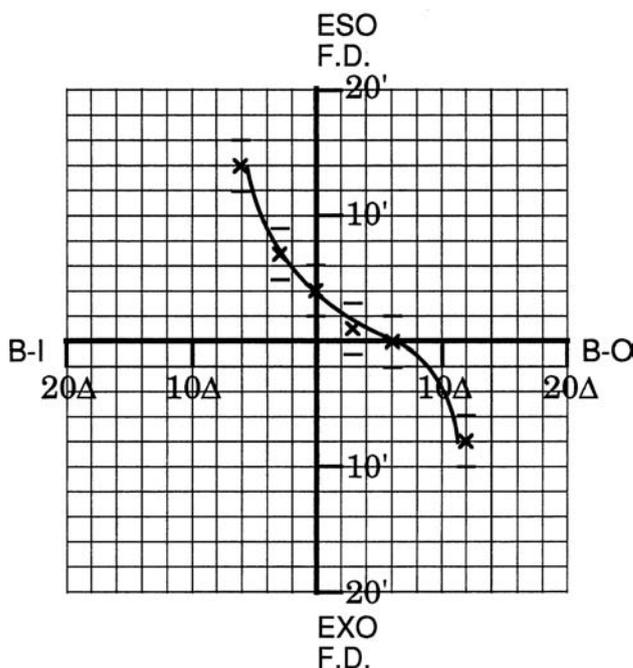
Often there will be diplopia for base-in vergence when the patient can still fuse base-out vergence demands. In addition, if vergence demands are always given in the same direction, the curve shape may be artificially altered because of prism adaptation (14). If diplopia occurs prematurely, vergence demands are alternated between the appropriate base-out demand and a base-in demand that the patient can just fuse. The base-out demands are graphed, and the last base-in demand to be graphed is the one before fusion was lost. This measurement technique is used to give alternating vergence demands and helps to maintain the curve shape. After all measurements are complete, the results are graphed.

Measurement in Free Space

Free space measurements permit the clinician to test in different positions of gaze, especially downgaze, using a prism bar before one eye. This is generally acceptable, despite the asymmetric vergence demand. The position of gaze and distance tested are recorded, along with a notation of the correction worn. When free space curves are measured, frequently a modified curve can be generated.

Modified Curve Generation

Measurements are made at zero demand and then alternated between 3 Δ base-out and base-in and then 6 Δ base-out and base-in. A prism bar or prism flippers may be used for convenience. When time is limited during a binocular vision analysis, the modified curve can also be generated through the phoropter using



■ **Figure 15.8** A modified curve can be generated through the phoropter, using vergence demands of zero, 3 Δ base-in and base-out, 6 Δ base-in and base-out, and 12 Δ base-out. These measurements allow rapid determination of the basic curve shape (type I), fixation disparity (4 minutes arc eso), associated phoria (6 Δ base-out), and slope.

vergence demands of zero, 3 Δ base-in and base-out, 6 Δ base-in and base-out, and 12 Δ base-out. These measurements will allow rapid determination of the basic curve shape, fixation disparity, associated phoria, and slope. Clinical experience indicates that these parameters are frequently all that are required to design an appropriate prism correction.

Example 15.2

Figure 15.8 documents the modified curve generated using vergence demands of zero, 3 Δ base-in and base-out, 6 Δ base-in and base-out, and 12 Δ base-out. As seen on the graph, these measurements allow determination of the curve shape, fixation disparity, associated phoria, and slope.

LENS-GENERATED FIXATION DISPARITY CURVES

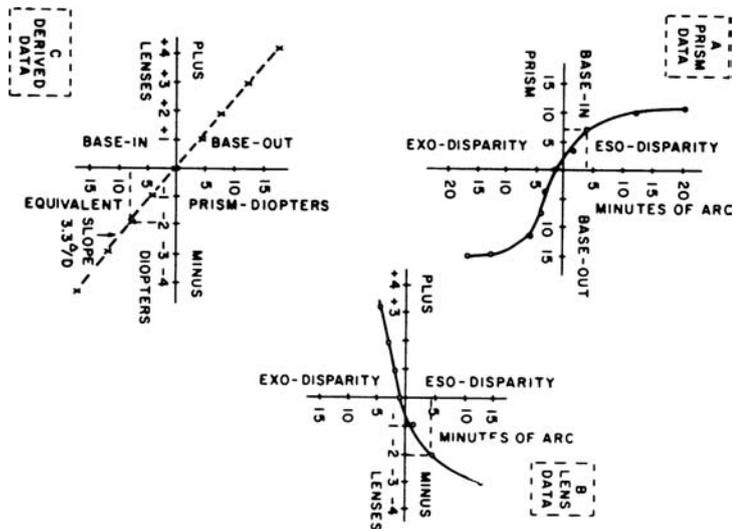
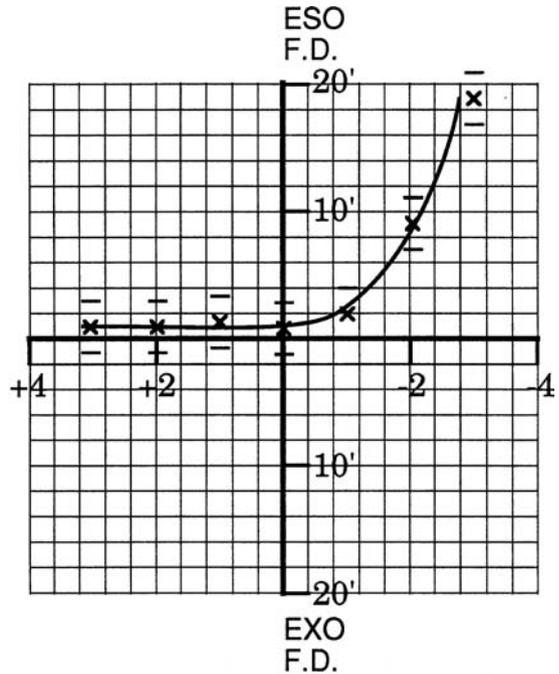
Changes in lens power can also alter fixation disparity responses. Graphical representation allows generation of the lens fixation disparity curve (Fig. 15.9) (6). Plus power is recorded on the left side of the y-axis and minus on the right, using 0.50 D to 1.00 D steps. First make measurements through plus, then through minus, in the approximate range of +2.00 to 3.00 D or the individual patient's limit.

The lens-generated fixation disparity curve can be combined with the prism curve to yield a binocularly derived AC/A ratio (Fig. 15.10) (6,23). This binocularly derived AC/A ratio includes interactions of convergence accommodation (CA/C) and may help direct more accurate prescription of near additions for presbyopic patients.

Graphing Findings

When graphing forced vergence fixation disparity findings, eso is above the horizontal and exo is below; base-out is to the right, and base-in is to the left. Using graph paper designed for fixation disparity curves, mark the midpoint of the interval where the patient reported alignment on the y-axis with an "X" or a dot and

■ **Figure 15.9** Plotting the change in fixation disparity against the change in lens power of 0.50–1.00 D allows representation of the lens fixation disparity curve.



■ **Figure 15.10** A binocularly derived AC/A ratio can be determined by combining the lens-generated fixation disparity curve data with the prism curve data. This binocularly derived AC/A ratio includes interactions of convergence accommodation and helps direct more accurate prescription of near additions for pre-presbyopic patients.

mark the interval ranges with horizontal slashes (refer to Fig. 15.8). Make sure to note the interval ranges, because they may change with training. Record the y-intercept, x-intercept, and slope on the top of the record. The y-intercept is the fixation disparity, whereas the x-intercept is the associated phoria measurement (prism required to reduce fixation disparity to zero). The slope is most frequently measured about the y-intercept (between 3 Δ base-in and 3 Δ base-out), because that is considered to reflect the vergence posture where the patient habitually functions. Measure and record the slope as the change in minutes of arc per 6 Δ (3 Δ base-in to 3 Δ base-out); see Example 2, Figure 15.8. The slope between the y- and x-intercepts may also be useful.

Interpretation

With a small amount of practice, forced vergence fixation disparity curves are easily interpreted. The major important parameters are the curve type, slope, fixation disparity, and associated phoria. All factors should be viewed together, rather than considering only one in isolation. For example, used by itself, the associated horizontal phoria may give little additional clinically useful information. However, when considered with other fixation disparity parameters, a great deal of useful patient care information is gained.

Clinical Usefulness for Prescribing

Forced vergence fixation disparity curves can be used to design prism prescriptions and modify spherical prescription power, and they are useful in monitoring the progress of vision therapy. The curves generally flatten as therapy is successfully completed. Usually there will be a small residual fixation disparity when the patient is tested with an instrument designed to measure fixation disparity (24).

PRISM CORRECTION DESIGN

Lateral Prism

A carefully designed prism correction reduces the need for corrective fusional movements and minimizes adverse interactions between convergence accommodation (25) and accommodative vergence. The area of most rapid adaptation to changing vergence stimuli is represented by the flattest portion (center of symmetry) of the fixation disparity curve. Prism is prescribed to move the center of symmetry toward, or more nearly centered about, the y -axis.

Example 15.3

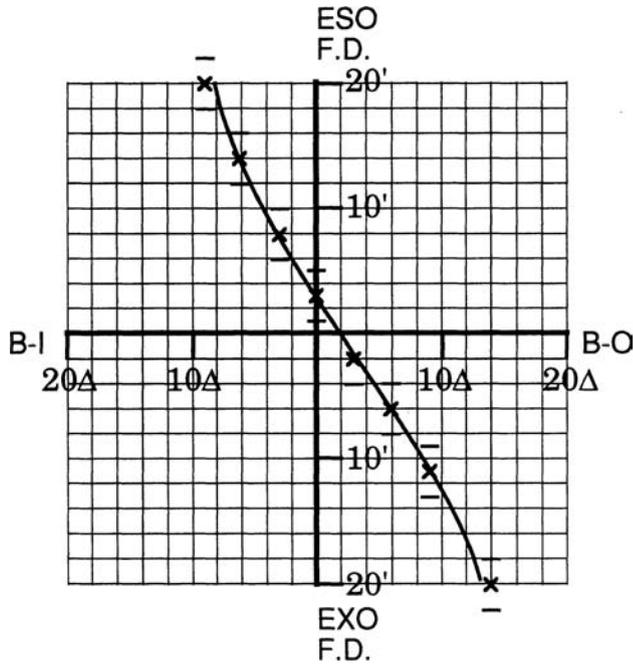
The fixation disparity curve shown in Figure 15.11 has a relatively steep slope, and the patient demonstrates a comparatively narrow range of fusion, as documented by the diplopia endpoints of the curve at 9 Δ base-in and 12 Δ base-out. Patients who demonstrate this type of pattern are typically esophores who benefit from prescription of prism that locates the center of symmetry about the y -axis. The patient depicted in Figure 15.11 was prescribed 2 Δ base-out for distance vision, which eliminated his symptoms of discomfort while driving and watching television. Calculation of Sheard's criterion for the same patient suggested a need for substantially more prism (5 Δ base-out).

When the forced vergence fixation disparity curve has a large flat slope, there is rapid vergence adaptation over a large area of vergence stress. Prism can be prescribed to shift the curve so that the flat (vergence adaptation) portion begins as close as possible to the y -axis. This allows the patient to maintain binocular vision in the area of maximum vergence adaptation, minimizing the amount of prism required. The prism prescribed is the minimum amount of base-out prism (for eso-fixation disparity/associated phoria) or base-in (for exofixation disparity/associated phoria) that allows the flat portion of the curve to first cross the y -axis.

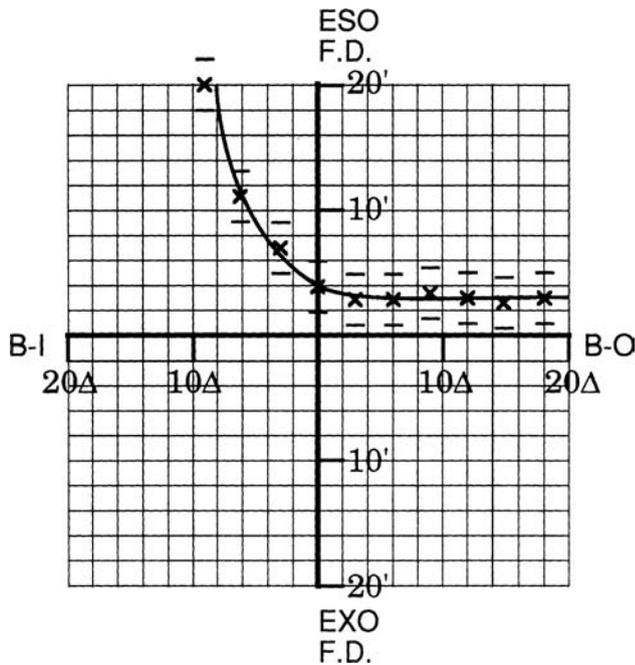
Example 15.4

The fixation disparity curve in Figure 15.12 has a large flat area, and the patient demonstrates a wide range of fusion from 9 Δ base-in to 30 Δ base-out. Often there is no center of symmetry for these patients. Patients who demonstrate this type of pattern are typically esophores. They are often made more comfortable by prescription of prism that shifts the curve so that the flat portion begins as closely as possible to the y -axis. The patient depicted in Figure 15.12 was prescribed 2.5 Δ base-out for distance vision, which eliminated his symptoms of occasional diplopia while playing tennis. Calculation of Sheard's criterion for the same patient suggested a need for 7 Δ base-out.

When patients have a steep curve, there is very little vergence adaptation and often no center of symmetry. Prism can be prescribed to reduce the fixation disparity to zero (associated phoria), or vision therapy can be prescribed to develop increased vergence adaptation. Complete correction of the associated phoria of patients with steeply sloped fixation disparity curves simplifies correction of binocular disorders and reduces the need to consider often complex CA/C and AC/A interactions (3,25).



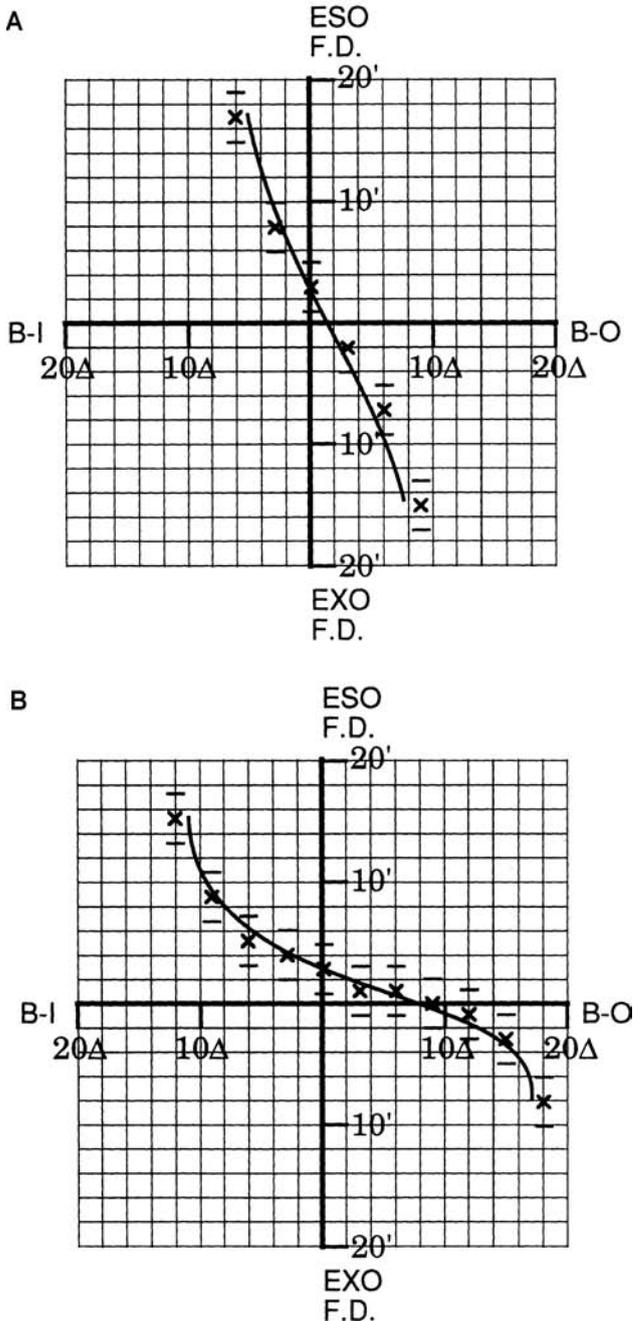
■ **Figure 15.11** The fixation disparity curve shows a relatively steep slope and a comparatively narrow range of fusion, as documented by the diplopia endpoints of the curve at 9 Δ base-in and 12 Δ base-out. Prescription of 2 Δ base-out for distance vision will locate the center of symmetry about the y-axis.



■ **Figure 15.12** The fixation disparity curve shows a large flat area and a wide range of fusion from 9 Δ base-in and 20 Δ base-out, with no center of symmetry. Prescription of 2.5 Δ base-out for distance vision shifts the curve so that the flat portion begins as closely as possible to the y-axis.

Example 15.5

The fixation disparity curve in Figure 15.13A has a steep slope, and the patient demonstrates a narrow range of fusion from 6 Δ base-in to 9 Δ base-out. There is no center of symmetry because there is no obvious



■ **Figure 15.13** **A:** The fixation disparity curve has a steep slope, and the patient demonstrates a narrow range of fusion from 6 Δ base-in to 9 Δ base-out. There is no center of symmetry because there is no obvious vergence adaptation. **B:** Vision therapy (which was prescribed for this patient to minimize suppression, expand fusional ranges, and enhance vergence accuracy) successfully eliminated the patient's symptoms of reading distress. Although the fixation disparity remained the same, there was a flattening and expansion of the flat portion of the fixation disparity curve.

vergence adaptation. Patients who demonstrate this type of pattern may be more comfortable after prescription of prism that shifts the curve so that the associated phoria is corrected; 2 Δ base-out was prescribed for this patient. However, it is generally superior management to prescribe vision therapy to develop more complete vergence adaptation. Vision therapy (which was prescribed for this patient to minimize suppression, expand fusional ranges, and enhance vergence accuracy) successfully eliminated the patient's symptoms of reading distress. His fixation disparity curve after therapy is shown in Figure 15.13B.

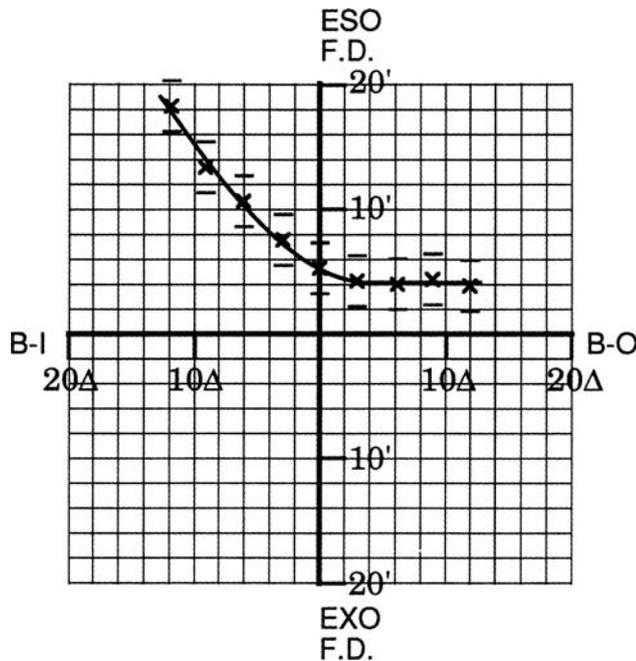
Figure 15.14 shows the distance fixation disparity curve of a myopic pre-presbyopic patient with a large distance esophoria and a small near esophoria (divergence insufficiency). This type II curve does not cross the x-axis, which is typical for patients with large esophorias. Generally, prism prescriptions for patients who have this curve type should contain enough power so that the flat portion of the curve starts before the x-axis. For example, contrast this with the discussion of the patient portrayed in Example 15.4.

Figure 15.15 shows a near fixation disparity curve for a patient with an equal esophoria at distance and near. This steep curve has essentially no central flat portion. There is a small associated esophoria. When there is a steep curve, prism that reduces fixation disparity to zero (associated phoria) provides the smallest prism correction that gives relief of symptoms. For this patient, 2 Δ base-out will move the associated phoria to the zero point and should eliminate symptoms. Comparing this curve with the curve for the divergence insufficiency patient (Fig. 15.14) illustrates the errors that can arise when only the associated phoria is used to determine prism corrections. Frequently, an indicated prism correction may not be appropriate when there is a type II or type III forced vergence fixation disparity curve that does not cross the y-axis. In general, vision therapy should be the initial therapy for these patients, with supplemental prism as needed.

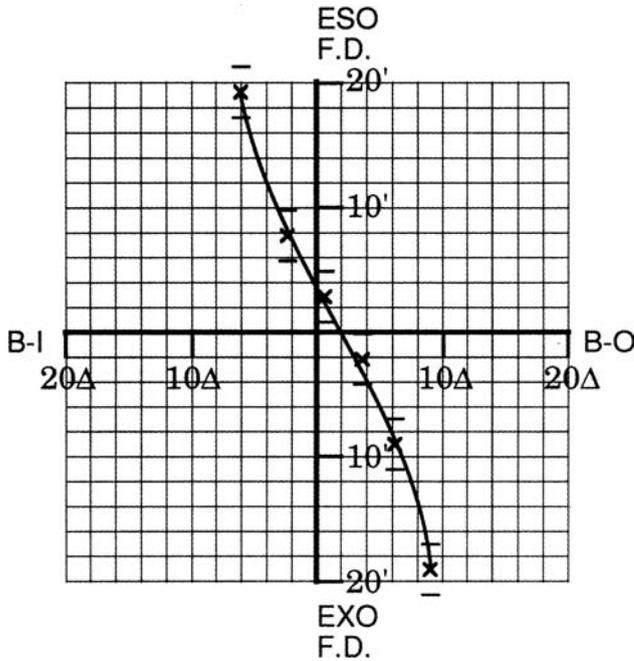
Vertical Prism

Proper management of lateral heterophorias often requires decisions as to whether or not a coexisting vertical heterophoria requires correction. Prism prescription design for vertical heterophoria requires clinical judgment, using any of the various techniques that have been recommended for prescription design: equating vergence ranges, flip prism techniques (26), and fixation disparity (27).

For patients who give accurate responses, tests based on vertical fixation disparity measurements and reducing the vertical fixation disparity to zero are the techniques of choice for vertical prism prescription design. Vertical associated phoria tests indicate the vertical prism required. Nearly all patients will notice a difference of 0.5 Δ on vertical fixation disparity testing (27), and most symptomatic patients with vertical



■ **Figure 15.14** This type II distance fixation disparity curve of a patient with a large distance esophoria does not cross the x-axis. Generally, prism prescriptions for patients who have this curve type should contain enough power so that the flat portion of the curve starts before the x-axis, about 3 Δ base-out for this patient.



■ **Figure 15.15** A near fixation disparity curve is shown for a patient with an equal esophoria at distance and near. This steep curve has essentially no central flat portion. There is a small associated esophoria. For this patient, 2 Δ base-out will move the associated phoria to the zero point.

associated phoria measurements of 0.75 Δ or more benefit from vertical prism corrections or vertical vergence therapy. Refer to Chapter 14 for a more complete description of the decision processes involved in determining the amount of vertical prism to prescribe.

Sphere Modification

NEAR ADDITION DETERMINATION

Therapy techniques for most binocular disturbances are based on the application of lenses, prisms, vision therapy, or a combination of these. For example, near plus additions are frequently helpful during management of patients with vergence or accommodative anomalies or both. For symptomatic esophoric patients, an approximate near addition is often easily determined by finding the plus lens addition that reduces an existing eso-fixation disparity to zero. If desired, forced vergence prism curves can be determined through the tentative near addition to verify the efficacy.

Example 15.6

A patient has orthophoria at 6 m and a 6 Δ esophoria at 40 cm, measured with prism dissociation. An eso-associated phoria is measured at 40 cm through the distance refractive correction. To determine a near addition power with fixation disparity testing, plus lenses are added in +0.25 D steps over the distance refractive correction until the patient reports alignment of the nonius lines (a zero associated phoria at near). The fixation disparity technique suggested a need for a near addition of +0.75. This prescription successfully eliminated the patient's symptoms of blur and tired eyes after 20 minutes of reading.

DISTANCE SPHERE MODIFICATION

For divergence excess patients younger than 15, minus power greater than the distance refractive findings may be combined with a near add and used to enhance fusion when an active vision therapy program is not feasible. Usually, only a small amount of additional minus power (a maximum of 1.00–1.50 D) is needed over the distance refractive findings. For selected patients, up to 3 D (or occasionally 4 D) of distance minus lens

overcorrection may be necessary. Because of the frequent symptoms of accommodative asthenopia, overcorrections of large magnitude should be used as an adjunct to vision therapy and should generally be reserved for part-time wear during therapy rather than full-time wear.

Before fixation disparity curves were used to measure binocular vergence responses to lens intervention, the amount of distance minus overcorrection had to be determined empirically. However, fixation disparity curves may be used to determine the amount of distance overcorrection to prescribe and to help determine the amount of the near addition. The amount used is just enough to facilitate convergence and fusion.

Example 15.7

Figure 15.16 A illustrates fixation disparity curves for a 10-year-old divergence excess patient. There is a type III curve; this is typical for patients with large exophorias. An exact associated exophoria cannot be determined for distance, although it is obviously exophoric. Figure 15.16B shows the response curves to added minus lens powers. Almost -2.00 D of minus lens power is required to allow the distance curve to cross the x -axis. Less than -1.00 D of added minus power causes the near curve to cross the x -axis. Thus, according to the data presented in these curves, if lens management alone is desired, a -2.00 D distance overcorrection is required. However, the -2.00 D distance overcorrection would create an eso-fixation disparity and eso-associated phoria at near. Consequently, if a distance minus overcorrection is used, a near addition of $+1.00$ to $+1.50$ D will be needed to allow both curves to cross the x -axis at about the same point.

PLANNING AND MONITORING VISION THERAPY PROGRAMS

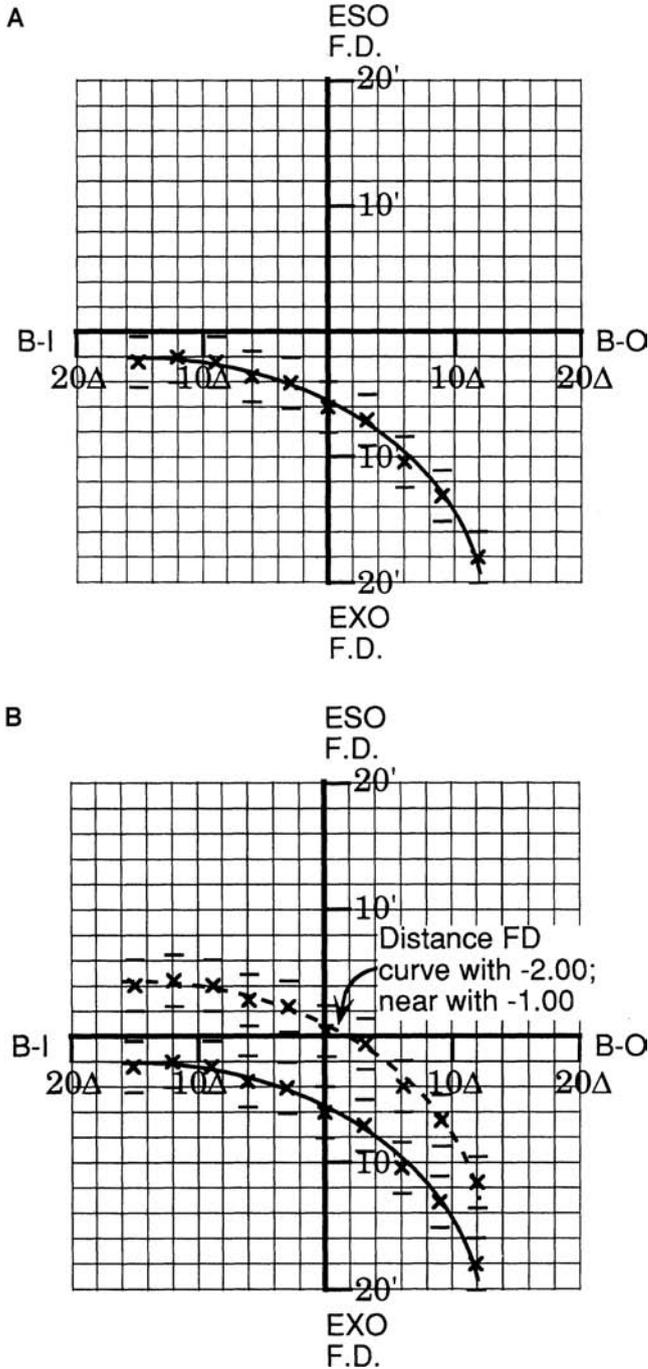
Using fixation disparity data (which include the effects of vergence adaptation ability, tonic vergence, and accommodation/convergence interactions), vision therapy programs can be modified so that training is specifically directed toward improving the deficient skill. Patients who have transient accommodative-based symptoms and high CA/C ratios respond best to vision therapy techniques that train rapid large magnitude responses to lenses (accommodative rock therapy) and incorporate a moderate amount of prism training (some jump vergence therapy). Patients with large heterophorias (tonic vergence disorders) respond best to vision therapy techniques that include rapid large vergence changes to prisms (primarily jump vergence therapy) and some lens therapy (accommodative rock therapy). Patients with reduced vergence adaptation (steep curves) require vision therapy that develops rapid sustained responses combined with some adaptive vergence training (isometric exercises) (28). Patients with both reduced vergence adaptation (steep slope) and abnormal CA/C and AC/A interactions are treated by adaptive vergence training (isometric exercises) and training that emphasizes rapid responses to moderate magnitude stimuli (jump and smooth vergence training plus accommodative rock).

Example 15.8

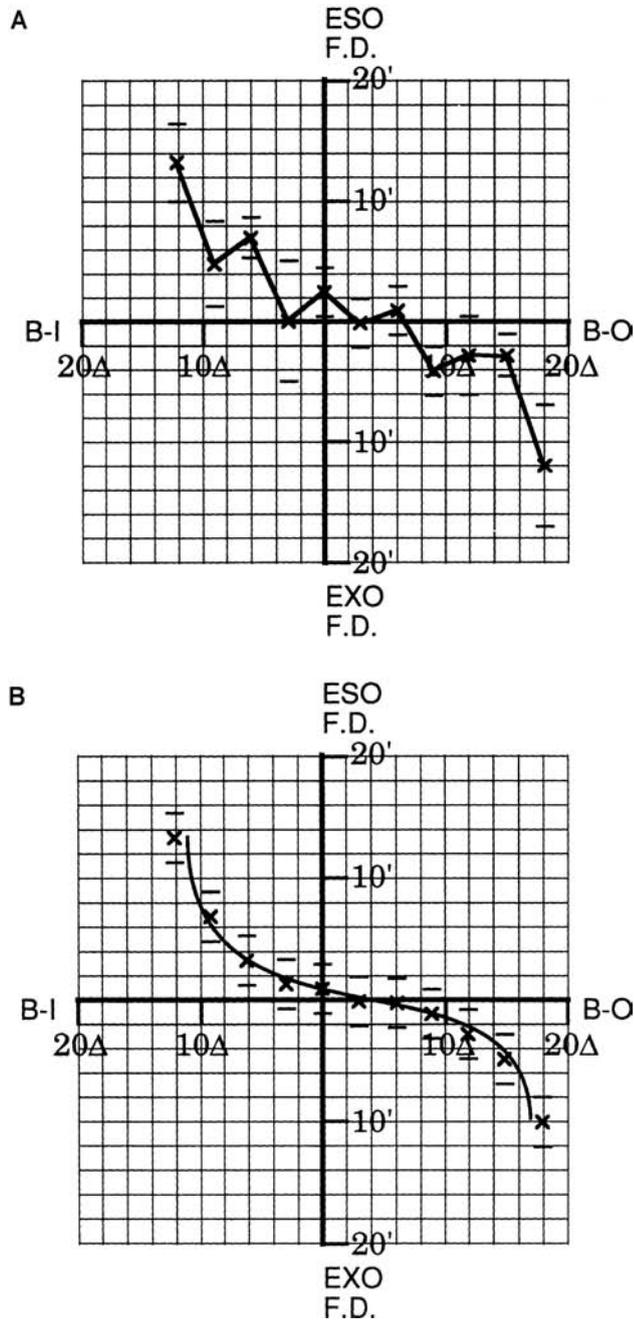
Figure 15.17 illustrates distance and near fixation disparity curves for a convergence insufficiency patient with associated accommodative problems. The near curve is irregular, with each measurement point having a large range where alignment was reported. Irregular curves with large ranges of alignment frequently result from accommodative inaccuracy that causes convergence problems. The patient inappropriately uses accommodation to assist convergence, and the result is a forced vergence fixation disparity curve that is irregular in shape, with large ranges of error for each measurement point. The near curve for the same patient after accommodative therapy is shown in Figure 15.17B. Each measurement point is more accurate (the curve is smoother), and there is a smaller fixation disparity (closer to the intercept). This illustrates an example of the use of fixation disparity curves to monitor the progress of vision therapy for a patient who underwent accommodative therapy. As therapy is successfully completed, the curves generally flatten and often smooth out. Usually a small fixation disparity remains when the patient is tested with an instrument designed to measure fixation disparity (24).

Example 15.9

Figure 15.18 illustrates distance (3 m) fixation disparity curves before (Fig. 15.18A) and after (Fig. 15.18B) therapy for an 18-year-old patient with a 16p.d. exophoria and associated fusion problems. The top pre-therapy curve (Fig. 15.18A) of this exophoric patient has an eso-associated phoria and eso-fixation disparity with a small range of fusion (diplopia with only 6BO). The patient inappropriately uses fusional vergence to maintain fusion, and the result is a fixation disparity curve that shows a paradoxical response (eso-fixation disparity with dissociated exophoria). The post-therapy curve for the same patient after fusional and accommodative therapy is shown



■ **Figure 15.16 A:** A 10-year-old divergence excess patient shows a type III curve; this is typical for patients with large exophorias. An exact associated exophoria cannot be determined for distance, although it is obviously exophoric. **B:** Almost 2.00 D of minus lens power is required to allow the distance curve to cross the x-axis. Only 1.00 D of added minus power causes the near curve to cross the x-axis. If lens management alone is desired, a 2.00 D distance overcorrection is required. However, the 2.00 D distance overcorrection would create an eso-fixation disparity and eso-associated phoria at near. Thus, if a distance minus overcorrection is used, a near addition of +1.00 to +1.50 D will be needed to allow both curves to cross the x-axis at about the same point.



■ **Figure 15.17 A:** The curve is irregular, with each measurement point having a large range where alignment was reported. Irregular curves with large ranges of alignment frequently result from accommodative inaccuracy that causes convergence problems. **B:** After accommodative therapy, each measurement point is more accurate (the curve is smoother) and there is a smaller fixation disparity (closer to the intercept). This illustrates an example of the use of fixation disparity curves to monitor the progress of vision therapy for a patient who underwent accommodative therapy.

in Figure 15.18B. Each measurement point is more accurate (the curve is smoother), the fusional range is much larger, and there is now a small exofixation disparity. This illustrates an example of the use of fixation disparity curves to monitor the progress of vision therapy for a patient who underwent fusional and accommodative therapy. As therapy is successfully completed, the curves generally normalize, although typically a small fixation disparity remains when the patient is tested with an instrument designed to measure fixation disparity (24).

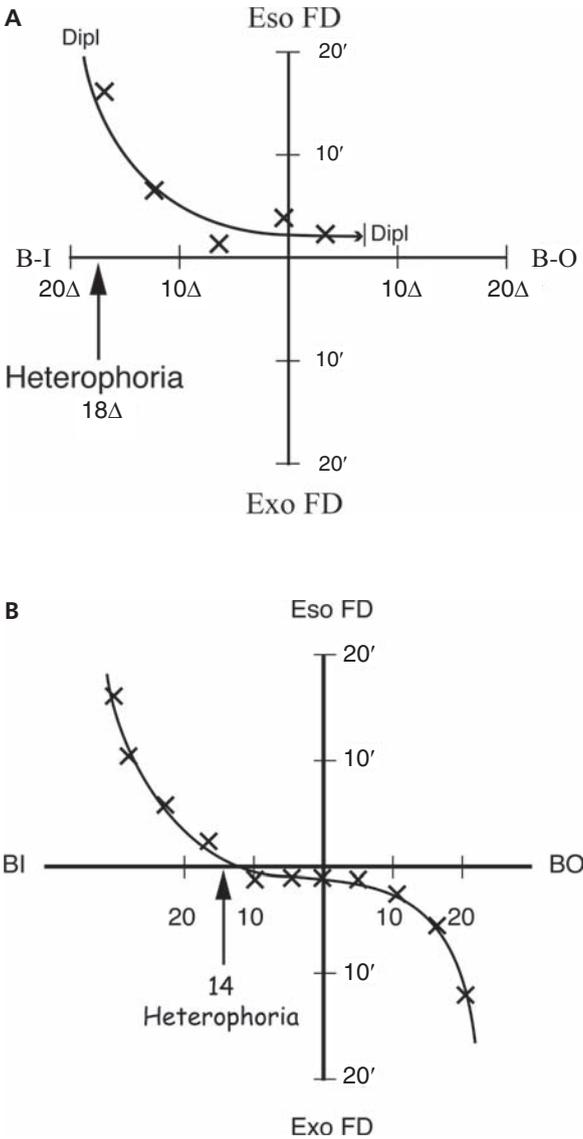


Figure 15.18 A: The top pre-therapy curve of this 18-year-old patient with a 16p.d. exophoria and associated fusion problems shows a paradoxical response (eso-fixation disparity with dissociated exophoria). **B:** In the post-therapy curve after fusional and accommodative therapy each measurement point is more accurate (the curve is smoother), the fusional range is much larger, and there is now a small exofixation disparity. This illustrates that as therapy is successfully completed, the curves generally normalize, although typically a small fixation disparity remains when the patient is tested with an instrument designed to measure fixation disparity (24).

Conclusion

There are many elaborate factors that combine, through a series of complex interactions, to result in single binocular vision. Many of these factors can be more appropriately analyzed using techniques that test under binocular conditions. Fixation disparity measures of ocular alignment responses to vergence or accommodative stress provide a useful technique for accurate assessment of many of these factors. With fixation disparity testing, it is not necessary to assume that a measured latent neuromuscular bias (heterophoria) is operative under binocular conditions. Rather, residual misalignment can be directly measured, along with assessment of the ability to adjust to induced external vergence and accommodative demands.

With fixation disparity data, treatment techniques can be designed using lenses, prisms, or vision therapy. The effects on performance when the sphere power of the prescription has been modified to include plus additions for near and/or minus overcorrections for distance can be monitored. Prism therapy can be easily designed to be appropriate for distance and near, a task that is frequently difficult using conventional analysis techniques. Vision therapy progress can also be monitored using forced vergence fixation disparity curves.

Study Questions

1. Describe how the characteristics of the four types of horizontal fixation disparity curves relate to the type of phoria the patient has.
2. What factors might lead to a different type of horizontal fixation disparity curve at distance and near?
3. What is the difference between associated and dissociated phoria?
4. How do the concepts of center of symmetry, associated phoria, and fixation disparity influence prism prescription decisions?
5. Why can't determination of the fixation disparity curve be done at distance with the vectographic adult slide?
6. Why can the basic shape of a fixation disparity curve be determined with only six measures (6 Δ base-in and base-out, 3 Δ base-in and base-out, and zero)?
7. What changes might be expected in the shape of the forced vergence fixation disparity curve after vision therapy?
8. How can an AC/A ratio be determined with fixation disparity testing? Why might it be useful to differentiate the associated AC/A from the dissociated AC/A?
9. Why is it often difficult to determine the amount of base-out prism to prescribe based on associated phoria measures alone?
10. How little prism might be useful in the treatment of vertical phoria? How would you determine this amount in a patient with good binocular vision and no suppression?

SOURCES OF EQUIPMENT

- (a) Available from Bruce Wick, 13615 Bellaire Blvd, Houston, TX 77083.
- (b) Not currently commercially available; used instruments may be available from time to time.
- (c) Available from Michael Wesson, OD, University of Alabama, Birmingham, College of Optometry, University Station, Birmingham, AL.

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SECTION

IV

Advanced Diagnostic and Management Issues

Interactions between Accommodation and Vergence

Binocular vision dysfunctions occur because of excessive tonic vergence; abnormal interactions of vergence, proximal vergence, and accommodation (1); and/or deficient vergence (prism) adaptation (2). Analysis of tonic vergence disorders (3) and accommodation/vergence interactions (2) suggests that classic analysis techniques are often not sufficient. More than one analysis system has traditionally been used to determine whether existing binocular deficiencies are related to existing symptoms (4). Because of the deficiencies in current analysis techniques, we introduced integrative analysis in Chapter 2 of this book.

Although many areas remain to be fully explored, this chapter discusses binocular vision from a theoretical and practical clinical viewpoint to introduce the concepts behind integrative analysis. Effects of the magnitude of proximal vergence and the influence of the depth of focus of the eye, lag of accommodation, and tonic vergence are considered and related to a dual interactive model of accommodation and vergence. It discusses many of the tests of binocular function that are currently performed clinically and relates them to the model. In addition, it suggests new tests that may be used in the future to provide diagnostic information (e.g., measurement of the convergence accommodation to convergence [CA/C] ratio and/or proximal vergence).

Analysis Approaches

TRADITIONAL ANALYSIS TECHNIQUES

Three techniques have been used for analysis of examination data to determine whether vergence or accommodative deficiencies exist in sufficient magnitude to result in symptoms. The graphical method of analysis (5) emphasizes the role of the vergence system in the etiology of symptoms. The analytical method emphasizes the role of accommodation (6), and the normative method is not selective (7).

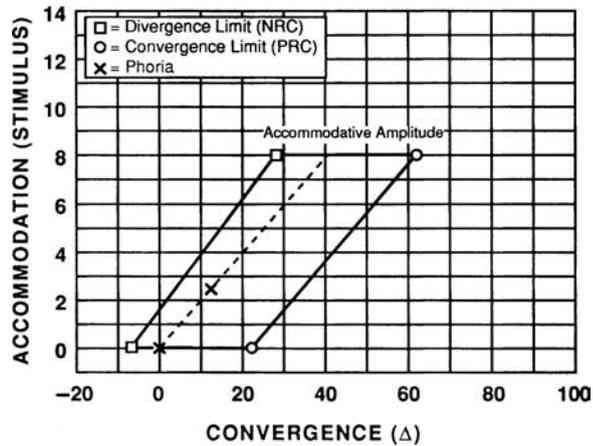
Graphical Analysis

Graphical analysis is based on the hierarchy of vergence mechanisms originally described by Maddox. Graphical analysis is designed to predict how tonic, accommodative, and fusional or disparity vergence (8) will result in the final eye position. Proximal vergence is generally not represented graphically (9). Conventional graphical analysis is based on the following:

- Distance dissociated heterophoria
- AC/A ratio
- Positive relative convergence
- Negative relative convergence
- Amplitude of accommodation

Using these parameters, the zone of clear single binocular vision is graphed (10) to visually represent the ranges of stimulus values through which the accommodative or vergence system or both can maintain binocular vision (Fig. 16.1).

The relationship of the heterophoria and AC/A ratio to relative vergence measurements is used to determine visual efficiency and, subsequently, to plan therapeutic intervention. In classic methods, the vertical lines of the zone are the reciprocal of the stimulus AC/A and represent the vergence limits of clear



■ **Figure 16.1** By using the parameters of distance dissociated heterophoria, AC/A, positive relative convergence, negative relative convergence, and amplitude of accommodation, the zone of clear single binocular vision is graphed to visually represent the ranges of stimulus values through which the accommodative or vergence system or both can maintain binocular vision.

single binocular vision (10). Proponents of graphical analysis imply that deficits or excesses of tonic and accommodative vergence are compensated by disparity (fusional) vergence, and that excessive demands on disparity (fusional) vergence cause asthenopic symptoms (11). Diagnostic criteria, such as those of Sheard (12) and Percival (13), have been adopted to determine lens or prism corrections that reduce the disparity (fusional) vergence demand in amounts needed to minimize symptoms. Unfortunately, using graphical analysis, it is sometimes difficult to identify the underlying problem when a purely accommodative dysfunction exists.

Analytical Analysis

The physiologic basis of analytical analysis is that faulty accommodation forces the visual system to compensate, resulting in development of a vergence dysfunction (14). The aspect of accommodation emphasized in this analysis is posture (lag). Aspects such as facility, sustaining ability, velocity, and amplitude are not typically considered. Further, nearly all anomalies (up to 95%) are given an accommodative basis, even when other causes often seem equally or, in some cases, even more likely.

Normative Analysis

Normative analysis involves determination of how individual test results (phorias, vergence and accommodative amplitudes, accommodation/vergence interactions) deviate from clinical norms (15). Normative analysis, which is most accurate when diagnosing a single problem, is not as accurate for diagnosis when there is excessive tonic vergence combined with abnormal vergence/accommodation interactions. Multiple interactions can be analyzed using a mechanistic approach (16) with partial success.

Key Concepts

The flaw with current systems that are used to analyze results of binocular visual function tests is that many important accommodation and vergence interactions can only be adequately evaluated under binocular conditions. For example, demands on disparity (fusional) vergence during binocular viewing may be dramatically different from predictions of stress on sensory and motor fusion based on measures of the dissociated heterophoria (17). Variations between results determined using monocular and binocular testing may be caused by two components neglected in the Maddox hierarchy—vergence (prism) adaptation (2) and CA/C ratio—and an additional one not usually considered in any analysis, proximal vergence.

DISSOCIATED VERSUS ASSOCIATED TESTING

Binocular testing provides a more complete picture of the interactions between binocular components than traditional systems that compare various monocular (dissociated) measures. The fixation disparity curve, measured at distance as well as near fixation distances, provides a binocular test that allows the clinician to determine a treatment that results in optimal binocularity. With the fixation disparity testing described in Chapter 15, residual misalignment can be directly determined; it is unnecessary to assume that a measured latent neuromuscular bias (heterophoria) also exists and causes symptoms noted during binocular viewing. These tests are useful clinically to determine prism prescriptions for patients who have eso- or hyperphorias and as a means to monitor vision therapy programs.

THEORETICAL INTERACTIONS

A previously published representation (18) of the interactions of accommodation and vergence is shown in Figure 16.2. The lower block diagram represents the components that describe vergence responses, and the upper section represents the accommodative system. The convergence and accommodative systems interact through separate crosslinks of CA/C and accommodative vergence. Because of these crosslinks, innervation to convergence drives accommodation through the CA/C, just as innervation to accommodation drives convergence through the AC/A. Proximal effects are input into each section of the system before the crosslinks.

The model in Figure 16.2 has significant implications for normal binocular vision, and we have considered these in developing the integrative analysis system (Chapter 2). In designing integrative analysis, we have incorporated implications about interactions between accommodation and convergence described by the model in Figure 16.2, tonic vergence, the depth of focus and lag of accommodation, and research implications concerning the influences of proximal vergence (19). Certain assumptions must be made about the model so that predictions about the accommodative and vergence systems can be made. For example, at this time, considerations are limited to static situations in which constant stimuli are held at a fixed position. This makes the potentially complex interactions somewhat less complicated. However, even with these limitations, the results apply to a large number of clinical and real-life situations.

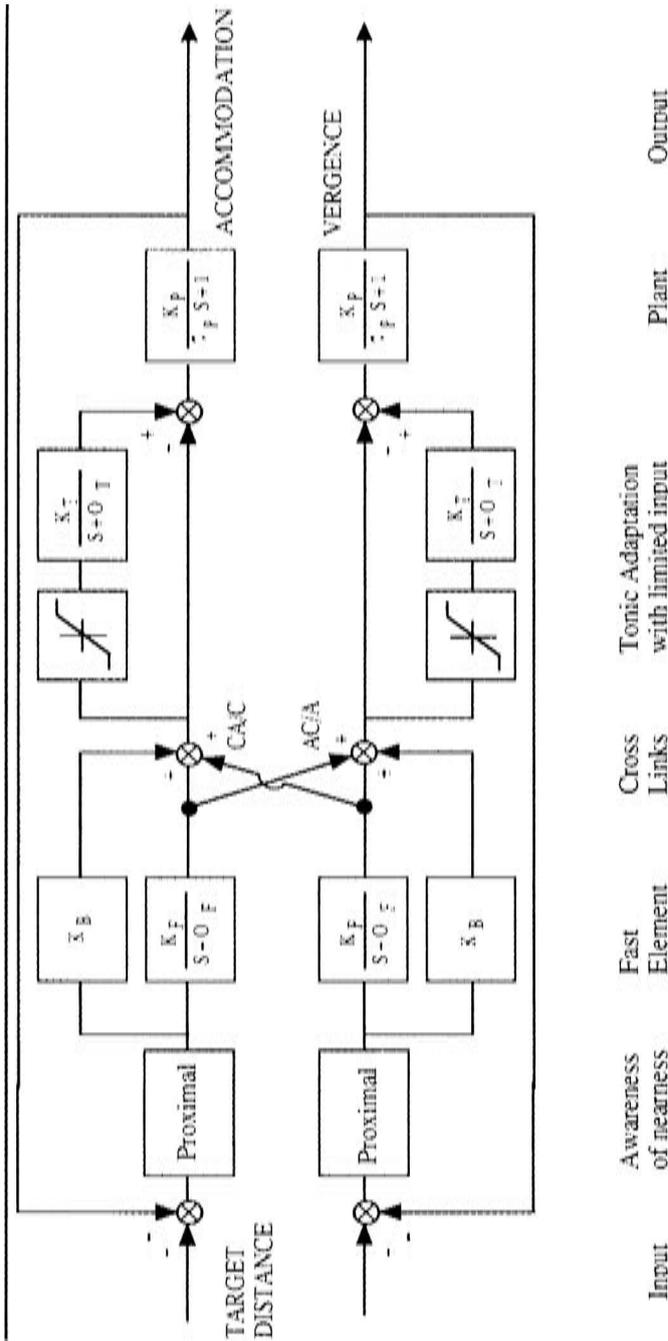
Application of the model to measurement of heterophorias, fixation disparity, associated phoria, and the zone of clear single binocular vision helps explain many binocular vision responses seen during clinical patient care, including why presbyopic patients are generally asymptomatic despite loss of accommodative vergence. The following sections describe how the model applies to many of the examination and diagnostic techniques we suggest in Chapter 1. Additionally, we discuss areas where further clinical research needs to be performed and how the model might direct such research.

Tonic Vergence

Tonic vergence represents the eye position that results in the absence of disparity, blur, and proximal stimuli. Tonic vergence can be measured directly by incorporating pinhole apertures during distance von Graefe phoria testing. The disparity and accommodative systems are open loop,¹ and proximal input is absent because fixation is at distance. Repeatable measures can be made because of the stable nature of tonic vergence.

Testing tonic vergence is typically not done in a clinical setting, and, for most patients, there is probably little need to add this testing. In normal adults, tonic vergence is only approximately 2 Δ more convergent than the distant phoria, and the distribution of tonic vergence is similar to the leptokertotic distribution of the distance phoria, where the peak is 1 Δ exo ±2. Thus, for normal adults, tonic vergence outside the range of 2 Δ exophoric or 1 Δ esophoric is abnormal. As will be seen in subsequent discussions, the model in Figure 16.2 suggests that significant tonic vergence has a major effect on interactions between accommodation and vergence (20). For patients who have large esophorias at distance, the assessment of tonic vergence may yield some useful diagnostic information. For example, a substantial difference between the distance

¹“Opening the loop” is done using any technique that eliminates feedback from either the vergence or accommodative system. For example, occlusion prevents fusion and opens the disparity loop because feedback about binocular eye alignment is prevented by the occluder. The vergence loop can also be opened by having the subject view a long horizontal line that has no fusion contours. In contrast, pinholes eliminate blur feedback and open the accommodative loop. Alternative methods of opening the accommodative loop are difference of Gaussian (DOG) targets or dim illumination, both of which render blur-driven accommodation ineffective.



■ **Figure 16.2** The lower block diagram represents the components that describe vergence responses, and the upper section represents the accommodative system. The vergence and accommodative systems interact through separate crosslinks of convergence accommodation (C/A/C) and accommodative vergence. Proximal effects are input into each section of the system before the crosslinks. Innervation to convergence drives accommodation through C/A/C, just as innervation to accommodation drives convergence through the A/C/A. (From Wick B, Currie D. Dynamic demonstration of proximal vergence and proximal accommodation. *Optom Vis Sci* 1991;68:163-167, with permission.)

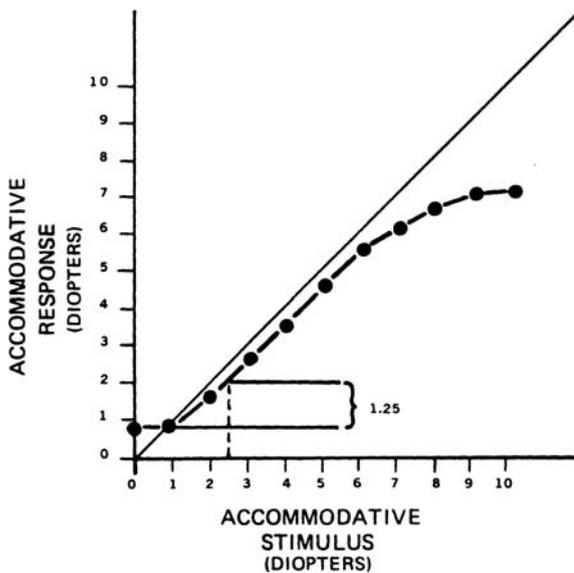
phoria and the tonic measure would suggest a need to increase the amount of base-out prism incorporated in the prescription.

DEPTH OF FOCUS AND LAG OF ACCOMMODATION

Determination of the role played by accommodation requires knowledge of the amount of accommodation (or accommodative effort) used (21). To maximally relax accommodation at distance, refraction is generally done to achieve best visual acuity with the maximum plus (or least minus) lenses possible. The maximum plus refraction places distant objects at the farthest focus point from the retina. Because of the refractive technique and the depth of focus of the eye, small accommodative stimuli do not affect accommodative activity (22) with distance fixation. As an object is moved closer, the blur circle moves through the limits of the depth of focus, and no change in accommodation occurs because no appreciable blur results until the object focus goes beyond the depth of focus of the eye.

Clinicians typically think in terms of the stimulus rather than the response to accommodation. However, the preceding discussion suggests that the accommodative response is generally significantly smaller than the stimulus. For approximately the first 0.75 D of accommodative stimulus, there is no accommodative change due to the refraction and the depth of focus of the eye (22). The distance depth of focus, combined with the normal lag of accommodation of 0.50 D or more when accommodating on near objects (23), causes only approximately 1.50 D of accommodative change when fixation is changed from distance to 40 cm (24) (Fig. 16.3). This is significantly less than the 2.5 D accommodative stimulus.

The average lag of accommodation is between 0.25 and 0.50 D for children and young adults. Determination of the accommodative lag is done routinely in clinics using monocular estimation method (MEM) retinoscopy. MEM retinoscopy is very useful for evaluating the accommodative response of patients who complain of near blur or other symptoms of accommodative dysfunction. A finding of a high lag of accommodation during MEM retinoscopy suggests a tentative power for a near addition or a need to prescribe accommodative therapy, or both. An excess of accommodation on MEM retinoscopy (lead of accommodation) directs treatment to techniques that maximally relax accommodation, such as the prescription of near plus additions, which reduce accommodative demand to zero, or vision training emphasizing plus acceptance, or both. Integrative analysis routinely includes MEM retinoscopy and thus incorporates many of the effects of accommodative lag and the depth of focus of the eye.



■ **Figure 16.3** The distance depth of focus combined with the normal lag of accommodation of 0.50 D or more when accommodating on near objects causes only approximately 1.50 D of accommodative change when fixation is changed from distance to 40 cm. (From Wick B. Clinical factors in proximal vergence. *Am J Optom Physiol Opt* 1985;62:119, with permission.)

Proximal Vergence

Proximal vergence contributes up to 70% of the vergence demand for near tasks (25) and is greater when measured under binocular conditions (24,26). Measurements of proximal vergence velocity using infrared limbal sensing have found that the mean peak velocities for proximal convergence and divergence (66 and 39 degrees per second, respectively) (27) are substantially faster than disparity vergence velocities of 14 and 10 degrees per second (28). The magnitude and velocity of proximal vergence responses suggest that this component is a major contributor to the total vergence response when looking from distance to near. Proximal effects are included as the initial entry in the vergence/accommodation interactive model shown in Figure 16.2.

Disparity vergence has been shown to have a shorter latency and more rapid course than accommodative vergence (29). As a result, most clinicians feel that disparity vergence initiates the near vergence response. However, there are a number of situations in which disparity cannot serve as the initiator of near vergence. For example, if a near object located such that it is seen by only one eye is to be fixated, an eye movement and a head movement will be required for bifoveal fixation. In this situation, knowledge of the object location and “awareness of nearness” (proximal vergence) probably provide the initial vergence and accommodative component. Another frequent situation involves copying from a blackboard in school. The images of the object are frequently located so far in the peripheral retina that disparity cues are not applicable (30) and, again, proximal vergence is more likely to be the initial vergence component. Because binocular proximal effects make up a large portion of the near demand (24), they can move the system within the ranges of foveal vision, where disparity vergence and blur-driven accommodation can fine-tune the response.

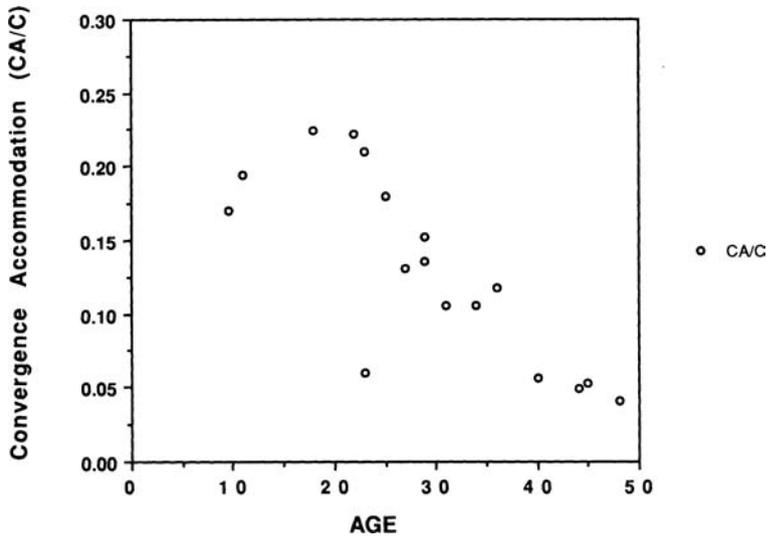
Proximal vergence can be measured clinically by incorporating pinholes (to eliminate accommodative vergence) and measuring the heterophoria at different distances using the von Graefe technique (to eliminate disparity vergence). Changes in the proximal stimulus are introduced using targets located at 2.0, 1.0, 0.5, and 0.25 m. The change in angle that is measured provides an estimate of proximal vergence. For an optimal stimulus to proximal vergence, the patient must be fully aware of the target location. This is accomplished by having the patient view the targets under natural viewing conditions before recording the measurements and by having him or her hold the target during the nearer measurements. Although these proximal measures are not currently used in routine clinical testing, they may provide useful information for clinical management. For example, in preliminary studies, deficient proximal vergence has been linked to the prolonged blur that some patients report after reading (31).

Binocular Vergence Interactions

The relationships considered in the preceding section become somewhat more complicated when considering interactions between vergence and accommodation. For example, consider the situation in which no output is needed from accommodation (such as when a pinhole is placed in front of the eyes to greatly increase the depth of field). This eliminates the effects of accommodative lag and depth of focus and reduces accommodation due to blur to zero. Thoughtful clinicians will recognize that accommodation due to blur is also zero in a common physical condition—absolute presbyopia when there is physiologically no accommodation. Analysis of the situation in which there is no blur-driven accommodation using the model described in Figure 16.2 helps explain why presbyopic patients are routinely asymptomatic when classic analysis systems frequently predict binocular distress (32). The effects of interactions between accommodation and vergence are often deleterious; presbyopia removes this interactive problem, and patients are commonly asymptomatic.

CONVERGENCE ACCOMMODATION

Measurement of the CA/C ratio provides information concerning the strength of the crosslink from the vergence system to accommodation. The model of Figure 16.2 shows why interactions between vergence and accommodation, via the CA/C ratio, complicate findings of classic graphical analysis. For example, suppose that vergence measures were made in a patient with a zero CA/C ratio (so that changes in vergence did not affect accommodation), while proximal vergence was held constant. Clinically, this measurement is called *relative vergence* or *vergence free of accommodation*. Under these conditions, graphical analysis techniques suggest that disparity vergence equals the dissociated phoria. However, except in presbyopia, the CA/C ratio is

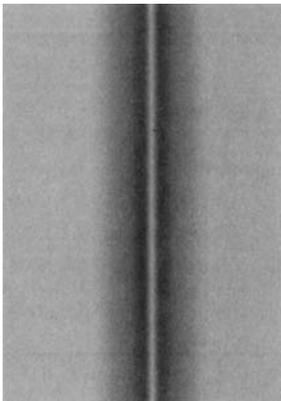


■ **Figure 16.4** The convergence accommodation (CA/C) ratio is inversely related to age. For young adults, the average CA/C ratio is about 0.5 D per meter angle (a meter angle [MA] is determined by dividing the interpupillary distance [IPD] by 10 and expressing the value in prism diopters). For clinical purposes, the average value is about 6 MA.

seldom zero, and changes in vergence are accompanied by changes in accommodation, forcing reflex accommodation to change to compensate for vergence accommodation. As a result, the relationship between the dissociated phoria and disparity vergence is not adequately predicted by classic methods of analysis.

Clinical research on the CA/C ratio indicates a linear relation, although as extremes of the vergence stimulus are reached, the range becomes nonlinear—possibly due, in part, to the decrease in pupil size and increased depth of focus that accompanies increased vergence (33). Because there is generally very little difference between the vergence stimulus and the vergence response, there is very little difference between the stimulus and the response CA/C ratios. For young adults, the CA/C ratio is about 0.5 D per meter angle (a meter angle [MA] is determined by dividing the interpupillary diameter [IPD], in millimeters, by 10 and expressing the value in prism diopters [see Chapter 1]); for clinical purposes, the average value of a meter angle is about 6 Δ . The CA/C ratio is inversely related to age (Fig. 16.4).

The CA/C ratio can be measured clinically using pinholes before each eye or using a “blur-free” grating target (DOG, or difference of Gaussian) (Fig. 16.5). These techniques open the accommodative system loop so that stimulation of accommodation by vergence is completely effective. The clinician who wishes to assess



■ **Figure 16.5** The CA/C ratio can be measured clinically using pinholes before each eye or using a “blur-free” grating target (DOG, or difference of Gaussian).

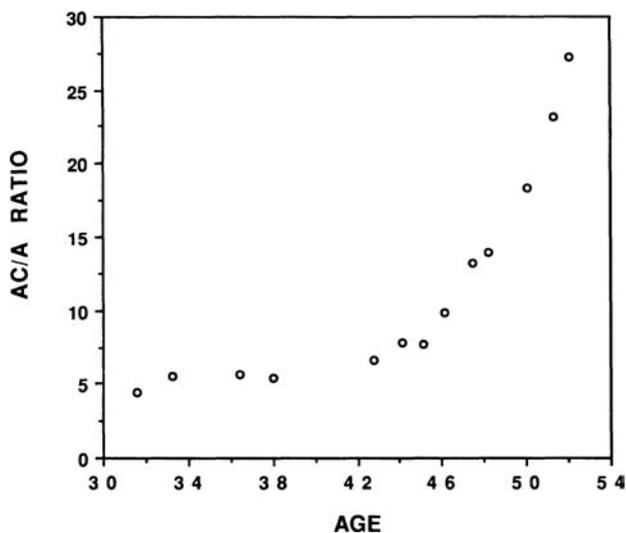
the CA/C ratio can use a Wesson DOG card (34) and perform MEM retinoscopy, with bifixation on the central bright target region, while the patient fuses disparity stimulation of 12 Δ base-in, 0 Δ , and 12 Δ base-out. The MEM findings can be determined at each vergence level, the change averaged (assuming linearity), and the CA/C ratio computed.

Although not yet commonly assessed clinically, measurement of the CA/C ratio has implications concerning the treatment of patients with greater exo at distance than at near (divergence excess exo-deviations). When the divergence excess patient converges to fuse at distance, there will usually be excess accommodation stimulated, due to CA/C. For divergence excess patients who cannot inhibit this extra accommodation, small amounts of added minus lens power, over and above the distance monocular subjective findings, may help maintain clear single binocular vision. This becomes less of a problem as the patient ages and the CA/C ratio decreases. This may explain why some intermittent exotropia patients have increased binocular skills with age, even though they have had no therapeutic intervention other than wearing a refractive correction (35).

AC/A RATIO

Measurement of the AC/A ratio, which provides insight into the relative strength of the crosslink from the accommodative system to vergence, is one of the most common clinical evaluations. In most clinical tests, the stimulus AC/A ratio is determined and the accommodative response is often simply assumed to equal the accommodative stimulus. However, the response AC/A ratio can be determined using MEM retinoscopy in the clinic or a research optometer in the laboratory, determining the change in both the vergence and the accommodative response. In normal patients, the response AC/A ratio is about 10% greater than the stimulus AC/A because the accommodative response is typically slightly less than the accommodative stimulus (23). In patients with abnormal binocular vision, such as those with divergence excess strabismus, this difference may be substantially greater. For young adults, the AC/A ratio is about 4.0 per diopter (36). The AC/A ratio remains about the same until the onset of presbyopia (37) (Fig. 16.6).

To measure the stimulus AC/A ratio, the disparity or fusional vergence system is made open loop, either by occlusion or introduction of a vertical dissociating prism before one eye. As described in Chapter 1, the stimulus to accommodation is altered in the fellow eye using negative lenses at a fixed near target distance (gradient technique) or by making the measurements at distance and near and calculating the AC/A ratio (calculated method).



■ **Figure 16.6** The AC/A ratio remains about the same until the onset of presbyopia. For young adults, the average AC/A ratio is about 4.0 per diopter. (From Eskridge JB. The AC/A ratio and age—a longitudinal study. *Am J Optom Physiol Opt* 1983;60:911–913, and Morgan MW. Clinical measurements of accommodation and vergence. *Am J Optom* 1944;21:301–313, with permission.)

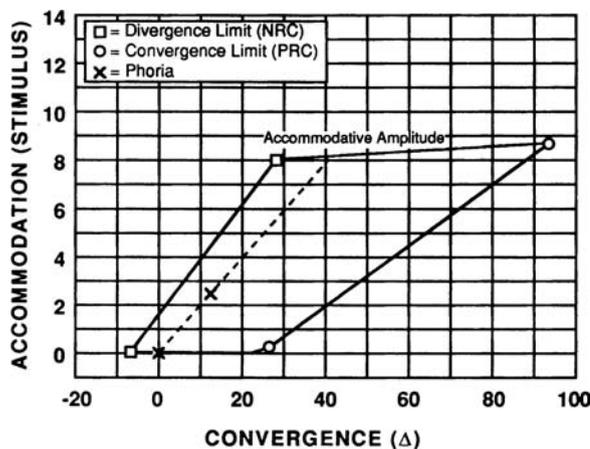
With the gradient technique, the patient is dissociated with prism, and a detailed target is provided to the fixating eye. The heterophoria is measured with the distance prescription and with an additional 1.00 and 2.00 D of minus lens power (see below). To determine the AC/A ratio, the accommodative convergence measured at each stimulus level can be averaged, since the AC/A ratio is generally linear. When measuring the AC/A ratio using the distance/near heterophoria method, a detailed target is presented at distance and then at near. The heterophoria is assessed at these two distances and the AC/A ratio is calculated as described in Chapter 1. With either technique, multiple measurements should be obtained at each stimulus level and averaged.

The AC/A ratio is routinely measured by virtually all clinicians. However, there are some important points that vision research has developed concerning measurement and use of the stimulus AC/A ratio. First, use of minus lenses is preferred when determining the AC/A ratio using the near gradient technique. Minus lenses stimulate within the linear region of the accommodative stimulus/response function (Fig. 16.3), making stimulation of accommodation more effective than relaxation for obtaining a realistic measure of blur-driven accommodation. Of course, measures can also be made to determine the effect of plus lenses on the near heterophoria, patient comfort, relative vergence, and accommodation ranges. Second, for diagnostic and management purposes, the calculated method, in which distance is used to alter the stimulus, is preferred over the gradient technique, in which lenses are used to alter the accommodative stimulus. The calculated method includes influences of proximal vergence in the measure and provides a more useful AC/A estimate, since proximal effects are present in all normal seeing conditions.

The AC/A ratio has a normal distribution (Fig. 16.7). When combined with the leptokertotic distribution of the distance phoria, the two measures (Fig. 16.7) can be used to roughly predict the numbers of patients who will be seen with any given distance and near phoria combination. Table 16.1 delineates these relations. The numbers suggest that there will be few patients with basic esophoria or exophoria, and relatively more will be seen who have convergence insufficiency and convergence excess. These predictions are similar to findings by Scheiman et al. (38) in grade school children and by Porcar and Nartinez-Palomera (39) in university students.

RELATIONSHIP BETWEEN CONVERGENCE ACCOMMODATION AND AC/A

In general, the interactive model in Figure 16.2 predicts that disparity vergence and accommodative vergence change in opposite directions when the stimulus to accommodation is held constant. When disparity vergence increases, accommodative vergence decreases. The reason for the reciprocal action can be traced to



■ **Figure 16.7** At the limits of fusion, the proximal-based interactive model predicts that the boundaries of the zone of clear single binocular vision should be two straight, but not parallel, lines. In contrast to Figure 16.1, the convergence side of the zone is more slanted than the divergence side, especially at maximal levels of accommodation, as more proximal vergence is introduced via increased “nearness.” In addition, the top of the zone is not parallel to the bottom, due to increased accommodation from convergence-driven accommodation.

TABLE 16.1 DELINEATION OF PHORIA PREDICTORS

Strabismus			Heterophoria								
			Low AC/A Ratio (16%)			Normal AC/A Ratio (68%)			High AC/A Ratio (16%)		
Esophoria	Exophoria		Tonic Vergence			Tonic Vergence			Tonic Vergence		
			Low (3%)	Normal (94%)	High (3%)	Low (3%)	Normal (94%)	High (3%)	Low (3%)	Normal (94%)	High (3%)
Expected per 100	3-	2+	1-	14	1-	2+	64	2+	1-	14	1-
Category			Convergence insufficiency		DI	BExo	Norm	BEso	DE	Convergence excess	

DI, divergence insufficiency; BExo, basic exo; BEso, basic eso; DE, divergence excess.

the negative feedback system. When the accommodative stimulus is constant, a change in vergence causes an opposite change in accommodation because of interactions between vergence and accommodation and the negative feedback loop in the accommodative system.

Disparity vergence and the dissociated heterophoria are influenced by the response AC/A and the response CA/C . Assuming that proximal vergence is held constant in the measurements, consider two situations:

1. When CA/C and AC/A are weakly related, the amount of disparity vergence required will be much larger than predicted from measures of the dissociated heterophoria. As an example, consider the situation of an exophoric patient when an occluder is removed from one eye. Initially, disparity vergence and increased proximal vergence with binocular viewing help bring the eyes to the appropriate binocular position. However, this change in vergence causes an increase in accommodation due to vergence accommodation, which means that reflex accommodation must be changed to compensate if clear vision is to be maintained, since the accommodative stimulus remains constant. This, in turn, decreases accommodative vergence, and more accommodative vergence is required. Consequently, except for the fact that proximal vergence is larger under binocular conditions as a partial compensation, the final amount of the disparity vergence would be larger than predicted from measures of the dissociated heterophoria.
2. When the AC/A and CA/C are strongly related, the disparity vergence used may, in fact, be in a direction opposite to the dissociated heterophoria. To understand this, consider another exophoric patient. Suppose that to regain fusion after an occluder is removed, proximal vergence increases under binocular conditions and disparity vergence converges the eyes to enable fusion to be regained. Just as in the previous case, accommodation is stimulated and reflex accommodation must be inhibited. However, the effect of accommodative interactions may be larger than disparity vergence; consequently, the eyes may overconverge. When the eyes finally reach the target, disparity vergence must be in the opposite direction to the initial dissociated heterophoria. This prediction helps explain why near plus additions are clinically useful to improve binocular responses of some exophoric patients, contrary to classic predictions. The prediction also explains why eso-fixation disparity and eso-associated phoria are seen during clinical measurement of some exophoric patients (40).

The relationship between the CA/C and AC/A critically determines the binocular responses described above. When the ratio becomes about 1.00, the model suggests an unstable relationship and compromised binocularity (41). Clinically, this occurs most frequently in the presence of a high AC/A ratio, where the demands on fusional vergence are underestimated when predicted from monocular heterophoria measures. This may explain why full correction of the angle of strabismus with prism is frequently necessary in esotropia with normal correspondence before binocularity can be enhanced with vision therapy.

Clinical Testing

In the preceding sections, current research findings were discussed to clarify tonic, accommodative, and proximal vergence. In this section, the model and current research will be considered with respect to the typical examination done by many clinicians.

NEAR POINT OF CONVERGENCE

The far point of convergence is represented by the intersection of the lines of sight when the eyes are in a position of minimum convergence, usually within a few minutes of arc of infinity. Assessment of the near point of convergence stimulates accommodative, disparity, and proximal vergence maximally, and interactions of all of these are included in the ultimate result. In normal persons, the amplitude of convergence is approximately 120Δ (about 20 MA).

Repeated or sustained measures of the near point of convergence stimulate tonic vergence in some patients, evidenced by a transient convergent shift in the distance heterophoria. For patients who complain of transient blur or diplopia when shifting gaze from distance to near, sustained measures of the near point of convergence may help identify whether the accommodative or vergence system is at fault. If vergence is at fault, the model predicts that distance diplopia will occur without blur; whereas if the accommodative system is implicated, distance blur will occur either alone or with diplopia. This is consistent with observations that patients with intermittent vertical strabismus typically only report diplopia; no accommodative component is present in vertical strabismus.

RELATIVE FUSIONAL VERGENCE

During patient examinations, fusional vergence measurements are performed at distance and near using loose or rotary prisms in free space or through a phoropter, or both. Loose prism measurements, which are presented in discrete steps, provide a useful indication of fusional ranges as well as recovery ability. Rotary prism measurement of vergence ranges through the phoropter can frequently be eliminated from the test sequence when forced vergence fixation disparity curves are measured.

When testing fusional vergence, the vergence stimulus is gradually changed while the accommodative stimulus remains constant. To maintain target clarity, the model suggests that accommodation driven through the CA/C ratio must be inhibited. For example, assume that the patient bifixates a target. Introducing base-out prisms forces the eyes to increase convergence to maintain fusion. Concurrently, the accommodative response increases due to increased vergence accommodation, with the magnitude related to the CA/C ratio. Thus, vergence-driven accommodation increases and blur-driven accommodation must be inhibited to maintain clear vision. According to the model in Figure 16.2, the blur limit of the test is reached when blur-driven accommodation can no longer be inhibited. As disparity is increased beyond the blur limit, diplopia results when fusion is no longer possible.

Prism Flipper Testing

Prism flippers are related to relative vergence range testing. However, rather than gradually increasing disparity, the prism flipper introduces comparatively large disparity steps (e.g., 12Δ base-out and 6Δ base-in). During testing, there are changes in the vergence stimulus, vergence response, and accommodative response as described previously. However, the prism flipper is a dynamic test in which frequency of the change is assessed over time, allowing inferences regarding dynamic aspects of vision (e.g., copying from the blackboard). Additionally, the large disparity steps of the prism flipper may stress an abnormal vergence system more than the gradual changes in vergence demand used in the fusional vergence measurement. As a result, the prism flipper may have greater diagnostic capabilities for patients who complain of problems when changing fixation distances.

ACCOMMODATIVE VERGENCE

Because of the interactions between the accommodative and the vergence systems shown in Figure 16.2, the conclusions made when discussing the vergence system also relate to the accommodative system. When looking from distance to near, the convergence required to bifoveally fixate a target causes an amount of accommodation determined by the convergence demand and the CA/C ratio (due to the crosslinkage between the vergence and the accommodative systems). When the CA/C ratio has an “average” ($0.50 \text{ D/MA } 42$) magnitude, the amount of accommodation generated by convergence is about 1.25 D .² Because of the refractive technique, depth of focus of the eye, and lag of accommodation at near, the amount that accommodation

²Determined by multiplying convergence accommodation by the convergence demand: $0.50 \text{ D/} 6 \Delta \times 15 \Delta = 1.25 \text{ D}$.

changes when looking from distance to near is also approximately 1.25 to 1.50 D (Fig. 16.3). Thus, accommodation caused by convergence makes up a large portion of the accommodative response so that the system is within the ranges where blur-driven accommodation can fine-tune the response.

When the CA/C ratio is greater than 0.5 D/MA, as it frequently is for young (grade school aged) children (18), there may be more accommodation than needed for near tasks. This could require inhibition of the excess—possibly seen as a lead of accommodation if there is no inhibition, as accommodative instability, or as an excessively high lag at near if the excess accommodation is overinhibited. When excess accommodation is not appropriately inhibited, there could be a convergent shift after prolonged near work. These factors may partially explain the apparently accommodation-based asthenopic symptoms frequently seen in the school-aged group. The model in Figure 16.2 suggests that small amounts of plus at near would be beneficial as a preventive measure if prescribed prior to the development of accommodative excess. The plus lenses would counteract the adverse relationship of CA/C interactions with accommodation, allowing more accurate use of the lag of accommodation for clear near vision. Integrative analysis can be used to determine these relationships (Chapter 2).

ACCOMMODATIVE PARAMETERS: LAG AND DEPTH OF FOCUS

According to usual convention, accommodative response is considered to be zero when the refractive error is fully corrected and the retina is conjugate to optical infinity. However, the accommodative response must be considered with respect to actual clinical findings. The refractive technique, influenced by the depth of focus of the eye and tonic accommodation, allows a residual accommodative activity, and therefore the actual accommodative response is greater than the stimulus at distance (Fig. 16.3). Clinical measurements at near indicate that the typical lag of accommodation is approximately 0.25 to 0.50 D (42). The aggregate of these findings often causes the total accommodative response to be only about one half of the accommodative stimulus. Clinical findings on symptomatic patients can indicate a much higher lag of accommodation—even up to 1.50 D in young patients is occasionally seen (42). Integrative analysis routinely requires assessment of the actual lag of accommodation so that application of interactive models of accommodation and convergence can be made to clinical findings.

BINOCULAR AMPLITUDE OF ACCOMMODATION

The binocular amplitude of accommodation represents the dioptric range between the farthest and the nearest point of clear vision under normal fused viewing. For simplicity, the far point of accommodation is assumed to be at infinity (the approximately 0.5 D normal depth of focus is ignored). During measurement, the stimulus is brought progressively closer to the patient until the first sustained blur is reported. This value is approximately 0.5 D greater than the monocular accommodative amplitude. The model suggests that this increase is due to added vergence drive to the accommodative system (CA/C).

RELATIVE ACCOMMODATION

In evaluation of relative accommodation, the binocular stimulus to accommodation is systematically altered while maintaining a constant vergence stimulus. The clinician binocularly introduces either plus (negative relative accommodation [NRA]) or minus (positive relative accommodation [PRA]) lenses in 0.25 D steps. This alters the accommodative response while vergence (fusion and fixation disparity) is maintained within the Panum area. Small changes in apparent target distance may also slightly alter the proximal effects. Testing of relative accommodation assesses the flexibility in the linkage between accommodation and vergence.

Clinically measuring relative accommodation requires the patient to bifixate a detailed target. Upon introduction of, say, minus lenses, the eyes are transiently driven to converge by the increased accommodation and corresponding accommodative vergence. To maintain fusion and return the target to the center of the Panum fusional area requires an immediate compensatory stimulus to negative fusional vergence (NFV) to place the target back toward the center of the Panum area, but there is a relative increase in eso-fixation disparity. In the absence of the compensatory vergence response, this relative increase in convergent error would become progressively larger with additional minus lenses until diplopia resulted (although most patients without a very high AC/A ratio maintain fusion and report a blurred image). Thus, as the model in Figure 16.2 suggests,

the blur point on relative accommodation testing indicates the amount that vergence can be inhibited while maintaining clear vision as accommodation is stimulated. The magnitude of the relative accommodation finding is determined by the vergence range and the AC/A ratio.

Under clinical test conditions, interactions between accommodation and vergence are assessed simultaneously; disparity vergence response is not determined in isolation from accommodative vergence. However, this has been performed experimentally by measuring fixation disparity curves through pinholes so that blur feedback was not available and only the disparity vergence system responded. Accommodative interactions account for up to 50% of the measured fixation disparity found under normal viewing conditions. These findings support the theory that accommodative abnormalities can contribute to vergence dysfunction.

Clinical testing in the future might incorporate assessment of forced vergence fixation disparity curves with and without pinholes. Such testing would allow the clinician to differentiate the contribution of accommodation from that of disparity in the vergence response. Treatment might then be more specifically tailored toward one system rather than the other.

Lens Flipper Testing

The lens flipper test is related to relative accommodation testing. However, rather than introducing small sequential steps of defocus, the flipper test introduces large changes that are either a fixed amount for each patient tested (typically ± 2.00 D—a total of 4 D) or scaled according to the accommodative amplitude (43). During lens flipper testing, there are changes in the accommodative stimulus, accommodative response, and vergence response. As with the prism flipper, the lens flipper is a dynamic test in which the frequency of the stimulus and system response change is assessed over time so that inferences regarding sustained clear near vision can be made. Lens flipper ability gives an accurate assessment of relative accommodative ability at high demand levels. The model in Figure 16.2 predicts that the lens flipper test produces considerable vergence stress. As a result, it may have particularly useful diagnostic capabilities. The flipper test is an integral part of integrative analysis (Chapter 2).

ZONE OF SINGLE BINOCULAR VISION

Determining the maximum convergent and divergent disparity that the system can handle gives a situation that drives the vergence system to its limit. At the limits of fusion, the proximal-based interactive model predicts that the boundaries of the zone should be two straight, but not parallel, lines. The convergence side of the zone is more slanted than the divergence side, especially at maximal levels of accommodation, as more proximal vergence is introduced via increased “nearness” (Fig. 16.7). As convergence stimulation increases, accommodation increases due to CA/C, causing a convergence “spike” at maximum accommodation. Due to influences of CA/C, there should also be a divergence spike at zero accommodation (44).

Similarly, accommodation can be driven to its limit, represented by a line with a slope equal to the CA/C ratio. This represents the top of the zone of clear single binocular vision. However, there is a difference between this zone and the classic zone. In the classic zone, the top portion is represented by a flat line, the location of which is determined by the accommodative amplitude. The model discussed here represents the top portion of the zone by a tilted line that is determined by the binocular accommodative amplitude, which is, in turn, related to the value of the stimulus CA/C ratio. Of course, the upper limit of the two zones becomes similar as the patient ages and the CA/C ratio approaches zero.

VERGENCE ADAPTATION

The stimulus to disparity vergence is the difference in image disparity between the angle subtended by the fixation target and the angle of convergence of the eyes after proximal vergence has brought the eyes nearly to binocular fixation. Vergence adaptation is stimulated by the effort of the disparity vergence system (45). Within 1 second, proximal vergence and disparity vergence reduce retinal image disparity to less than 28 seconds of arc (26). Vergence adaptation occurs well after this and serves to reduce the demand on disparity vergence to a minimum by resetting the “zero point” so that less vergence is required to maintain fusion. Asymmetries in vergence adaptation to different prism stimuli (base-in or base-out) cause different fixation

disparity curve types (46), and these same asymmetries also cause symptoms of binocular discomfort when binocularity is insufficient.

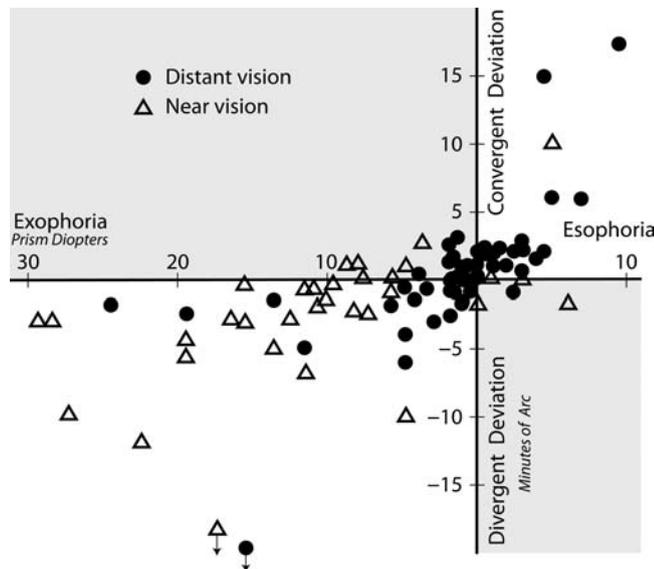
Stimulating disparity vergence for several minutes with prism often results in prolonged alteration of the heterophoria in the direction of the prism stimulus (20). Changes in the heterophoria with prism stimulation have been proposed as evidence of a slow-acting fusional vergence change known as *vergence adaptation*, which exists under binocular viewing conditions (46). A clinical estimate of the magnitude of vergence adaptation can be obtained by assessing the change in tonic vergence (distance heterophoria) immediately after a period of sustained near vision. Although this information is not routinely gathered clinically at the present time, it may prove useful in the future after further research.

The model in Figure 16.2 suggests that adaptation of disparity vergence would not be stimulated during measurement of the near point of convergence, because there has been no sustained bifixation at a fixed near distance. However, repeated measurement of the near point of convergence does transiently affect tonic vergence in some individuals. In symptomatic patients with a receded near point of convergence, the increased effort to converge and maintain fusion seems to be sufficient to elicit a vergence adaptive response. This suggests that these patients have very rapid adaptive responses. As such, assessment of distance tonic vergence of these individuals may be important diagnostically.

FIXATION DISPARITY

Fixation disparity is the result of an incomplete/inaccurate vergence response to the stimulus. Although the eyes are brought within the Panum's fusional area, they may not maintain exact bifoveal alignment; the remaining residual misalignment is termed *fixation disparity*. Schor (46) proposed that the fixation disparity is a steady-state error that enables disparity vergence to maintain fusion. In this view, fixation disparity serves as a control for the vergence system and acts to stimulate continued vergence to maintain binocular alignment.

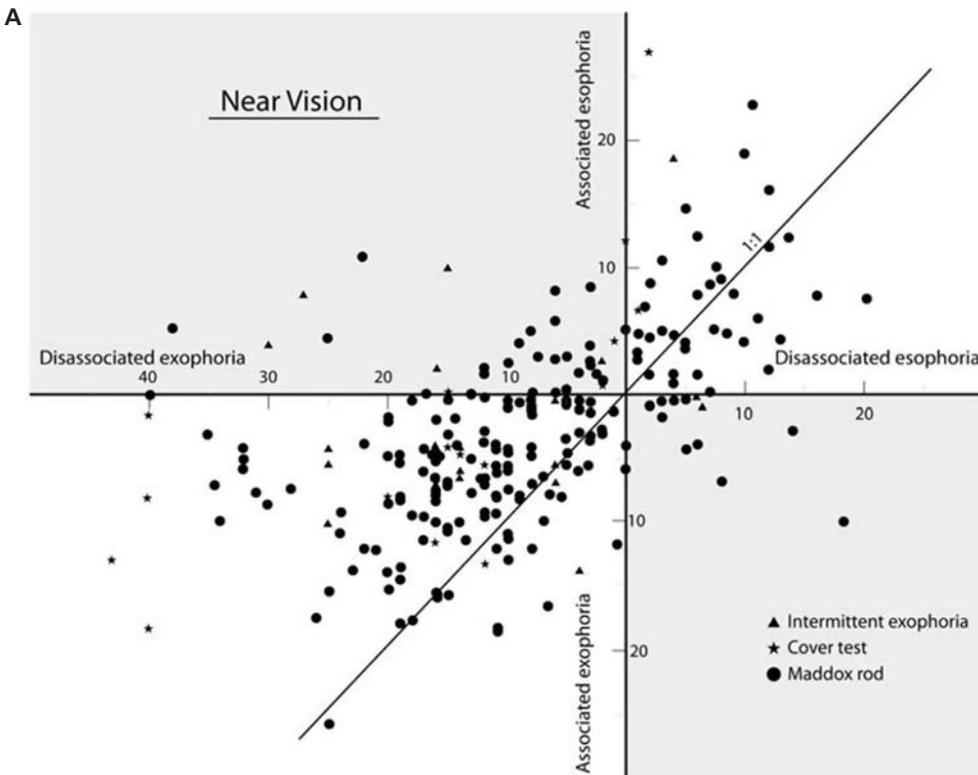
A fixation disparity is usually of the magnitude of only a few seconds of arc and is virtually never greater than 30 seconds of arc (47). As seen in Figure 16.8, the fixation disparity is generally in the direction of the



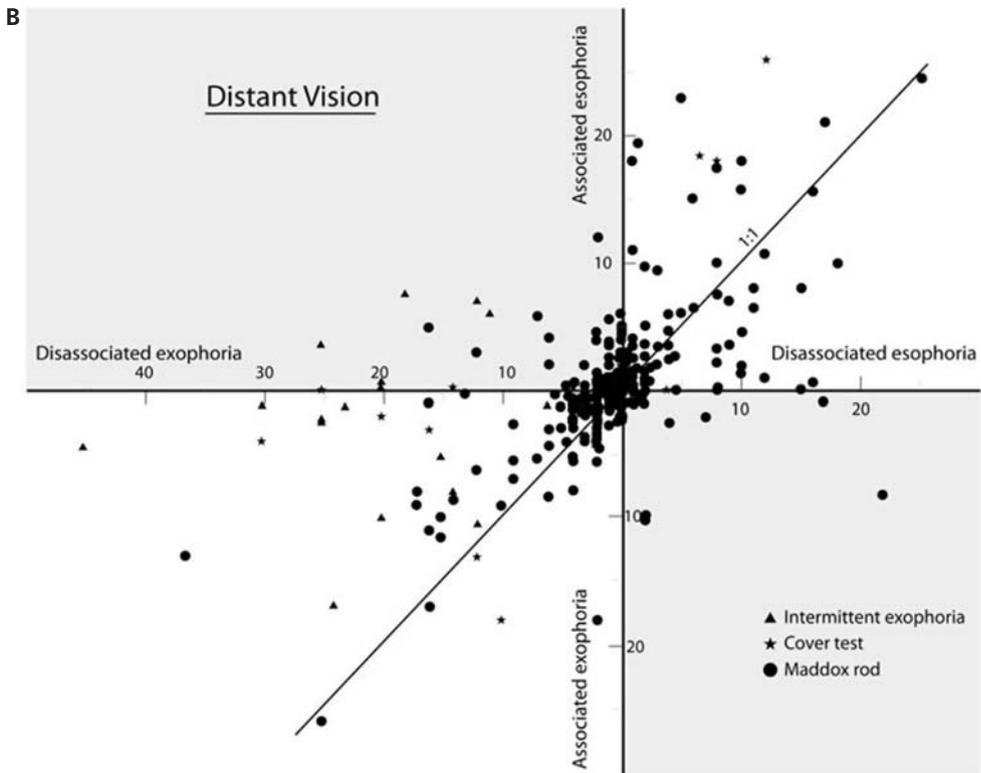
■ **Figure 16.8** A scatter plot of data showing the relationship between the dissociated heterophoria and the fixation disparity for distance (2.5 m) and near vision (30 cm). The heterophoria was measured by white Maddox rod and white fixation light. The fixation disparity was determined with a Polaroid apparatus using nonius lines visible (to either the right or the left eye, respectively) within a central fusion lock of 2.5 degrees while fusion was maintained. A paradoxical response is seen in the "gray areas" where a small number of patients who have exo-dissociated phoria and eso-fixation disparity (and rarely when there is an eso-dissociated phoria and exo-fixation disparity). (Adapted from Ogle KN. *Researches in binocular vision*. New York: Hafner, 1972:75.)

heterophoria at both distance and near (26). This same relation is also observed when comparing the associated phoria and the heterophoria where the associated and dissociated phoria are typically in the same direction (Fig. 16.9) (17). Ogle suggested that this fixation disparity–heterophoria relationship was a consequence of mechanical and tonic neuromuscular stress, as well as functional innervations of a different order arising from fusional stimuli (26). The heterophoria, which is a phenomenon of dissociating the eyes, is often only a partial indication of these resultant stresses.

For some patients seen clinically, the fixation disparity and/or the associated phoria will be in the opposite direction of the heterophoria (40). When the heterophoria and either the associated phoria or the fixation disparity are in the opposite direction from that expected, the response has been termed “paradoxical”. This paradoxical response (Fig. 16.9) is more common for patients who have a large exophoria or intermittent exotropia although there are rarely esophoric patients with either exo-fixation disparity (see Fig. 16.8) or exo-associated phoria (Fig. 16.9). For the exophoric/intermittent exotropic patient, the paradoxical result typically is associated with the use of excessive fusional convergence to maintain single vision. For the esophoric patient, the result is often due to poorly controlled accommodation. A paradoxical response is also seen during therapy when the patient uses inappropriate vergence or accommodative responses to assist fusion. Observation of a paradoxical response during therapy should alert the clinician to alter therapy so



■ **Figure 16.9 A and B:** A scatter plot diagram of the horizontal dissociated heterophoria and the horizontal associated phoria for about 200 subjects determined by the fixation disparity method for near (30 cm – top; 16.9A) and distance (2.5 m – bottom; 16.9B). The heterophoria was measured by white Maddox rod and white fixation light. The fixation disparity was determined with a Polaroid apparatus using nonius lines (visible to either the right or the left eye, respectively) within a central fusion lock of 2.5 degrees while fusion was maintained. A paradoxical response is seen in the “gray areas” where a small number of patients who have exo-dissociated phoria and eso-associated phoria (and more seldom when there is an eso-dissociated phoria and exo-associated phoria). (Adapted from Ogle KN, Martens TG, Dyer JA. *Oculomotor imbalance in binocular vision and fixation disparity*. Philadelphia: Lea & Febiger, 1967:109.) (Continued)

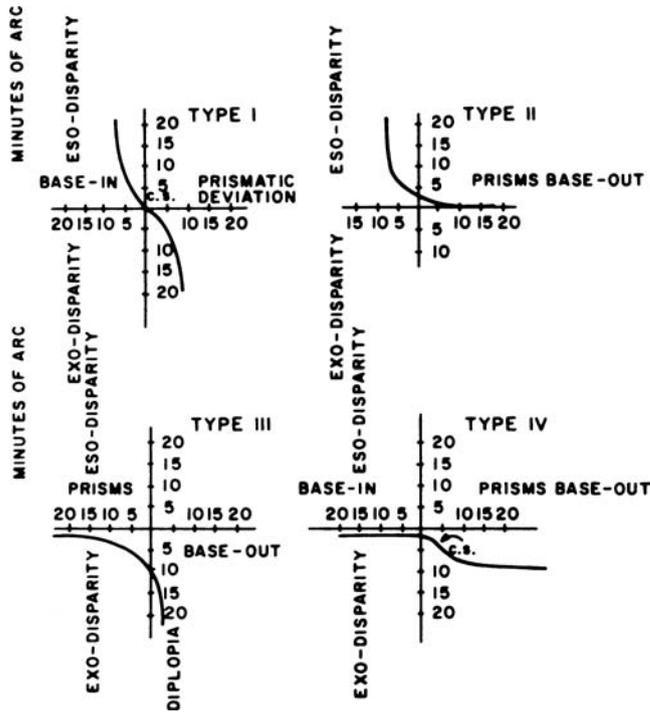


■ **Figure 16.9** (Continued)

that it is more appropriate for the patient's condition (include both convergence and divergence therapy for patients with exo-deviations; emphasize accommodative accuracy during vergence therapy for patients with eso-deviations).

The model in Figure 16.2 predicts that fixation disparity will change nonlinearly with alteration in the vergence demand. These nonlinearities, which are caused by CA/C (47) and vergence adaptation (40), are represented by the four different shapes of fixation disparity curves (Fig. 16.10). Persons who have more vergence adaptation to base-out prism have type II curves, and persons who have more adaptation to base-in prism have type III curves (48).

Clinical studies (49) indicate that analyzing binocular vision using forced vergence fixation disparity techniques is useful for detecting patients likely to have binocular symptoms and results in appropriate prism prescriptions with good prognosis for relieving binocular symptoms. Curves with steep slopes, high associated heterophorias, and large fixation disparities are found more frequently when testing symptomatic patients (4). Asymptomatic patients usually have type I curves. Other curve types are frequently associated with patients who have large heterophorias (type II eso, type III exo). For pre-presbyopic patients, type IV curves are considered to be associated with symptoms and caused by unstable binocularity due to abnormal CA/C interactions. Presbyopic patients, who have type IV curves more frequently, do not have CA/C and therefore do not have the associated symptoms (32). Generally for patients who have paradoxical fixation disparity responses (where the fixation disparity or associated phoria is in the opposite direction from that expected from the heterophoria measurement) fusional and/or accommodative therapy help restore both the expected finding and a more normal symptom-free binocular status. Fixation disparity curves are assessed in integrative analysis to help design prism prescriptions for patients with esophorias and hyperphorias and to monitor effects of various therapeutic interventions.



■ **Figure 16.10** Nonlinearities in fixation disparity with forced vergence are caused by convergence accommodation and vergence adaptation. These nonlinearities are represented by the four different shapes of fixation disparity curves.

Lens or Prism Therapy

Addition of prism or lens power will change the accommodation/vergence interactions. For example, consider an esophoric patient with a greater esophoria at near than distance (convergence excess). Because the patient is overconverged, there is a high amount of convergence-associated accommodation to inhibit. As a result, to maintain clear near vision, accommodative vergence must be used, which tends to stimulate more esophoria. Near plus lenses or prism or both are prescribed to make accommodative inhibition easier, reduce the demand to a reasonable amount, and improve binocular responses.

Clinical implications of the model for convergence excess patients are that esophoric patients generally have more blur-driven accommodative demands (AC/A) than exophoric patients whose accommodation comes as a result of convergence (CA/C). Clinical findings have shown that convergence excess patients have more proximal vergence and higher response AC/A ratios than average (49). For esophores, the effects of near plus lenses can be determined by considering the estimated lens power in conjunction with the relationship between the response AC/A and response CA/C ratios. The changing relationship between CA/C and AC/A may also explain why young patients with exo-deviations become less symptomatic (50) as their CA/C ratio decreases with age.

Conclusion

A model of binocular vision system interactions has been discussed that treats the accommodative and vergence systems as negative feedback systems with “cross talk” between the two systems. This cross talk is accommodative vergence and vergence accommodation. The model incorporates proximal vergence, as well

as accommodative lag and the depth of focus of the eye, in an attempt to more closely account for common clinical findings.

Clinical implications of this model are best understood by considering the examples in this chapter. Many clinical patients have findings that are accurately explained by the model in Figure 16.2 (51). The model allows for the common clinical findings of large lags in accommodation and explains why patients can have a large lag and maintain binocularity. Proximal vergence helps explain why presbyopic patients, who lose accommodative vergence, remain asymptomatic. For many patients seen clinically, vergence and accommodative responses are not equal to the stimuli because of proximal vergence and interactions between accommodative vergence and vergence accommodation. Binocular interactions also help explain why the dissociated and associated phoria frequently differ in magnitude. We based integrative analysis (introduced in Chapter 2) on this model and other current binocular vision research. Integrative analysis thus allows enhanced assessment of binocular findings with improved results over previous systems of analysis.

Study Questions

1. Why is the AC/A ratio derived from calculated measures typically different from that measured using gradient measures?
2. Why is the push-up amplitude of accommodation different when measured monocularly and binocularly?
3. What effect does the CA/C ratio have on measures of fusional vergence?
4. Is the leptokertotic distribution of tonic vergence a significant influence on the distribution of the near phoria?
5. In examining 100 pre-presbyopic patients, what is the single most important factor that determines the distribution of the near phoria?
6. When the patient has a maximum plus refraction and looks from distance to near, how does the accommodation stimulus/response curve predict the amount of accommodative change?
7. How could a patient with a convergence insufficiency (phoria; distance, 1 Δ exo; near, 11 Δ exo) have a normal AC/A ratio when measured with a gradient test?
8. Why might a divergence excess patient report blurred distance vision when he or she fuses? (Hint: Present one reason related to CA/C and one to AC/A.)
9. Why are pinholes used when determining the CA/C ratio?
10. How might we explain an increase in esophoria after measures of fusional convergence?

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Refractive Amblyopia

Included among the amblyopic patients are those whose amblyopia results from uncorrected refractive errors. Such amblyopia is of particular clinical importance because of its prevalence, prognosis, and relative ease of management. Because many patients with refractive amblyopia are not strabismic, their treatment requires only slight modification of the binocular procedures described in previous chapters.

The study of amblyopia is frequently a study of the effects of vision deprivation. From the investigations of Wiesel and Hubel (1) to current studies, it is clear that deprivation occurring in early life has dramatic long-lasting effects on the visual system (2). The essence of animal research is that vision deprivation, such as is produced by lid suture, results in a variety of anatomic and physiologic changes throughout the visual pathway (3). Anatomic changes associated with lid suture are typically more extensive at the lateral geniculate nucleus (4), whereas physiologic changes are more pronounced and varied in the visual cortex (5). Detailed reviews of these findings often provide clinically relevant information (6), including two concepts that directly affect the management of anisometropic and isoametropic amblyopia. These concepts—abnormal binocular competition and the critical period—are discussed in the section on etiology.

This chapter describes examination techniques and differential diagnosis and presents a sequential management of refractive amblyopia that extends the treatment period well into adulthood. Virtually, all amblyopic patients should have careful diagnosis and aggressive management. It is important to treat these patients; it is not acceptable to simply monitor them, because it is possible to dramatically improve visual acuity and binocular function using sequential considerations of (a) correction of the refractive error, (b) added lenses or prisms, or both, to improve fusion, (c) passive therapy (either part-time direct occlusion or penalization of the sound eye with atropine drops), and (d) vision therapy to improve monocular and binocular function.

Etiology and Prevalence of Refractive Amblyopia

DEFINITION

Amblyopia is defined (7) as a unilateral or bilateral condition in which the best corrected visual acuity is poorer than 20/20 in the absence of any obvious structural or pathologic anomalies, but with one or more of the following conditions occurring before the age of 6 years:

- Amblyogenic anisometropia
- Constant unilateral esotropia or exotropia
- Amblyogenic bilateral isometropia
- Amblyogenic unilateral or bilateral astigmatism
- Image degradation

Whenever visual acuity is less than 20/20, it is clinically significant and needs to be investigated further. If one of the five conditions associated with amblyopia is not present, then possible organic changes should be investigated.

Refractive amblyopia may be subdivided into two categories: anisometropic and isoametropic. *Anisometropic amblyopia* occurs as a result of clinically significant and unequal amounts of uncorrected refractive error in each eye (8). The most ametropic eye develops amblyopia as a result of the unilaterally blurred retinal image. *Isoametropic amblyopia* results from the presence of very high, but clinically equal, uncorrected refractive errors (8). Both eyes become amblyopic as a result of bilateral visual deprivation from the significantly blurred retinal images of each eye.

CLASSIFICATION

Amblyopia has traditionally been classified in a dichotomy between organic and functional, with various subclassifications (9) (Table 17.1). Von Noorden suggested classification of functional amblyopias based on clinical causes (10). Such a classification is based on the clinical conditions thought to be responsible for creating the amblyopia. This chapter discusses two types of amblyopia, classified according to the refractive errors that result in a decrease in acuity and unilateral difference in refractive error (anisometropic) or significant bilateral refractive error (isoametropic).

ETIOLOGY

The factors that result in refractive amblyopia have been investigated in experimental studies on the effects of vision deprivation. In general, the primary factor that results in amblyopia is an uncorrected refractive error that does not permit clear retinal images of equal size or shape, or both, in each eye. These blurred images do not allow adequate stimulation of the visual system, and amblyopia develops. Although refractive amblyopia is regarded as functional, as opposed to organic, the basic amblyogenic factors are much better understood than the term *functional* implies. Indeed, investigations have correlated the clinical conditions that result in amblyopia with resulting deficits in the basic underlying neurophysiology.

Abnormal Binocular Competition

The effects of deprivation are most significant when there is an imbalance in the visual input between the eyes. A competitive interaction exists between the two eyes during early visual development (11), and conditions that allow one eye a competitive advantage result in dramatic changes in the visual pathway of the disadvantaged eye. The accepted explanation for these changes involves a competition for synaptic space on cortical neurons (12). Neurons in the visual pathway of the disadvantaged eye decrease in function and number as a result of this competition, and pathways from the advantaged eye gradually gain more synapses. Thus, this basic science research suggests that genetic coding determines the initial neural pathways and that early visual experience subsequently refines and maintains these connections. Abnormal visual experience disturbs the basic pattern and reduces visual capabilities in one or both eyes. Visual pathway changes are more difficult to demonstrate when the eyes are equally disadvantaged.

Anisometropic Amblyopia

In patients with uncorrected anisometropia, the images falling on the two foveae have the same common visual direction and give rise to a single percept. However, the images may be of substantially different clarity. As a result, in uncorrected anisometropia, the foveal image of the most ametropic eye is likely to be suppressed. This cortical suppression or signal inhibition can eventually result in amblyopia if it occurs for a sufficient time at the appropriate stage in development. Unfortunately, vision deprivation present in uncorrected anisometropia may escape early detection because one eye sees clearly and there may be no signs or symptoms.

Isoametropic Amblyopia

When there is an isoametropic refractive error, interference from dissimilar images does not occur. Thus, any resultant loss of acuity must be from lack of proper stimulation of the visual system (bilateral visual deprivation)

TABLE 17.1 CLASSIFICATION OF AMBLYOPIA

Von Noorden (9)	Traditional
Amblyopia exanopsia	Amblyopia exanopsia anisometropic strabismic
Anisometropic	
Ametropic	Isometropic
Hysterical	Hysterical
	Isometropic
	Light deprivation
Strabismic	

during early development, rather than a result of congenital or organic amblyopia. For bilateral visual deprivation to occur, there must generally be a significant decrease in the visual input to both eyes. The most dramatic clinical example of bilateral visual deprivation occurs when an infant has congenital cataracts. Unless removal is initiated very early in life, the resultant acuity is substantially below normal (13). Refractive errors can also “deprive” the visual system of proper stimulation, but they must be very large, and even then the visual loss is seldom severe (14), at least in comparison to that seen in patients with congenital cataracts.

Critical and Sensitive Periods

Imbalances between the visual information reaching the two eyes have the most profound results early in development. Animal studies have established that there is a developmental period for anisometropic amblyopia that probably lasts through most of the first decade of life (15,16). Clinical observations also suggest a similar time course for amblyopia development (17,18). This developmental period can be roughly divided into two portions, a critical period and a sensitive period. The *critical period* is a relatively short duration of time of maximum sensitivity, perhaps lasting until age 3 in humans. During the longer-lasting *sensitive period*, the visual system is still susceptible to change, but damage is progressively less severe. The sensitive period probably begins at about age 3 and may last until around age 10. Imbalances that occur later have reduced or nonexistent effects. Certain anatomic changes coincide with these periods, allowing vision researchers to predict that human visual development continues through at least the first decade.

Plastic Period

The critical period for amblyopia development does not necessarily follow the same time course as the *plastic period*, during which the amblyopic visual system is still amenable to successful treatment. Clinical evidence suggests that plasticity of the visual system remains for periods substantially longer than the first few years. For example, the dramatic response of adult patients with anisometropic amblyopia to treatment (19) suggests that residual plasticity remains in the human visual system for much longer periods than the critical period for development of amblyopia. The ability of older patients to recover from cerebral vascular accidents is further evidence that the human nervous system retains some plasticity throughout life. Basic research studies in cats (20) show that the plastic period, during which the visual system can still change, extends well into adulthood.

PREVALENCE

Anisometropic Amblyopia

Flom and Neumaier (21) investigated the prevalence of amblyopia in 2,762 schoolchildren from kindergarten to the sixth grade. They found that 1% of the population had amblyopia, using a criterion of monocular uncorrected acuity of 20/40 or worse, with a difference between the eyes of more than one line of acuity. All children with amblyopia had either strabismus (38%), 1 diopter (D) or more of anisometropia (34%), or both conditions (28%).

The prevalence of amblyopia without strabismus was also summarized by Schapero (22), who determined (from data averaged from six studies) that 62% of amblyopes have binocular alignment of the visual axes. Although one cannot assume that all 62% of the cases of nonstrabismic amblyopia were of refractive etiology, amblyopia appears to occur quite frequently in patients without strabismus. Because anisometropia occurs more frequently than unilateral strabismus, it is not surprising that anisometropic amblyopia occurs more frequently than strabismic amblyopia.

Isoametropic Amblyopia

There is little epidemiologic information concerning the prevalence of isoametropic amblyopia. Theodore et al. (23) surveyed 190,012 inducted soldiers; in a group labeled “unexplained amblyopia,” they found that 14 of 2,509 men (0.56%) had bilateral amblyopia. In a similar study, Agatson (24) found 7 of 20,000 inducted men to have bilateral amblyopia associated with high refractive errors. More recently, Abraham (25) used an amblyopia criterion of correctable acuity less than 20/25 and reported that 162 of 7,225 patients had bilateral amblyopia. He included patients with 5.00 D or more of hyperopia or 1.25 D of astigmatism or both.

Linksz (26) associated bilateral amblyopia with myopia and astigmatism rather than hyperopia. However, Abraham (25) definitively demonstrated that bilateral amblyopia occurs in a substantial number of patients with

significant hyperopia or astigmatism or both. Similarly, Friedman, Neuman, and Abel-Peleg (27) suggested that bilateral hyperopia was the most common cause of amblyopia, in a series of 39 patients with marked ametropia.

These studies suggest that bilateral amblyopia secondary to uncorrected isoametropia accounts for approximately 2% of nonstrabismic amblyopia. Although the true prevalence of bilateral amblyopia in the general population is unknown, Griffin (28) implied that the prevalence of isoametropic amblyopia is decreasing in countries where early vision examinations are emphasized.

Characteristics of Amblyopia

SIGNS

Unfortunately, there are no reliable signs to make the patient, parent, or clinician suspect the presence of refractive amblyopia. When there is amblyopia, a very young child may rub his or her eyes, and an older child or adult may squint to improve vision. However, these signs occur in a variety of refractive conditions and are not reliable indicators of the anisometropia that is most likely to produce refractive amblyopia.

SYMPTOMS

Much of what was presented in regard to signs also applies to the presence of symptoms. Complaints of blurred vision, headaches, and ocular discomfort are potential symptoms that patients with amblyopia may report, but it is also very likely that there will be no symptoms. There are only a few refractive situations that create the proper conditions for anisometropic or isoametropic amblyopia. The patient's age and visual requirements, along with the refractive status, all combine to determine whatever symptoms may be present, and there are many refractive conditions that cause symptoms without ever producing amblyopia.

CLINICAL CHARACTERISTICS

There are a variety of visual conditions that are characteristic of refractive amblyopia. Clinically, it is necessary to be familiar with the important characteristics of anisometropic or isoametropic amblyopia listed in this section.

Refractive Error

Jampolsky et al. (29) examined a sample of approximately 200 patients with nonstrabismic amblyopia and reported that the eye with the greater ametropia, regardless of the type of refractive error, had the greatest loss of acuity. However, this statement does not totally reflect the differential effect that hyperopia has on the development of amblyopia.

Hyperopia

Jampolsky et al. (29) found that hyperopia or astigmatism or both have a greater effect on visual acuity loss than myopia. In their study, the difference in power between the horizontal or the vertical meridians of the eyes was closely related to the unequal acuity—that is, the greater the anisometropia, the greater the amblyopia. Sugar (30) found similar results and concluded that hyperopic anisometropia was the predominating factor associated with nonstrabismic amblyopia. Hyperopic anisometropes had more amblyopia, and the amblyopia increased with the amount of hyperopia and the amount of anisometropia.

The greater prevalence of amblyopia in hyperopic anisometropia is primarily a result of the different image clarity and the accommodative response. The more hyperopic eye has a blurred image, and the amount of blur depends on the amount of anisometropia. Because the eye with the lower refractive error typically accommodates for any near target, the more hyperopic eye always remains with a blurred image. Consequently, hyperopic anisometropia in amounts greater than 1.25 D may create sufficient long-term blur to cause a form of vision deprivation in the hyperopic eye. If this occurs during the critical period during development, amblyopia may result.

Myopia

These studies document that the prevalence of amblyopia is greater in patients with hyperopic anisometropia than with myopic anisometropia. Indeed, in simple myopic anisometropia or anisomyopia,

an amount of 5 or 6 D (or perhaps more) is necessary before one image is sufficiently and continuously blurred so that vision deprivation and amblyopia result (28). Horwich (31) concurs that refractive amblyopia is not expected unless the myopia in the amblyopic eye is more than 6 D. He suggests that the possibility of maculopathy be investigated whenever decreased visual acuity is present in the most myopic eye.

Astigmatism

Astigmatic differences between the eyes can also contribute to the development of amblyopia. The reduction of acuity for a given amount of uncorrected astigmatism is usually less than would occur with an equal amount of spherical hyperopic anisometropia (32). However, astigmatism may be an even greater deterrent to fusion than simple anisohyperopia when combined with hyperopic anisometropia. It is possible that uncorrected astigmatism of 1.50 D or more (depending on axis position) might cause enough image blur to result in amblyopia, since accommodation is also unable to compensate for this refractive error (33).

Fixation Characteristics

In almost all cases of anisometric and isoametric amblyopia, fixation is unsteady and central (34). Given central fixation as a primary characteristic, an important differential diagnostic test for refractive amblyopia is objective assessment of fixation. Assessment is facilitated using direct ophthalmoscopes with fixation targets incorporated in the illumination system (35) (Fig. 17.1A). Because a characteristic of central fixation is stable subjective localization of objects in visual space, when the patient with central fixation fixates on the target projected on the retina, the fovea will be within the circular portion of the target (Fig. 17.1B). If eccentric fixation is present during ophthalmoscopy in an eye that is apparently without ocular deviation, a microtropia is probably present (36). This is an important diagnostic point because the prognosis for successful remediation of anisometric amblyopia is much higher than that for microstrabismus.

Unilateral High Myopia

Patients with unilateral high myopia may be an exception to the rule that there is central fixation in anisometric amblyopia. A high percentage of anisomyopic patients with amblyopia demonstrate eccentric fixation in the eye with the greatest myopia (37). Eccentric fixation is a common, although not necessarily constant, feature of this type of amblyopia.

Suppression Characteristics

Anisometric Amblyopia

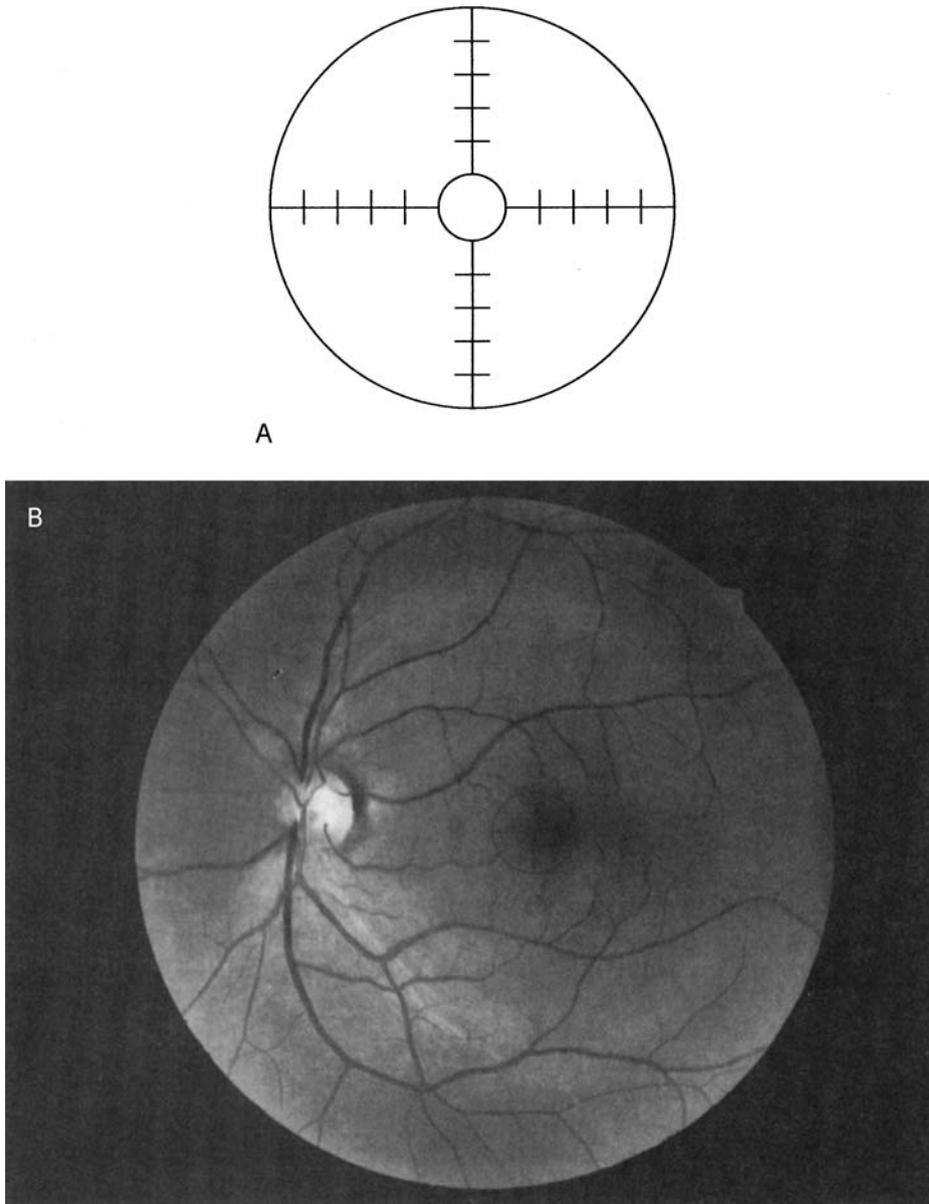
The suppression characteristics of 13 patients with anisometric amblyopia were investigated by Pratt-Johnson et al. (38). Under binocular testing conditions, 10 of 13 patients had small relative foveal suppression areas in the amblyopic eye. The suppression areas were never absolute, and stimuli could always be perceived under binocular conditions, regardless of the acuity. While presenting similar results, Jampolsky (39) reported great variability between the age of onset, depth of suppression, fixation distance, and size of the suppression area.

Isoametric Amblyopia

Pratt-Johnson et al. (38) also reported the suppression characteristics of five patients with isoametric amblyopia. Three patients had no suppression scotoma, one demonstrated alternating suppression, and one showed suppression in the more amblyopic eye.

Crowding Phenomenon

The crowding phenomenon, or separation difficulty, describes the clinical finding that resolution ability is related to the separation of acuity targets (40). This phenomenon exists in all eyes, although it is



■ **Figure 17.1** **A:** Assessment of fixation is facilitated using direct ophthalmoscopes with fixation targets incorporated in the illumination system. The most common clinically available target is a circle with central grid lines. Each line represents 1Δ of eccentric fixation. **B:** Because a characteristic of anisometropic amblyopia is central fixation, when the patient with central fixation fixates on the target projected on the retina, the fovea will be within the circular portion of the target. The presence of eccentric fixation during ophthalmoscopy generally indicates microtropia if there appears to be binocular alignment.

particularly important in amblyopes with strabismus. Linksz (41) suggests that in cases of hyperopic anisometropic amblyopia, central fixation is present and there is also relatively normal separation difficulty. Maraini, Pasino, and Peralta (42) found no significant difference in separation difficulty between anisometropic amblyopes and normal subjects. However, strabismic amblyopes had a significant difference in ability to correctly identify single versus crowded E's. The crowding phenomenon is thus a useful method for differential diagnosis of anisometropic or isoametropic amblyopia from strabismic amblyopia.

Electrodiagnostic Tests

Electrodiagnostic tests such as the electroretinogram (ERG) and the visually evoked response (VER) are used in the laboratory to investigate the visual system of subjects with amblyopia (43,44). These tests require a substantial commitment of cash and time and therefore are not yet useful clinically. Differences have been shown between the responses of patients with strabismic and anisometropic amblyopia on some testing protocols (45), and these tests may prove clinically useful in the future.

Course and Prognosis

The course of refractive amblyopia is that visual acuity remains decreased as long as the underlying refractive condition goes untreated. The severity of the amblyopia depends on age of onset of the refractive error, the amount of anisometropia or isoametropia, changes in refractive error during the critical period, and perhaps on individual differences in sensitivity to vision deprivation.

The prognosis of refractive amblyopia is generally good for the recovery of improved levels of visual acuity. Improvement in visual acuity may also be found well into adulthood (19, 46–52). Wick et al. (46) examined records of 19 patients over 6 years of age who had been treated for anisometropic amblyopia using refractive correction, added lenses, patching, and vision therapy. After 15.2 (+/– 7.7) weeks of treatment, they found an average improvement in visual acuity of 92.1% with a range from a low of 75% by a 49-year-old patient to a maximum of 100% achieved by 42.1% of the patients (8 of 19). Patients who had completed therapy one or more years ago maintained their acuity improvement. The authors concluded that the treatment of anisometropic amblyopia can yield substantial long-lasting improvement in visual acuity and binocular function for patients of any age.

Although there are no published controlled clinical trials for treatment of amblyopia in adults, there are a number of case series that suggest that amblyopic adults can improve. For example, Carl Kupfer (19) showed marked improvement in acuity in seven adult strabismic amblyopes, aged 18–22. All seven showed improvements ranging from 71% (20/70–20/20) to a very dramatic improvement from being able to report hand movements only, to an acuity of 20/25 after 4 weeks. Kupfer's treatment was aggressive with patients hospitalized for 4 weeks during which time they were continuously patched and given fixation training. Since Kupfer's study, there have been other reports of improvement in acuity of older people with amblyopia (46,53,54). Plasticity in adults with amblyopia is also evident in reports of recovery of visual acuity in the amblyopic eye of adults after the sound eye develops eye disease (55–57) These studies are consistent with the notion that the connections from the amblyopic eye may be suppressed rather than destroyed (52).

The Pediatric Eye Disease Investigator Group (PEDIG) conducted one prospective study (58) and two randomized clinical trials to investigate the treatment of amblyopia in older children 7–17 years old (59,60). In a major randomized clinical trial to evaluate the effectiveness of treatment of amblyopia in children aged 7 to 17 years, 507 patients with amblyopic eye visual acuity ranging from 20/40 to 20/400 were provided with optimal optical correction and then randomized to a treatment group (2–6 hours per day of prescribed patching combined with near visual activities for all patients plus atropine sulfate for children aged 7 to 12 years) or an optical correction group (optical correction alone). Patients whose amblyopic eye acuity improved 10 or more letters by 24 weeks were considered responders. The authors found that in the 7- to 12-year-olds, 53% of the treatment group were responders compared with 25% of the optical correction group. In the 13- to 17-year-olds (n = 103), the responder rates were 25% and 23%, respectively, overall but 47% and 20%, respectively, among patients not previously treated with patching and/or atropine for amblyopia. In a long-term follow-up study of these patients, the authors found a very low recurrence rate of about 5% (61).

Levi and his co-investigators have explored (47,48,51,52,62) another approach to study plasticity in adult amblyopia using a training approach referred to as Perceptual Learning. Li et al. (51) examined whether playing video games can induce plasticity in the visual system of adults with amblyopia. Specifically 20 adults with amblyopia (age 15–61 years) were allocated into three intervention groups: action videogame group, non-action videogame group, and crossover control group. They found that playing video games (both action and non-action games) for a short period of time (40–80 hours, 2 hours/day) using the amblyopic eye results in a substantial improvement in a wide range of fundamental visual functions, from low level to high level, including visual acuity (33%), positional acuity (16%), spatial attention (37%), and stereopsis (54%). A large-scale randomized clinical study is needed to confirm the therapeutic value of video-game treatment in clinical situations.

Sequential Management Protocol

The ultimate goal of all therapy protocols for amblyopia is to achieve functional binocular vision with equal visual acuity. According to Flom (63), a functional cure results in equal visual acuity in each eye, along with comfortable single binocular vision at all distances, from the far point to a normal near point of convergence. There should be stereopsis and normal ranges of motor fusion. Corrective lenses and small amounts of prism may be worn if necessary; however, prismatic power is limited to 5 Δ.

This section describes and gives the rationale for treatment of refractive amblyopia. Our management recommendation for anisometropic amblyopia is a sequential program that consists of four steps: (a) full refractive correction, (b) added lenses or prism when needed to improve alignment of the visual axes, (c) passive therapy utilizing either 2 to 6 hours per day of direct occlusion or atropine penalization (one drop of atropine sulfate in the better-seeing eye at bedtime two times per week), and (d) active vision therapy to develop best acuity and improve binocular function (Table 17.2).

Isoametropic amblyopia can best be treated by simply prescribing the full refractive correction (14,64) (Case 17.1). Occasionally antisuppression therapy is also indicated, but generally the full refractive

TABLE 17.2 SEQUENTIAL MANAGEMENT OF ANISOMETROPIC AMBLYOPIA

1. Full refractive correction
2. Improve alignment of the visual axes when needed
 - a. Added lenses if:
 - 1) High AC/A ratio
 - 2) Inaccurate or insufficient accommodation
 - b. Prism if:
 - 1) Esophoric at distance (base-out)
 - 2) Hyperphoric (base-down)
3. Direct occlusion (part-time, 2 to 6 h/d) or atropine penalization of the sound eye (one drop in the sound eye two times per week at bedtime)
4. Vision therapy
 - a. Monocular—maximize monocular acuity
 - b. Binocular—improve binocular function

Case 17.1 Isoametropic Amblyopia

The mother of a 5-year-old girl felt that her daughter sat too close to the television. This was the child's first eye examination. External and internal ocular health was within normal limits. Visual acuity and refraction with cycloplegia was as follows:

OD: +8.25 c – 1.00 × 25 20/200 – 1
 OS: +8.75 c – 2.00 × 005 20/100 – 1
 OU: 20/100

There was a comitant 5 Δ esophoria at 6 m and 40 cm. Stereopsis was 100 seconds at 40 cm with Randot circles. There was no suppression. Fixation was central with both eyes.

The cycloplegic refractive finding was prescribed, and the patient was instructed to return for reevaluation in 1 month. She had worn the correction full time without complaint. Aided visual acuity (VA) was as follows:

OD: 20/60 – 2
 OS: 20/60
 OU: 20/50

Over the next 3 years, the patient's acuity gradually improved to 20/25–, with only small changes in the refractive correction.

correction will yield the best possible result; usually there is gradual improvement in vision over the next few years after the full correction is prescribed. In a prospective study, 113 children (mean age 5.1 years) with previously untreated isometropic amblyopia were treated with eyeglasses alone for 1 year. The authors reported that the average visual acuity improved from 20/63 to 20/25 at 1 year, with an average improvement of 3.9 lines (64).

DETERMINING COMPLIANCE

For management to be effective, substantial patient motivation is often required, especially when older children and adults are treated. Indeed, differences in patient compliance may be the most common cause of variation in the results seen when treating amblyopia in older patients. It is important to anticipate patient noncompliance and take precautions to avoid this potentiality. To facilitate patient compliance and motivation, written instructions should accompany home therapy procedures, and the therapy should be demonstrated and performed in the office so that the patient fully understands the tasks required. When home therapy is instituted, frequent office follow-up visits (every 2 to 3 weeks) are needed to monitor progress.

REFRACTIVE CORRECTION

The first step that we recommend in our treatment sequence for anisometropic amblyopia is to fully correct the refractive error of each eye (Case 17.2). Refractive correction alone can have a substantial effect on improving acuity in children with both refractive and strabismic amblyopia, with about 25% of the cases resolving completely just with appropriate refractive correction (60, 65–71). In a prospective study of 84 children 3 to <7 years old with untreated anisometropic amblyopia ranging from 20/40 to 20/250, the PEDIG group evaluated the effectiveness of refractive correction alone for the treatment of untreated anisometropic (71). Optimal refractive correction was provided, and visual acuity was measured with the new spectacle correction at baseline and at 5-week intervals until VA stabilized or amblyopia resolved. Visual acuity improved with

Case 17.2 Refractive Correction Alone

A 12-year-old girl presented with the chief complaint of blurred vision when looking from reading books to the chalkboard. She also complained of irregular headaches and felt that the left eye bothered her more than the right. Her parents reported that she had received a visual examination 2 years previously, but did not wear the prescription. External and internal ocular health was within normal limits. Visual acuity and refraction with cycloplegia was as follows:

OD: plano	20/20 – 1
OS: +3.75 – 2.00 × 005	20/60 – 1
OU: 20/20	

There was a comitant 5 Δ esophoria at 6 m and 8 Δ esophoria at 40 cm. Stereopsis was 100 seconds at 40 cm with Randot circles. There was no suppression. Fixation was central with both eyes.

The cycloplegic refractive finding was prescribed. The patient was instructed to return for reevaluation in 1 month, but she did not return until 3 months later. She had noticed diplopia for the first 2 days while wearing the new glasses, but now wore them full time without complaint.

Aided VA

OD: 20/15 – 2
OS: 20/20
OU: 20/15

Eye alignment was 2 Δ esophoria at 6 m and 4 Δ esophoria at 40 cm. Stereopsis was 20 seconds at 40 cm with Random Dot circles.

optical correction by $>$ or $=2$ lines in 77% of the patients and resolved in 27%. Treatment outcome was not related to age, but was related to better baseline VA and lesser amounts of anisometropia. The authors concluded that refractive correction alone improves VA in many cases and results in resolution of amblyopia in at least one-third of 3- to <7 -year-old children with untreated anisometropic amblyopia. Another important conclusion was that the average three-line improvement in VA resulting from treatment with spectacles may lessen the burden of subsequent amblyopia therapy for those with denser levels of amblyopia (71). A unilaterally blurred retinal image is generally considered to be the primary amblyogenic factor in anisometropic amblyopia, and full refractive corrections are routinely prescribed in treatment of amblyopia in young children. We suggest that a full refractive correction for each eye is required to achieve the maximum result from management for any patient. Thus, our goal is to prescribe, for each eye, the full plus lens power that completely corrects all anisometropia and astigmatism.

Refractive error should be determined with accommodation stabilized in each eye—a potential problem with anisometropic amblyopia, in which the amblyopic eye sometimes has very inaccurate accommodation under monocular conditions. We suggest that refraction be performed with either binocular or cycloplegic evaluation. Such examinations are particularly applicable for patients with hyperopic anisometropia, in which an eye that appears to be amblyopic under monocular conditions may have normal or nearly normal vision when accommodation is stable and the total hyperopic correction is in place. A viable alternative to binocular refraction that is preferred by many practitioners is cycloplegic refraction.

As discussed in Chapter 3, the full-plus prescription might cause significant distance blur for the nonamblyopic eye and be impractical or difficult to wear because the blurred vision makes distance tasks difficult. At times, the refractive findings may need to be reduced so that the nonamblyopic eye can maintain clear distance vision. To achieve this, we recommend slightly reducing only the spherical power of the lenses, thereby retaining the complete anisometropic and astigmatic correction. For example, assume that the patient had reduced distance acuity through the full cycloplegic refraction for the nonamblyopic right eye:

OD: +2.00 c 1.00 \times 180 20/30
OS: +6.00 c 2.00 \times 5 20/70

If a reduction in the sphere power of the right lens of 0.75 D allowed clear distance vision, then the spherical power of *each* lens can be reduced (retaining the anisometropic and astigmatic correction), resulting in the following final prescription:

OD: +1.25 c 1.00 \times 180 20/20
OS: +5.25 c 2.00 \times 5 20/70

The refractive error should be reevaluated at each 2- to 3-week follow-up visit. Appropriate lens changes can be made when necessary to maintain the optimum balance and astigmatic correction while continuing to strive for maximum plus acceptance.

Because improvement in resolution of an amblyopic eye occurs with substantial frequency when simply wearing the best correction full time (60,65,71), we always prescribe the full refractive correction as the first step in management. Spontaneous improvement in acuity for patients with anisometropic amblyopia who have had only refractive treatment tends to be related to better baseline VA and lesser amounts of anisometropia (71,72) is illustrated by the following case report.

Refractive correction can be accomplished with either spectacles or contact lenses. In the case of a large difference between the refractive error of the two eyes, contact lenses are often the treatment of choice because thick spectacle lenses may produce intolerable distortions, be cosmetically unappealing, or induce prism when viewing off axis through two lenses of significantly different power. The induced prism (especially vertical prism) may cause diplopia. Induced prism with lateral gaze is minimized with contact lens corrections—a distinct advantage, since reestablishing normal binocularity is a major part of achieving a functional cure. On the other hand, unilateral refractive differences greater than 2.00 D between the spherical equivalents of the two eyes usually result from differences in axial length. Correction of these patients with contact lenses might theoretically cause aniseikonia (Chapter 19). Empirically, however, it has been found that neither form of refractive correction (glasses or contact lenses) prevents binocularity. This suggests that binocular vision is facilitated by clear retinal images, and we suggest that a potential difference in image size with spectacle or contact lens correction should not prevent prescription of the full refractive correction.

ADDED LENSES AND PRISMS

After the best refractive correction has been determined, the next step in the sequence of management is to prescribe added lens power or prism if needed to improve eye alignment. Optimum eye alignment should facilitate redevelopment of normal interactions between accommodation and vergence and therefore enhance binocularity.

Plus (or Minus) Lens Power in Addition to the Full Refractive Correction

Added lens power can be prescribed to stimulate or relax accommodation and improve eye alignment. Added plus lenses should be prescribed for near work to reduce an esodeviation in the presence of a high accommodative convergence to accommodation (AC/A) ratio, as described in Chapter 10. Added plus lenses can also be used in the treatment of accommodative insufficiencies or accommodative inaccuracies, which often coexist with amblyopia (73). Added minus lens power may be a consideration during training if an exodeviation is present and the patient has a high AC/A ratio (Chapter 10).

Prism

If optimum eye alignment is not achieved with the refractive correction and added lenses, small amounts of prism can be included in the prescription. Special attention should be given to correction of any primary vertical phoria or strabismus. Base-out prism can be prescribed for esophoria, and vertical prism can be prescribed for hyperphoria. Convergence training is our treatment of choice for exodeviations, and base-in prism is typically not suggested.

PASSIVE THERAPY

Passive therapy can involve either occlusion (patching) or penalization (atropine therapy) of the better-seeing eye. Both treatments force the patient to use the amblyopic eye, stimulating vision improvement in that eye by reactivating the visual pathways. Thus, when the patient does not improve with spectacle correction alone, we recommend passive therapy—either part-time (rather than constant) occlusion or penalization (atropine therapy)—on the following basis.

Occlusion

Direct occlusion has been used for over 200 years as a treatment for amblyopia. Typically, patients with anisometropic amblyopia respond better to occlusion when their initial visual acuity is good (20/60 or better) (74,75), probably because there is already some binocular vision, for which occlusion has also been found to have better effect (74). Even though patients younger than 4 years tend to respond better than those older than 6 years (60,76), children up to age 17 (60,75,77) and adults also respond well to occlusion (46) or therapy. When treating anisometropic patients with occlusion, amblyopia acuity improves most rapidly initially, with the majority of improvement occurring during the first weeks (53,54,56). Notwithstanding the initial rapid improvement, around 200 hours of cumulative occlusion are typically needed for maximum results (76); thus, assuming perfect compliance, a 200-hour course of occlusion therapy takes about 5 weeks at 6 hours per day (6 hours/day \times 7 days/week \times 5 weeks = 210 hours) or 14 weeks at 2 hours per day (2 hours/day \times 7 days/week \times 14 weeks = 196 hours).

We recommend part-time (rather than constant) occlusion for patients with anisometropic amblyopia, with the times based on research with moderate and severe amblyopia (59,60,75,78–81). For moderate amblyopia (better than 20/100), begin with 2 hours of patching per day (75); for severe amblyopia (20/100 and worse), the initial patching should be 6 hours per day (79). Fortunately, even though full-time occlusion works very well for amblyopia treatment (82), part-time occlusion has been found to work just as well for patients with anisometropic amblyopia (59,60,78,79,81,83). Also, 2 hours per day of direct occlusion (when combined with active therapy [visual activities]) ultimately provides an improvement in amblyopic acuity equal to 6 hours per day (78). The more rapid improvement achieved with longer times of occlusion per day (76) is simply an effect of more quickly reaching the cumulative time required (see above), rather than any actual benefit of more hours per day. Patients should be followed about every 6 weeks. If visual acuity improves at least one line, the occlusion dosage can remain the same as the starting dosage. If visual acuity has not improved at least one line, we suggest doubling the number of hours of occlusion per day.

Schor and Wick (84) demonstrated that as few as 15 minutes of occlusion improve visual acuity for some amblyopic subjects. Notwithstanding the results of Schor and Wick, we suggest that the minimum amount of occlusion should not be substantially shorter than the 2-hour period, as found in clinical trials (78). It takes more than 7 months to reach 200 hours of cumulative occlusion at only 1 hour per day (1 hours/day \times 7 days/week \times 28 weeks = 196 hours)—too long for many patients to maintain the commitment needed for success.

Our clinical approach has been to titrate the initial time that occlusion is prescribed based on the initial aided acuity found with the best lens correction at the initial exam. As shown in Figure 17.2, when the patient has more severe acuity reduction, we recommend longer occlusion times than when visual acuity is not as compromised. This approach is consistent with the research described above (2 hours for moderate amblyopia and 6 hours for severe amblyopia). However, when acuity is severely impaired (20/200 or worse), modification of the schedule may be needed because of the problems that patients with substantially reduced acuity have when they try to perform daily tasks while occluded. Thus, if 6 hours of occlusion is too difficult for a child with severe amblyopia, we recommend initially reducing the time of occlusion. In these instances, however, we also suggest increasing the amount of amblyopia acuity training so that rapid progress will still be made by the patient. Once acuity improves to about 20/100, the time of occlusion can be increased back to 6 hours per day (Fig. 17.2).

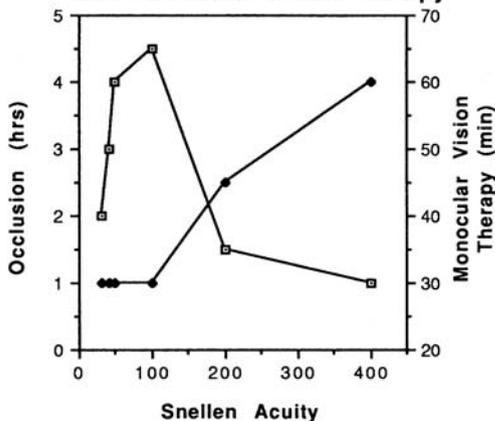
Atropine

Atropine penalization of the sound eye has been used for over 100 years as a treatment for amblyopia. Although patients with anisometropic amblyopia who are treated with atropine take slightly longer to reach maximum acuity, the ultimate acuity improvement is essentially equal for atropine and occlusion (83). Studies have demonstrated that 1% atropine used twice per week (on weekends) is as effective as daily atropine (85).

Systemic toxicity (increased pulse rate, dryness of mouth and throat, loss of neuromuscular coordination, raised blood pressure, and mental confusion) with atropine treatment is uncommonly seen with the standard clinical doses; atropine treatment is typically safe, seldom causes significant systemic distress, and is well accepted by patients and parents (85). If a child experiences systemic toxicity with 1% atropine, 5% homatropine can be used in its place. The primary clinical side effect of atropine treatment is light sensitivity due to pupillary dilation (which can be compensated with sunglasses with ultraviolet protection for outdoor wear) (85).

Taken together, these results suggest that both patching and atropine penalization are appropriate treatment modalities for the initial management of anisometropic amblyopia. Thus, after prescribing the best refractive correction with any added lenses or prism needed to help maintain binocular alignment, passive therapy should be used as the next step in the management sequence once visual acuity no longer improves with spectacles alone. Based on the discussion above, we recommend discussing the use of either part-time direct occlusion for 2 or 6 hours per day (depending on the best corrected visual acuity) or atropine

Relation between Visual Acuity, Occlusion, and Monocular Vision Therapy



■ **Figure 17.2** The amount of time spent occluding or performing vision therapy, or both, is determined by the corrected visual acuity of the patient. When acuity is very poor, relatively more time is spent initially doing active therapy (*black symbols*) and less time occluding (*open squares*), so that compliance with occlusion can be facilitated and the patient does not have to perform potentially dangerous daily tasks while occluded. As acuity improves, the time spent occluding is increased.

penalization with the parent and child. The initial choice can be made by balancing the desire for more rapid improvement with the objection to the patch while considering the issues of light sensitivity and other side effects of each treatment. Incomplete responders to one treatment should later be considered for the other treatment to be sure that maximum acuity improvement has been achieved. In general, either treatment should be continued for 2, 6-week follow-ups after improvement stops before considering the other (86).

ACTIVE AMBLYOPIA AND SUPPRESSION THERAPY

We next prescribe active monocular and binocular amblyopia therapy because active treatment, as opposed to passive management (such as occlusion or atropine penalization), has been suggested to significantly reduce the total amount of time that therapy needs to be performed in order to achieve the best visual acuity (87) (Cases 17.3 and 17.4). Figure 17.3 compares the results achieved using occlusion alone with those achieved using occlusion and active therapy (46). In a recent study (88), the Pediatric Eye Disease Investigator Group completed a randomized clinical trial to determine whether performing near activities while patching for amblyopia enhances improvement in visual acuity. The study included a total of 425 children, aged 3 to <7 years, with amblyopia (20/40–20/400) that was caused by anisometropia, strabismus, or both, and that persisted after treatment with spectacles. Children were randomized to 2 hours of patching per day with *near* activities or 2 hours of patching per day with *distance* activities. Instruction sheets describing common

Case 17.3 Sequential Management

A 6-year-old boy presented for a routine preschool examination. He had no symptoms. External and internal ocular health was within normal limits. Visual acuity and refraction with cycloplegia was as follows:

OD: +3.00 – 1.00 × 103 20/60
 OS: +0.25 20/20
 OU: 20/20

There was a comitant 3 Δ esophoria at 6 m and 40 cm. Fixation was central with both eyes. There was intermittent suppression of the right eye on Worth dot testing, and stereopsis was 140 seconds at 40 cm with Randot circles.

The cycloplegic refractive finding was prescribed. The patient returned for reevaluation in 2 weeks, with acuities unchanged from above. Three hours per day of direct occlusion and binocular antisuppression therapy were prescribed. Binocular therapy consisted of dot-to-dot books with a red pencil while wearing red/green glasses (red lens over left eye) to enhance the acuity of the right eye, and reading using a red/green bar reader to reduce suppression. Accommodative therapy using lens flippers (starting with ±1.25) was included at week 4. Over the next 8 weeks, the print was made progressively smaller and the accommodative flippers made progressively stronger as the patient's acuity and binocular status improved, as summarized in the following table.

Week	Management	Acuity of Amblyopic Eye	Stereopsis (s)
1	Exam Best prescription (spectacles)	Aided: 20/60	140
2	Progress visit; 2 hours/day direct occlusion Binocular vision therapy (VT)	Aided: 20/60 + 1	140
4	Binocular and accommodative VT	Aided: 20/40	100
6	Binocular and accommodative VT	Aided: 20/30	60
8	Binocular and accommodative VT	Aided: 20/25	40
10	Binocular and accommodative VT	Aided: 20/20	20

Case 17.4 Sequential Management of an Adult Patient

A 41-year-old man with an amblyopic right eye presented for a routine yearly examination. He had been told that he was “too old” for successful treatment, so he wore a small correction for the left eye, with a “balance” lens for the right eye when reading. External and internal ocular health was within normal limits. Visual acuity and refraction with cycloplegia was as follows:

OD: +6.00 – 6.00 × 005 20/40
 OS: +0.25 – 0.75 × 105 20/15
 OU: 20/20

There was a comitant 3 Δ exophoria at 6 m and 40 cm. Fixation was central with both eyes. There was intermittent suppression of the right eye on Worth dot testing, and stereopsis was 140 seconds at 40 cm with Randot circles.

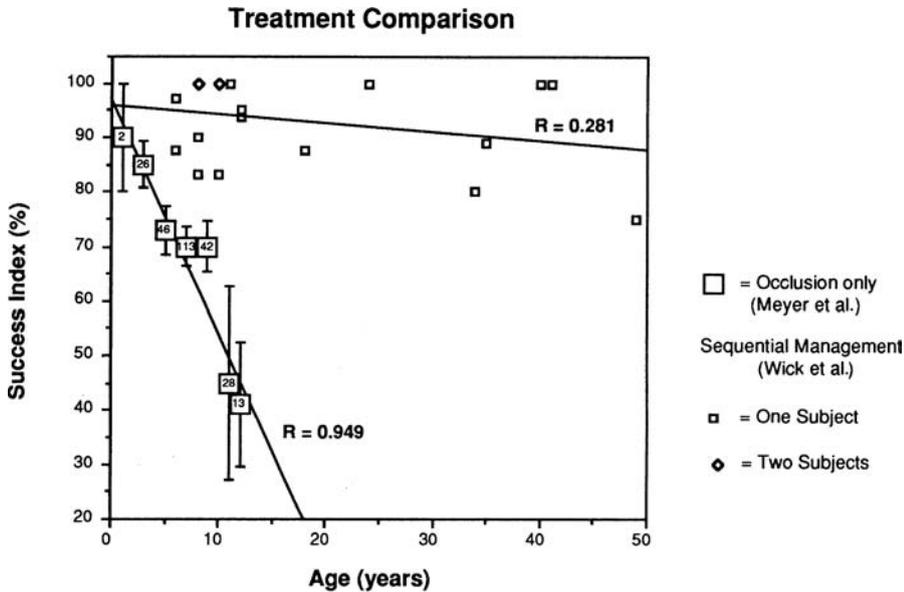
The cycloplegic refractive finding was prescribed. The patient returned for reevaluation in 2 weeks, with acuities unchanged. Two hours per day of direct occlusion and binocular antisuppression therapy were prescribed. Binocular therapy consisted of crossword puzzles with a red pen while wearing red/green glasses (red lens over left eye) to enhance the acuity of the right eye, and reading using a red/green bar reader to reduce suppression. Over the next 8 weeks, the print was made progressively smaller as the patient’s acuity and binocular status improved, as summarized in the following table.

Week	Management	Acuity of Amblyopic Eye	Stereopsis (s)
1	Exam Best prescription (spectacles)	Aided: 20/40	140
2	Progress visit; 2 hours/day direct occlusion	Aided: 20/40	140
4	Binocular vision therapy	Aided: 20/38	100
6		Aided: 20/30	60
8		Aided: 20/26	40
10		Aided: 20/20	20

These results suggest that anisometric amblyopic patients who are older than the “critical age” for development of amblyopia can achieve substantial increases in acuity with the sequential management approach described in this chapter.

near and distance activities were given to the parents. The results showed that at 8 weeks, improvement in amblyopic eye visual acuity averaged 2.6 lines in the distance activities group and 2.5 lines in the near activities group. The two groups also appeared statistically similar at the 2-, 5-, and 17-week visits. The authors concluded that performing common near activities does not improve visual acuity outcome when treating anisometric, strabismic, or combined amblyopia with 2 hours of daily patching. It is important to emphasize that this study only showed that the use of “common” or unstructured near visual activities is not useful. Thus, simply telling the parent to have the child engage in near visual activities like drawing, reading, coloring, etc. does not appear useful. It does not indicate that more structures and sophisticated vision therapy using accommodative, eye movement and binocular vision therapy is not useful. Additional study is required to evaluate the effectiveness of optometric vision therapy for improving the outcomes of amblyopia treatment.

Monocular therapy should be designed to provide stimulation of the fovea with resolvable targets. This therapy, which is done while the patient is occluded, should utilize about 20 minutes per day of the monocular stimulation techniques that have previously been shown to enhance amblyopic resolution and foster more normal eye movements and accommodation of the amblyopic eye. Because moderate amounts of central suppression are often present in patients with anisometric amblyopia, we recommend also prescribing about 15 minutes per day of binocular antisuppression therapy as soon as possible in the management program.



■ **Figure 17.3** Using only occlusion (*large squares*) results in less acuity improvement than sequential management for older patients (*small squares and diamonds*). When the patients are young, occlusion alone results in the same ultimate acuity. At all ages, sequential management probably results in the most rapid improvement.

This should be designed to force the amblyopic eye to function in a more natural and competitive binocular situation and to reinforce the normal binocular interactions that are required for a functional cure.

Sensory and Motor Function

For an ideal result, sensory and motor fusion must be maximally enhanced. For patients with anisometric amblyopia, we recommend prescription of vision therapy to treat the vergence or accommodative systems, or both. The vision therapy programs recommended in Chapters 9 to 13 outline the vergence therapy procedures to follow. Simply determine the nature of the binocular vision disorder that is present with the amblyopia and follow the vision therapy program for that condition. We also prescribe vergence facility therapy. For accommodation, monocular and/or binocular accommodative facility therapy is prescribed, with the emphasis placed on accuracy of the response. These therapies are used in an attempt to develop more normal interactions between accommodation and vergence.

An alternative amblyopia therapy has been suggested by Sherman (89). He recommends a treatment protocol for anisometric amblyopia that requires only two steps: (a) partial refractive correction of the amblyopic eye and (b) substantial time spent performing active vision therapy procedures designed to develop monocular acuity and improve binocular visual function (see Case 24.7 for a case report detailing Sherman's treatment). Occlusion is not used. Sherman's rationale is that compliance with occlusion is often difficult to achieve and that it is also difficult for patients to wear a highly anisometric spectacle correction. Because compliance is substantially related to the success of amblyopia treatment, it is obvious that any treatment protocol that will improve compliance will facilitate treatment results. However, Sherman's protocol requires more time in vision therapy than many patients are able or willing to commit, and we feel that a sequential treatment program that includes occlusion will be more effective and yield more rapid results.

SURGERY

Strabismus Surgery

Strabismus surgery has no place in the management of anisometric or isoametric amblyopia. There is generally only a small heterophoria, and surgery is not appropriate in these cases.

Refractive Surgery

For patients unable or unwilling to use contact lens, glasses, and occlusion therapy to treat the amblyopia, there may be a benefit to considering refractive surgery (90). In the absence of clinical trial data, consideration should be given to reports that after refractive surgery for recalcitrant adult amblyopic patients, best spectacle-corrected visual acuity improves by two lines, as does stereopsis, in about one-third of patients (91). In a recent review of the literature (92) the authors included studies reporting individual data of pediatric cases (age 1 to 17 years) undergoing refractive surgery. A total of 15 articles including data from a total of 213 amblyopic eyes were considered. A significant increase in visual acuity was found in the overall sample of amblyopic eyes after surgery. The authors concluded that laser refractive surgery is an effective option for improving the visual acuity in children with an amblyopic eye in association with anisometropia.

Duration of Results of Sequential Management

Typically there is a substantial improvement of acuity in the amblyopic eye when patients are treated using the sequential management protocol. There is also long-term stability of this acuity improvement (93,94) The Pediatric Eye Disease Investigator Group followed children who had been treated for amblyopia when they were 3 to <7 years old until they reached the age of 10 years old. The mean amblyopic eye acuity, measured in 169 patients, at age 10 years was approximately 20/32, and 46% of amblyopic eyes had an acuity of 20/25 or better. The authors concluded that at age 10 years, the improvement of the amblyopic eye is maintained, although residual amblyopia is common after treatment initiated at age 3 years to younger than 7 years. The outcome is similar regardless of initial treatment with atropine or patching.

With sequential treatment of patients with anisometropic amblyopia, regression of acuity is unlikely. Re-establishing normal binocular function has been shown to be an important factor for preventing regression (95). Further, maintenance therapy is also less likely to be required by patients who are older at the time therapy is completed. However, sometimes younger patients regress. Thus, although acuity gains are typically relatively long-lasting, it is probably important that maintenance therapy be continued until the patient reaches age 8 or 10 and is less likely to regress.

Two prospective studies have investigated the issue of recurrence (96,97). In a prospective study of cessation of treatment in children with successfully treated amblyopia due to anisometropia, strabismus, or both, the authors found the risk of amblyopia recurrence to be 24% (96). They also found that patients treated with 6 or 8 hours of daily patching had a fourfold greater chance of recurrence if patching was stopped abruptly rather than being reduced to 2 hours per day prior to cessation. The authors referred to the gradual reduction of treatment as “weaning” (96). They also found that the risk of recurrence was higher with better visual acuity at the time of cessation of treatment, a greater number of lines improved during the previous treatment, and a prior history of recurrence. Orthophoria or excellent stereoacuity at the time of patching cessation did not have a protective effect on the risk of recurrence (97).

In a prospective study of 88 older amblyopic children between 7 and 17 years of age, visual acuity improvement of ten or more letters (two or more lines) that occurred with patching/atropine treatment was generally sustained during 1 year of observation after treatment other than refractive correction was discontinued (61). The 1-year probability of a worsening of acuity of ten or more letters (two or more lines) was only 7% (61).

The risk of recurrence of amblyopia and absence of protection from orthotropia and excellent Randot dot stereoacuity suggest that careful and prolonged follow-up is needed for all children who have been previously treated for amblyopia.

Summary and Conclusion

We suggest that a systematic approach to visual remediation of the anisometropic amblyope will yield a substantial functional improvement for all patients, a result dramatically better than that seen with occlusion alone. The key points are as follows:

1. Provide the full refractive correction for each eye.
2. Use added lenses or prism, when needed, to maximize alignment of the visual axes.

3. Occlude 2 to 6 hours per day or use atropine penalization of the sound eye (one drop at bedtime 2 days per week).
4. Utilize approximately 30 minutes per day of active therapy to develop monocular acuity and improve binocular function.

Following such a sequential plan for treatment of anisometropic amblyopia can yield a long-lasting improvement in visual acuity and binocular function for patients of any age, demonstrating that the plastic period extends well into adulthood and suggesting that the age of the patient should not be a factor in determining whether or not to institute therapy.

Study Questions

1. At what age is the amblyopic patient too old to treat?
2. Differentiate between the critical and sensitive periods, as defined in this chapter. Explain why the difference might be important in treatment of patients with amblyopia.
3. Describe the main amblyogenic factors in refractive amblyopia and how their presence or absence influences the diagnosis of patients with amblyopia.
4. Why do patients with anisohyperopia have amblyopia with less refractive error difference than those with anisomyopia?
5. Why is full refractive correction an important part of the management sequence listed in this chapter?
6. How important is compliance in treating amblyopia patients?
7. How would you increase compliance with treatment? Of the techniques listed in this chapter, which seem like they would work best for you in your practice?
8. In prescribing occlusion, what issues influence how long to occlude the patient with refractive amblyopia?
9. Support or refute this statement: Occlusion success is directly related to age.

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Nystagmus

Nystagmus can present a difficult diagnostic challenge for even the most experienced clinician. The varied etiologic factors include genetic and developmental anomalies, as well as active pathology (which can occur at any age). When nystagmus is present, patients often experience considerable anxiety; while hoping for the best, they are forced to rely on the clinician's knowledge, experience, and management skill. To properly manage nystagmus patients, it is necessary to describe/diagnose the relevant characteristics, classify the condition, identify the possible causes and associations, and determine and implement appropriate management.

This chapter describes examination techniques, differential diagnosis, and treatment for many of the common types of nystagmus seen in clinical practice. The examination and diagnostic emphasis is on determination of the underlying disorder, since nystagmus is typically not a discrete disease entity. In many instances, the clinician's primary consideration is to identify and provide access to treatment of the underlying condition. When nystagmus treatment is indicated, therapy is designed to dampen the oscillations and reduce symptoms. In most cases, functional (and sometimes cosmetic) improvement is possible.

Virtually, all nystagmus patients should have aggressive management following a careful diagnosis. It is not acceptable to simply monitor these patients without treatment. It is possible to improve acuity, ocular motor control, cosmesis, and visual comfort using sequential considerations of (a) correction of the refractive error with spectacles or contact lenses, (b) prisms to improve fusion, induce convergence, and reduce a head turn, and (c) vision therapy to improve fusion capability and enhance stability of fixation. Surgery and medication also have an application in certain cases.

Etiology and Prevalence

DEFINITION AND ETIOLOGY

Nystagmus (involuntary rhythmic oscillations of one or both eyes) may be the presenting sign of either a pathologic afferent visual pathway lesion or a disorder in ocular motor control (1). Nystagmus can be considered a disorder of the mechanisms that keep fixation/eye position stable (2). The pursuit, optokinetic, and vestibular systems act to maintain a steady image on the retina (3). Any lesion that creates an imbalance in these neurologic systems can make the eyes drift off target, requiring a saccadic movement to regain fixation; continual drifts and refixation saccades result in horizontal or vertical nystagmus. Torsional nystagmus results when there is an instability of vertical eye position requiring continual repositioning.

The appearance of nystagmus causes considerable distress for parents and other family members. Its presence usually is interpreted as a sign of serious visual dysfunction or possibly brain damage. Patients with nystagmus challenge a clinician's skills in differential diagnosis, sensitive communication, and management.

PREVALENCE

Nystagmus affects about 1 in every 5,000 to 10,000 persons (4). It is much more prevalent, however, in patients who have certain ocular or systemic health conditions. For example, a large percentage of persons with albinism have nystagmus (5), and 13% of cerebral palsy patients have nystagmus (6). Approximately 10% to 15% of visually impaired school-aged children have nystagmus (7). Nystagmus that starts before age 6 months is termed *infantile nystagmus* (8).

Characteristics

Detailed observation and a comprehensive case history usually provide sufficient information to determine the type and cause of nystagmus. Complete description of nystagmus requires evaluation of postural affections, type and direction of oscillations, amplitude and frequency of the nystagmus, symmetry between the movement of the two eyes, constancy, and the latent component, as well as evaluation of movements in all fields of gaze and with convergence (Table 18.1).

As in the strabismus examination, it is essential to initially make an overall observation of the patient's general posture, head position, and facial characteristics. These observations can be made by visual inspection at three fixation distances in the primary position: (a) distance fixation (4 to 6 m), (b) near fixation (50 to 100 cm, simulating a common distance of social interaction), and (c) at the preferred reading distance. The same observations should be repeated with the patient assuming the preferred head position and at the computer if the patient spends much time on this task.

The importance of these observations is that they allow determination of the patient's performance in real life as well as examination situations. Because the oscillations present in some forms of nystagmus decrease in certain fields of gaze, many patients have a habitual head tilt or face turn. The cosmesis of the nystagmus and other disfiguring conditions (e.g., facial asymmetries, ptosis, or strabismus) can be a major social concern of the parents or patient. In addition to influencing cosmetic and functional considerations, careful observation may provide diagnostic information concerning the cause of the nystagmus.

Observation of the characteristics of nystagmus should be made under magnification using slit lamp, a high plus lens or loop, and a penlight or ophthalmoscope. Slit lamp inspection, which is preferable, is usually possible with children aged 2 years or older. An assistant can attract a young child's attention with sounds or small toys.

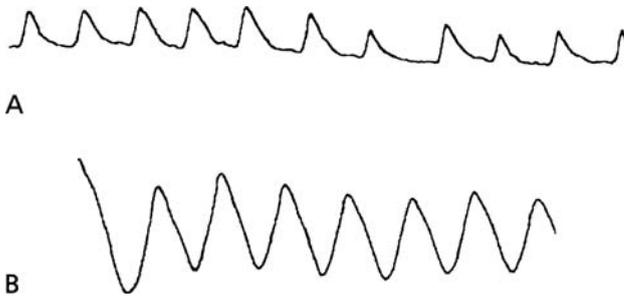
Primary diagnostic characteristics include the type and direction of oscillations. Nystagmoid eye movements are typically classified clinically into two broad categories: jerk and pendular.

- *Jerk movements* have both quick and slow components (Fig. 18.1A). There may be intervals, known as *foveations*, in which the eye movement is relatively slower for a short duration as the target crosses the fovea and then the velocity increases. At some point, there is a fast corrective saccade to bring the eyes back on target. If the foveations are of sufficient duration (approximately 60 milliseconds [ms]) and accuracy, visual acuity may not be significantly impaired (9). Differential diagnosis of patients who can be helped with therapy will thus depend upon determining the accuracy and duration of the foveations. Patients with short-duration inaccurate foveations are much more likely to have a satisfactory increase in acuity with a vision therapy program.
- *Pendular movements* consist of to-and-fro eye movements of approximately equal velocity in each direction (Fig. 18.1B). A pendular waveform can be sinusoidal (smooth transition to the opposite direction) or triangular (an abrupt direction shift).

Occasionally, the waveform (and sometimes the direction of the waveform) alternates between jerk and pendular as a function of position of gaze or time. This is more common in patients with infantile nystagmus. Research (10) shows that "horizontal" nystagmus typically includes a torsional component and that, in many

TABLE 18.1 CLINICAL CHARACTERISTICS OF NYSTAGMUS

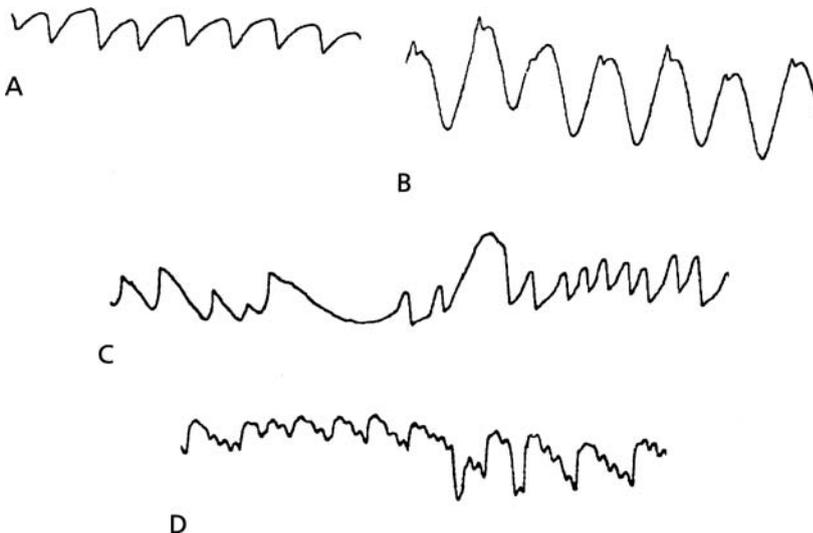
Observation	Posture, head position (face turn or head tilt)
Nystagmus	
Amplitude	Small (<2°), moderate (2 to 9°), or large (>10°)
Direction	Horizontal, vertical, torsional, or combined
Frequency	Slow (<0.5 Hz), moderate (0.5 to 2 Hz), or fast (>2 Hz)
Type	Jerk, pendular, or mixed
Conjugacy	Eyes move in same direction; disconjugate means eyes move independently
Constancy	Always present, intermittent, or periodic
Symmetry	Symmetrical, asymmetric, or monocular
Field of gaze changes	Null point in some field of gaze or change in nystagmus with convergence
Latency	Increase or change with occlusion of one eye



■ **Figure 18.1** **A:** Eye movement traces are shown for a patient with jerk nystagmus. There is a fast phase (saccade) toward the top of the figure and then a drift away from the target. **B:** The eye movement trace shows pendular nystagmus. There are approximately equal velocity movements in both directions, with a fairly smooth transition between directions of movement (sinusoidal).

patients with infantile nystagmus, the waveform is actually seesaw, with a large horizontal component, a smaller torsional one, and an even tinier vertical component (11). There are also patients who alternate the direction of the fast phase of the waveform, generally as a function of time (periodic alternating nystagmus). Figure 18.2 shows many of these variations, which can easily be missed if eye movements are not inspected under magnification or evaluated with eye position detectors.

Nystagmus is described clinically with reference to the horizontal (x), vertical (y), and rotary (z or anterior polar) axes, because the eyes may move in one, two, or all three directions. Most of the time the clinical description is of the most visible movement (e.g., jerk right) because the other, more complex components (vertical and torsional) are not easily recognized without eye movement recordings. Jerk nystagmus is characterized by the direction of the fast component (right, left, up, or down) in addition to description of the type of movement (e.g., jerk right nystagmus). Describing jerk nystagmus based on the direction of the quick phase can be misleading because the slow phase of nystagmus usually reflects the underlying abnormality. The eyes drift from the target because of a neurologic imbalance in the position maintenance (fixation) system, and the quick phase of nystagmus is a correcting saccade to return the fovea to the target (12).



■ **Figure 18.2** **A:** The eye movement trace shows jerk nystagmus, with fairly long foveations indicated by the flat portion of the trace. **B:** The eye movement trace shows pendular nystagmus, with foveating saccades seen at the top of the waveform. **C:** This patient's eye movements are an example of periodic alternating jerk nystagmus. Note the center of the trace, where the patient's nystagmus switches direction. **D:** Pendular and jerk nystagmus are superimposed for this patient's waveform.

The amplitude and frequency of the nystagmus are additional diagnostic features. The amplitude can be estimated using a millimeter ruler or a reticule in the magnifier used to evaluate the type of nystagmus. As the patient fixates a target at 6 m, measurement of the overall excursion is made by holding the ruler in front of the eye with the best acuity (either eye, if the movements are conjugate). One millimeter of movement at the plane of the cornea translates to about 22° (12° degrees of visual angle) (13). Therefore, if 2 mm of movement is noted, the eyes are moving approximately 24° .

One Hertz (Hz) (1 cycle per second) means that the waveform completes one full rotation in 1 second. Frequencies greater than 2 Hz are considered fast, and frequencies less than 1 Hz are considered slow. Frequencies slower than 2 Hz can be timed with a stopwatch as the oscillations are counted. More rapid frequencies can be estimated with observation under low magnification of the slit lamp.

Additional features of nystagmus that should be routinely investigated include variations in different fields of gaze, changes with occlusion, and changes with visual demand. Frequently, patients are seen who have nystagmus waveform changes (pendular to jerk) when changing fixation between left or right gaze. Such patients may have a habitual head turn or tilt favoring one position of fixation. The amplitude of nystagmus may decrease with convergence, and the eye movements should be observed during testing of the near point of convergence. Many patients with nystagmus have a latent component revealed by covering one eye. In patients with latent nystagmus, the fast phase of the waveform is toward the uncovered eye, and the amplitude and frequency often increase. A latent component usually indicates a congenital rather than an acquired condition, and treatment that restores or enhances binocularity often reduces the nystagmus and improves acuity. Contrary to clinical wisdom, objective measurements do not indicate that the severity of infantile nystagmus increases with visual demand. However, these studies do not deny that nystagmus increases because of stress (14,15).

Some patients have nystagmus that is characterized by variations in conjugacy, constancy, and symmetry between the eyes. Prolonged observation may be required to evaluate these features. For example, spasmus nutans can be constant or intermittent, appearing to start and stop randomly (16). It may be present more in one eye than the other and only during purposeful fixation. The rapid pendular oscillations are typically conjugate but may have unequal amplitudes in each eye. Occasionally, patients are seen who appear to have monocular spasmus nutans; close inspection of the “quiet” eye usually indicates a conjugate movement.

Clinical Evaluation

Most of the equipment and procedures used for evaluation of patients with nystagmus are used in many clinical vision examinations. However, these procedures must be modified to obtain the clinically relevant information; it is awareness of how and when to modify the usual clinical evaluation that makes clinical care of nystagmus patients an art.

PATIENT HISTORY

Onset, Associated Conditions, and Symptoms

The usual case history must be expanded to include a number of additional questions when evaluating patients with nystagmus. These include questions relating to the onset (i.e., at birth, before 6 months of age, or specifically when) and association of the onset with any infection, drugs or medications, metabolic disease, or trauma. Answers to such questions can help establish the often elusive cause of nystagmus. Information must be sought about observations by the parents or patient concerning variability of the frequency, amplitude, position of gaze, or time characteristics of the nystagmus. Symptoms should be assessed, especially those related to visual acuity, visual discomfort, periodic blurring of vision, or oscillopsia. Except for the severely visually impaired, children with congenital nystagmus seldom complain of visual symptoms.

Neurologic and Developmental Factors

General questioning concerning neurologic and developmental factors should be added to the questions about the features of the nystagmus. Investigate general neurologic signs or symptoms, including dizziness, local pains, numbness, poor balance, ringing of the ears, seizures, uncoordinated movements and gait

irregularities, weakness, or other recent unusual symptoms. By the age of 7 or 8 years, most children can be quite accurate in their answers. In young children, the Denver Development Test can be used to evaluate developmental status, including language acquisition, social development, and gross and fine motor coordination and perception.¹

Genetic Factors

Many of the motor and sensory causes of nystagmus are inherited (17); as interest in genetic research increases, more genes may be identified that are associated with infantile nystagmus (18). To determine a possible hereditary nature, the family history should investigate at least three generations for nystagmus and other visual disorders. This information will help determine the hereditary pattern of a disorder. When a family inheritance pattern is apparent, referral to a genetic counselor is an important part of management.

REFRACTIVE ERROR

The clinical impression that patients with nystagmus have a higher prevalence of significant refractive error is not well documented. However, in most cases, it is reasonable to assume that a significant refractive error is present until examination provides contrary findings. Patients who have nystagmus resulting from a sensory etiology sometimes have considerable improvement in ocular motor control and binocular fusion simply from correcting a significant refractive error.

Determining the refractive error in patients with nystagmus can be a trying experience. The most efficacious procedure is cycloplegic retinoscopy, usually using 1% cyclopentolate. The accuracy of retinoscopy can be enhanced by directing fixation to a gaze position that gives maximum ocular stability. Most patients turn their heads to the null position automatically, but sometimes a parent or assistant may have to hold the patient's head in the proper position. Use trial lenses or a lens bar so that the refractive error can be measured directly along the optical axes and the two eyes can be quickly compared. Sometimes determination of astigmatism can be difficult. Use of a Placido disc or illuminated keratoscope can help identify corneal astigmatism or detect an optical irregularity when the eyes are directed to the position of least nystagmus. It is always wise to reevaluate the refraction on subsequent visits.

VISUAL ACUITY

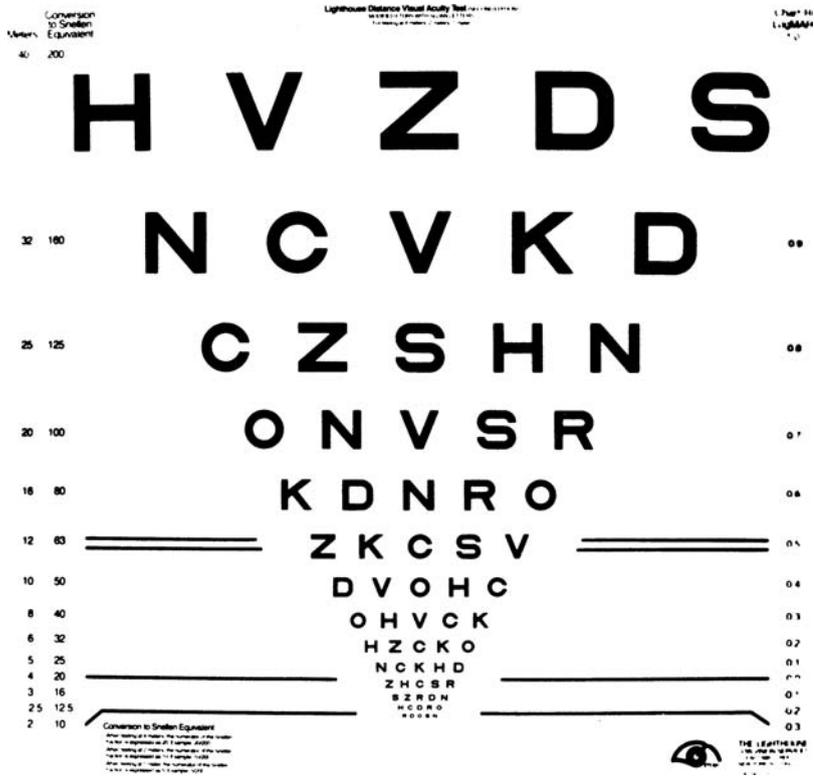
Visual acuity in patients with nystagmus varies from nearly normal to severely impaired, depending on the etiology, associated conditions, and waveform. Nystagmus caused by disturbances of motor coordination usually results in less severe disturbances than nystagmus secondary to sensory conditions such as albinism, aniridia, or congenital cataracts. Indeed, some patients with motor etiology have normal or near normal acuity. For these patients, nystagmus may be a cosmetic problem without significant visual deficit. Visual acuities of adult patients without major sensory impairment typically are not worse than 20/80.

Acuity testing of patients who read optotypes can proceed in the standard manner. It is often more reliable to determine line or single-letter acuity with children rather than to assess full-chart Snellen acuity. When visual acuity is reduced, a Bailey–Lovie chart (with logarithmic proportionally spaced letters) or low vision chart may be needed (Fig. 18.3). Determine acuity thresholds at distance (6 m) and at near (40 cm) for each eye independently, as well as for binocular viewing. Allow the patient to assume the preferred head position for distance and near testing.

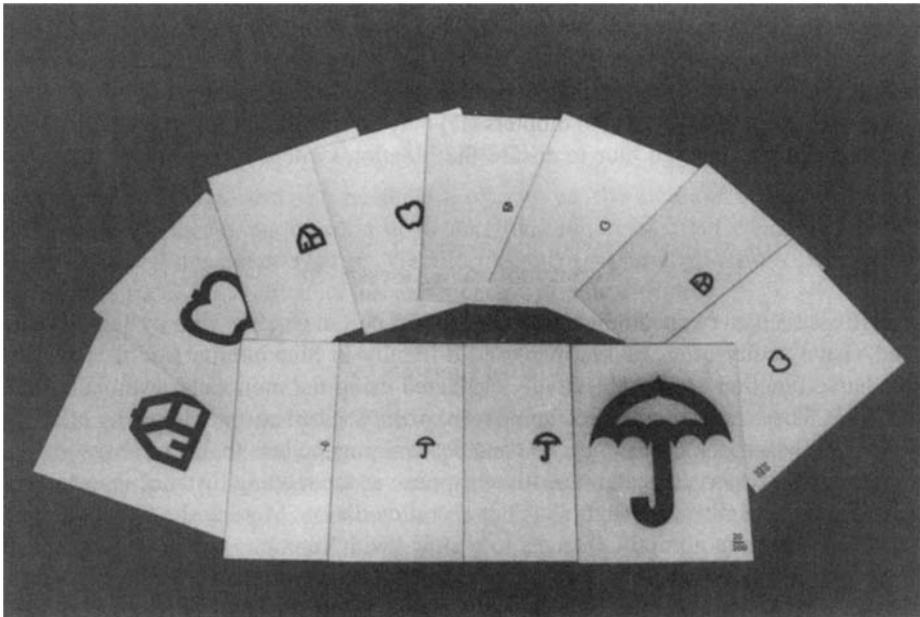
Preschool children may need to be evaluated with hand-held figure cards (Fig. 18.4), and it may not be possible to determine an exact clinical acuity for children younger than 2 years. However, an indication of visual ability can be determined by comparing visual and hand–eye behavior with each eye. For example, if an infant objects to having a particular eye covered, amblyopia or some other deficit of monocular visual acuity should be suspected. When deficient visual acuity is suspected in these patients, a visual evoked potential (VEP) acuity threshold should be considered.

Monocular acuity differences are frequently seen in patients with nystagmus. Clinical differentiation needs to be between amblyopia (functionally reduced acuity in one eye) and latent nystagmus (in which the nystagmus increases in amplitude with occlusion). If there is high astigmatism, anisometropia, or strabismus—and amblyopia is suspected—a comparison of the acuity thresholds may help make a differential diagnosis.

¹The Denver Development Test is available from Denver Developmental Materials, Inc, Box 6919, Denver, CO 80206-0919.



■ **Figure 18.3** The Bailey-Lovie acuity chart has logarithmic proportional spacing. Because each line has the same number of test characters with the same spacing, the Bailey-Lovie chart is ideal for evaluation of patients with nystagmus or amblyopia.



■ **Figure 18.4** Occasionally, preschool children are not able to accurately respond when Snellen letters are used. In these instances, a hand-held acuity test card can be substituted.

Contour interaction bars may be useful because they tend to depress the acuity threshold more in an amblyopic eye (19).

Latent nystagmus is characterized by an occlusion-induced increase in jerk nystagmus that has a fast phase in the direction of the uncovered eye. When nystagmus increases with occlusion, assess acuity using a method that does not disassociate the eyes, such as the vectographic adult slide, or use a plus lens and blur one eye while measuring the acuity of the other eye. Use enough plus (usually between +2.00 and +5.00 D) to blur the eye without totally disrupting binocular vision, so that the latent nystagmus does not become manifest.

BINOCULAR VISION AND OCULAR MOTILITY

It is often difficult to assess binocular vision in a patient whose eyes are constantly moving. However, binocular evaluation is important because sensory and motor fusion can stabilize nystagmus in patients who have latent or manifest latent nystagmus.

Preliminary Testing

Preliminary testing is performed in the usual manner. Changes in the type, frequency, and amplitude of nystagmoid movements can be evaluated as the patient follows a penlight into the nine diagnostic fields of gaze. Gross convergence ability can be investigated using the penlight, although a small letter, picture, or toy provides a better accommodative stimulus (patients with infantile nystagmus often have a decrease in the nystagmus at near with convergence (20) which does not lead to an immediate improvement in acuity (21)). Investigating pupil responses using a penlight in dim room illumination will reveal the direct, consensual, and accommodative reflexes, and a swinging light test will detect the presence of an afferent pupillary defect.

Motor Alignment

Angles of strabismus greater than 20 to 25 Δ are usually cosmetically evident, and comitancy can often be determined by direct observation of variations in the angle of deviation in different fields of gaze. Because of the constant eye movements, observations on the unilateral and alternate cover test are often equivocal when there is a small-angle strabismus or heterophoria. A direct comparison of eye alignment can be gained using the Bruckner technique. This procedure is performed by simultaneously illuminating both eyes with an ophthalmoscope and observing the reflex at 0.5 m (22). If possible, observations should be made in the primary position and a position of gaze in which the oscillations are minimum. As the patient fixates the light, the clinician observes the corneal light reflexes within the red pupillary reflex. If the corneal light reflexes are in the same position and have symmetrical limits of movement within the red reflexes, binocular alignment is suggested. Strabismus or uncorrected refractive error causes unequal brightness of the red reflex, and, as in the Hirschberg test, when the corneal light reflexes are not symmetrically located, each 1 mm of difference between the eyes indicates 22 Δ of strabismus (13). To roughly measure the angle of deviation, prisms can be inserted in front of one eye until there is symmetry of the corneal light reflex movements (Krimsky technique) (23).

Although the presence of nystagmus may make observations less reliable, the cover test should be attempted in the primary position and the null position. Typically, a standard occluder is used, and the unilateral and alternate cover tests are performed using the conventional technique. However, when there is a latent component and nystagmus increases with occlusion, a trial case plus lens of about +5.00 diopters (D) may be substituted for an occluder. The plus lens occluder causes enough blur to ensure that fixation switches, but seldom increases the intensity of nystagmus.

Accommodative Assessment

Subjective assessment of accommodation may be difficult in patients with nystagmus because reduced visual acuity often causes increased difficulty in blur interpretation. However, accommodative function can be objectively evaluated using the monocular estimation method (MEM) (24). The accuracy of the accommodative response can be determined by briefly placing a plus lens before the eye being tested and determining the lens that neutralizes movement of the reflex. The observed accommodative response at the reading distance is usually a fast “with” motion, indicative of a slight lag of accommodation. Moving the target closer until the fast “with” motion abruptly changes to a slow “with” motion will allow determination of the accommodative

amplitude. Although reduced accommodative function is not unusual when there is reduced visual acuity, a large difference in MEM findings between the two eyes may indicate a third nerve lesion. Accurate objective measurement can be compromised by eye movements and inattention; thus, repeated observation of deficient responses is often necessary for accurate diagnosis.

Sensory Testing

Stereopsis and suppression testing can be very valuable when evaluating the nystagmus patient. Stereopsis testing is useful because there is probably a heterophoria when stereopsis is at least 100 seconds of arc (25). Suppression testing will often suggest which patients should have a vision therapy program. In general, heterophoric patients who have suppression on the Worth four-dot test or on Mallett testing at near should undergo treatment to reduce suppression. Reduction in suppression with vision therapy can stabilize nystagmus and increase visual acuity in patients who have latent or manifest latent nystagmus.

OCULAR HEALTH AND SYSTEMIC HEALTH

Ocular Health

The ocular health examination is conducted in the usual manner.

Slit Lamp Evaluation

Most patients can cooperate for slit lamp examination. However, if a child is too young, direct ophthalmoscopy using a high plus lens can be substituted, or a hand-held slit lamp can be used.

Ophthalmoscopy

Direct and indirect ophthalmoscopy with pupil dilation is needed to complete inspection of the posterior pole and retinal periphery. However, even full dilation sometimes is not sufficient to allow detailed evaluation when the nystagmoid movements are too great. If the patient's gaze can be directed to a null point, the fundus examination can generally be successful. When assessment at the null point is not satisfactory, fundus photographs will allow a detailed view because the strobe flash stops movement and provides a clear photographic record of the retinal features.

Tonometry

Air tonometry may yield the best result, if a reading can be attained. Unless the patient is under general anesthesia, applanation or indentation tonometry often yields poor results in nystagmus, due to the eye movement. Tactile (digital) pressures give a gross screening of interocular pressure, if the clinician has experience with this method.

Visual Fields

Visual field testing is generally difficult with nystagmus patients because of the frequent changes in fixation. Monocular confrontation perimetry, using targets approaching from various angles in the periphery, is a reasonable technique to screen for gross field defects. Automated perimeters can be used, as long as the clinician realizes the limitations on interpreting the results because of the variable fixation.

Oculomotor Movement Systems

Because nystagmus can result from an imbalance or disorder in one or more of the systems that maintain foveal fixation, it is important to investigate the optokinetic and vestibular systems.

Optokinetic Nystagmus

As part of nystagmus evaluation, it is important to determine whether optokinetic nystagmus (OKN) is functional. True OKN is accompanied by a sensation of self-rotation or movement, and precise OKN testing requires a moving stimulus that fills the field of vision. This cannot be achieved using hand-held drums or

tapes that test the pursuit system; rather, the patient must sit inside a large, rotating, patterned optokinetic drum. The drum is rotated opposite to the nystagmus direction to investigate the integrity of OKN responses. Thus, if there is horizontal nystagmus, the drum should be slowly rotated vertically. A reduced OKN response suggests a lesion involving that system.

Vestibular System

The visual system is limited by relatively slow (about 70 ms) retinal processing and cannot act rapidly enough in the presence of head movements to maintain a steady retinal image. The vestibulo-ocular reflex (VOR), which depends upon motion sensors in the labyrinthine semicircular canals and has a latency of only 10 ms (26), stabilizes gaze to maintain clear vision during head movements. Vestibular nystagmus is accentuated when fixation targets are removed, so the patient should be observed with the eyes open and watching the lid motion with the eyes closed. If the amplitude of the jerk nystagmus increases with the eyes closed, vestibular nystagmus is suspected. Head shaking can also be used to increase vestibular nystagmus. After the head has been vigorously shaken for 10 seconds, the eyes are observed under magnification for an increase in nystagmus. The headshake test should be repeated with horizontal and vertical shaking.

Evaluation of VOR function involves (a) caloric testing to detect dynamic imbalances and (b) rotational testing, which generally gives more accurate and reproducible results than caloric tests (27). In caloric testing, which induces nausea in some people, the patient is positioned with the head elevated at an angle of 60 degrees. Water is slowly poured into one ear, with the head turned to one side, and the direction of the fast phase of induced nystagmus is observed. If cold water stimulates the right ear, the fast phase of induced nystagmus moves toward the left; however, if warm water is used in the same ear, then the fast phase is to the right (cold opposite, warm same—COWS). If differences are observed between the two eyes, a lesion in the vestibular track should be suspected.

Eye Movement Evaluation

If possible, the eye movement patterns should be evaluated using infrared or video-based eye movement monitors (27). Although this testing is not routinely performed by most clinicians, it is very helpful for diagnostic and treatment purposes. Parameters to evaluate include the type of waveform, the length of time and accuracy of foveations, and the velocity of the nystagmus. Refer to Figure 18.2 for the appearance of the eye position records for some of the important characteristics of nystagmus.

Specialized Testing

Computerized tomography (CT) scans and magnetic resonance imagery (MRI) are not routine procedures for the diagnosis of patients with congenital nystagmus. These procedures should be suggested in acquired nystagmus where active brainstem, cerebellar, or cortical lesions may be present (28).

Differential Diagnosis

Once the examination is complete and the characteristics of the nystagmus and associated conditions are noted, the proper diagnosis must be made so that appropriate management can begin. This section reviews the common types of nystagmus seen in clinical practice. The clinical observations are summarized in Table 18.2.

INFANTILE NYSTAGMUS

Nystagmus that is present at (or shortly after) birth is referred to as *infantile nystagmus*. Infantile nystagmus affects males twice as frequently as females (29). Although this common form of nystagmus has variable presentations, it has certain characteristic clinical features (Table 18.2). Strabismus may be difficult to detect because of the nystagmus; as a result, the incidence of strabismus may be underestimated, although it is estimated to be about 40% to 50% (30). Most of the time, the nystagmus and strabismus are part of the underlying systemic or visual defect, but the etiology of strabismus can be independent of the nystagmus.

The neuropathology of infantile nystagmus is not well understood, but the etiology has been broadly classified as afferent or efferent. Afferent nystagmus, which constitutes about 40% of all infantile nystagmus,

TABLE 18.2 CHARACTERISTICS OF SELECTED FORMS OF NYSTAGMUS

	Infantile (congenital)	Latent	Physiologic	Vestibular	Voluntary
Amplitude	Variable	Variable	Small	Increase with gaze toward fast phase	Small, 2° to 3°
Constancy	Usually constant; occasionally quiet	Occurs with occlusion of an eye	Occasional; worse when tired	Constant if central; intermittent if peripheral	Occasional, about 30s at most
Direction	Usually horizontal; rarely vertical	Horizontal; fast phase toward the nose	Horizontal	Often horizontal or mixed; never just vertical if peripheral	Horizontal
Frequency	Variable. Lower in albinism (55).	Variable	Rapid	Increase with gaze toward fast phase	Very rapid, up to 40 Hz
Gaze direction	Increases in periphery	Decrease in gaze toward covered eye	Occurs in extreme lateral gaze (>30°)	See above	Convergence
Latency	Usually	Yes	Sometimes	None or reduced if cerebellar; increased if vestibular	None
Waveform	Pendular (genetic) and/or jerk (albinism) (55)	Jerk	Jerk	Jerk	Sawtooth saccades
Associated conditions	Esotropia (more in albinism) (55), amblyopia, astigmatism, head shaking	Esotropia, amblyopia, astigmatism, head shaking	None	Neurologic signs if central; deafness or tinnitus if peripheral	None; malingering in school children
Etiology	Congenital	Congenital	Fatigue	Vestibular nucleus or nerve damage	May be hereditary
Symptoms	Reduced acuity (worse in albinism) (55), cosmesis	Reduced acuity when one eye is covered	Blur on lateral gaze	Vertigo, nausea	Oscillopsia
Comments	May improve with age; treatments help	Complicates examinations	Rest relieves the symptoms	Caloric testing, central has lower prevalence	Trick of the eyes that about 8% of persons can do



■ **Figure 18.5** The flat portions at the top of the eye movement trace indicate very long foveations. These foveations are also accurate, since they appear in the same position in the eye movement each time. This patient's acuity was 20/25+, and the main complaint was a cosmetically noticeable jerk nystagmus.

is associated with poor visual acuity, and the etiology is usually obvious upon clinical examination. Acuity reduction is typically substantial, with only a moderate prognosis for improvement. Congenital diseases of the eye or the afferent visual pathway that might result in reduced acuity and subsequent nystagmus include achromatopsia, aniridia, cataracts, ocular albinism, and optic nerve atrophy or hypoplasia. About 60% of cases of infantile nystagmus are considered to result from some disorder of the ocular motor systems. Such efferent nystagmus may result from disorders or lesions of the pursuit system at the brainstem (26). For example, Lo (31) reported brainstem abnormalities in 50% of infantile nystagmus patients; using CT testing and MRI scanning may identify even more. In many efferent cases, the etiology remains idiopathic. Fortunately, the patient with efferent infantile nystagmus generally has better visual acuity than those with afferent types. Further, acuity in a child with efferent nystagmus may even improve with the child's development.

In efferent forms, acuity is affected in varying amounts, depending on the nystagmus waveform. In cases with good acuity, inspection of the nystagmus characteristics using an eye movement monitor can reveal prolonged foveations. Figure 18.5 demonstrates jerk nystagmus, and the eye movement record reveals that the foveation is on target long enough for good acuity. Thus, some patients experience only minimal visual impairment, even though their nystagmus may be cosmetically disfiguring. Even though these patients may not be severely restricted in visual activities, clinical treatment can help them achieve better ocular control. This will improve cosmesis and perhaps acuity, comfort, and visual efficiency.

Infantile nystagmus usually is conjugate and horizontal, although there are occasionally vertical, torsional, or even combination waveforms. When nystagmus is horizontal, it usually remains horizontal even on upgaze and down gaze. The most prevalent oscillation pattern is jerk, but pendular and spontaneous or gaze-induced variations from one waveform to another are also frequently seen. When there is a jerk waveform, the fast phase typically occurs in the direction of gaze (32).

Often there is an increase in amplitude in some field of gaze, and patients frequently adopt a face turn or head tilt in an attempt to decrease the nystagmus. The position of gaze at which the eyes are quiet is known as the *null region*. In all forms, the amplitude and frequency often vary, although there may be head nodding or shaking, and occasionally the eyes may become quiet. Active fixation, attention, or anxiety can increase nystagmus, and convergence and purposeful lid closure may diminish it. There is rarely oscillopsia, even though the eyes are often in constant motion. A latent component to the nystagmus is commonly observed upon covering one eye. Treatment is to increase foveations, decrease nystagmus amplitude, and enhance binocularity.

LATENT NYSTAGMUS

Latent nystagmus is a congenital condition that is often associated with strabismus (especially congenital esotropia) and amblyopia, although it occasionally occurs independent of other visual conditions. There is a conjugate jerk nystagmus evoked by occlusion of one eye (Table 18.2). Additionally, a latent component to congenital nystagmus is often seen. The jerk pattern of latent nystagmus is characterized by a fast phase in the direction toward the fixating eye, and the amplitude increases when gaze is directed temporal to the fixating eye. Acuity is typically better with both eyes open than with either eye occluded. Therapy is to maximize binocular vision and minimize suppression.

NYSTAGMUS BLOCKAGE SYNDROME

Although the mechanism is not fully understood, the association of an infantile nystagmus in a patient who later develops an esotropia is known as *nystagmus blockage syndrome*. In these patients, there is an abnormal head posture, with the head turned toward the adducted fixating eye (e.g., a right head turn if the fixating eye is the right eye). The fixating eye remains adducted even with occlusion of the fellow eye. Nystagmus is reduced or absent on adduction of the fixating eye and increases as the fixating eye moves toward the primary position and into abduction. The condition can simulate paralysis of the lateral rectus, but abduction can be demonstrated, indicating pseudoparalysis of abduction.

The cause is theorized to be development of hypertonicity of the medial rectus (resulting in esotropia and suppression of the fellow eye), brought about by holding the fixating eye in adduction to “block” the nystagmus. Often there also is an accommodative element to the strabismus. Treatment of nystagmus and esotropia in nystagmus blockage syndrome can be more difficult than management of either condition independently. Surgical treatment is often recommended to compensate for the head turn and the strabismus.

PHYSIOLOGIC NYSTAGMUS

Some patients develop jerk nystagmus in extreme positions of horizontal (and occasionally vertical) gaze when they are very tired. The small-amplitude oscillations are conjugate, rapid, and occasionally unequal in each eye. The condition is usually intermittent, although if it is sustained, it must be distinguished from pathologic types of nystagmus. A clinical rule of thumb is to consider fine conjugate jerk nystagmus that is present beyond 30 degrees of gaze to be physiologic. Treatment for patients who have blurred vision in lateral gaze secondary to exceptionally large physiologic nystagmus involves training head turning rather than eye turning to fixate objects, which minimizes the extent of peripheral gaze and reduces the symptoms. Some of these patients also fail road-side sobriety tests because large physiologic nystagmus mimics findings of increased nystagmus on lateral gaze during sobriety testing. These patients should be counseled not to ever drink before driving as it is difficult to convince authorities that their “failure” on sobriety testing was due to a normal physiological condition rather than driving while alcohol impaired.

SPASMUS NUTANS

Spasmus nutans is virtually always characterized by nystagmus and head nodding. A head turn or tilt also occurs at least 50% of the time. Amblyopia, strabismus, and refractive error occur in approximately the same frequency as in the general population. Spasmus nutans is found with equal frequency in both sexes and may occur in several family members. Spasmus nutans usually occurs between the fourth and twelfth month after birth and lasts around 2 years, although it may last as long as 8 years (33). There is pendular, high-frequency, low-amplitude (2 degrees or less) nystagmus, which is usually horizontal. The nystagmus is usually asymmetric, with a larger amplitude in one eye. It may even be unilateral and is occasionally disjunctive. The nystagmus can be constant or appear only with purposeful fixation.

Spasmus nutans has few long-term consequences, and it is not typically associated with other neurologic conditions. However, there have been reports of associations with neurologic abnormalities, including Leigh disease and anterior visual pathway gliomas (34). It is important to distinguish this usually benign condition from congenital nystagmus (Table 18.2) and ocular flutter (a rare condition associated with cerebellar disease)—forms of nystagmus that have a less favorable prognosis. Given the occasional life-threatening associated conditions, it is prudent to consider a CT scan or MRI in patients for whom the diagnosis of spasmus nutans might be considered. Otherwise, deferring treatment is usually indicated.

VESTIBULAR NYSTAGMUS

Vestibular disease may result in damage to the labyrinth, vestibular nerve, central vestibular nuclei, or vestibular connections in the brainstem or cerebellum. Such damage causes an imbalance in the vestibular nuclei output, resulting in a slow, constant-velocity drift of the eyes from the target. A corrective saccade occurs after the eyes have drifted sufficiently, and the repeating cycle creates a pathologic jerk nystagmus waveform. The imbalance in the vestibular system also results in the reports of nausea, oscillopsia, and vertigo that are common in patients with acquired vestibular nystagmus.

Vestibular nystagmus can be central (within the brain or brainstem) or peripheral (inner ear related). See Table 18.2 for a listing of the features and causes of vestibular nystagmus. Central vestibular nystagmus may occur as a result of brainstem ischemia, demyelination, and tumors. As a result, there are frequently other associated neurologic signs (35). Central brainstem lesions that involve the vestibular nuclei and associated pathways are rare and typically result in a unidirectional jerk nystagmus (purely horizontal, vertical, or torsional). Central vestibular lesions occasionally mimic peripheral disease. The vertigo is moderate, and the symptoms are constant and not lessened by attempts to fixate. Appropriate differential diagnostic tests include caloric and rotary testing and brain scans (CT or MRI). Treatment is directed at curing or ameliorating the underlying disease.

Peripheral lesions of the vestibular apparatus or nerve are associated with severe nausea, oscillopsia, and vertigo. The direction of the jerk nystagmus usually is mixed (horizontal torsional or vertical torsional). Both

nystagmus and vertigo symptoms often have sudden episodic onset. Common causes of peripheral vestibular nystagmus are deafness, degenerative inner ear disease, drug toxicity, infections (e.g., labyrinthitis), Ménière disease, tinnitus, trauma, vascular disease, and vestibular neuropathy. Children who have frequent ear infections may have a higher risk of developing peripheral vestibular nystagmus. Treatment is medical therapy for the underlying disease.

VOLUNTARY NYSTAGMUS

Approximately 5% to 8% of the population can demonstrate voluntary nystagmus, an ability that seems to run in families (26). Voluntary nystagmus is a series of rapid oscillations that are pendular, conjugate, horizontal, rapid (3 to 43 Hz), usually small in amplitude, and of short duration. This “ocular trick” is induced by convergence and accompanied by oscillopsia. It can be sustained for only short periods, usually a maximum of 30 seconds, because of the fatiguing nature of the saccades. The rapid oscillations of spasmus nutans might be confused with voluntary nystagmus, except that spasmus nutans does not present in school-aged children and is much more sustained. Voluntary nystagmus can be part of a spasm of the near reflex (27). Treatment is generally not indicated for this eye movement curiosity.

OTHER FORMS OF NYSTAGMUS

There are other types of nystagmus that are present at any age because of pathologic factors. These include developmental anomalies such as Arnold-Chiari syndrome, drug toxicity, endocrine imbalances, trauma, and vascular accidents. Table 18.3 includes conditions that mimic nystagmus but which require neurologic assessment and management. CT scans are recommended in virtually all of these cases.

Genetic Counseling

Although there may not be a family history of genetic defects that result in infantile nystagmus, the etiology may be genetic as a result of spontaneous gene mutations. Further, many conditions that can result in nystagmus are inherited in an autosomal dominant manner by both sexes. Among these are aniridia,

TABLE 18.3 CHARACTERISTICS OF CONDITIONS THAT MIMIC NYSTAGMUS

	Ocular Bobbing	Dysmetria	Flutter	Opsoclonus	Retraction
Amplitude	Large	Diminished saccades	Large	Random	Small
Constancy	Intermittent, continues during sleep	Intermittent	Intermittent	Intermittent	Intermittent
Direction	Vertical; fast phase downward	Horizontal	Horizontal	Multidirectional	Anterior–posterior in orbit
Frequency	Slow, 2 to 15 per min	Only with large saccades	Short, rapid bursts	Rapid, rhythmic	Slow
Gaze direction	No lateral gaze possible	Lateral movements to and from primary	Occurs in extreme lateral gaze (>30°)	All fields, spontaneous	All fields, fixation worsens
Latency	None	None	None	None	None
Associated conditions	Horizontal gaze, paralysis	Cerebellar disease	Cerebellar disease	Cerebellar signs, motor jerks	Paralysis of upgaze
Symptoms	Comatose	Inaccurate saccades, neurologic signs	Blurred vision, neurologic signs	Nausea, vomiting, gait unsteadiness	Inability to elevate eyes
Waveform	Saccade and drift	Inaccurate saccades	Pendular	Conjugate jerky	Beats of retraction

congenital cataracts, and congenital motor nystagmus. Autosomal recessive conditions also have a 25% risk of next-generation inheritance. Autosomal recessive conditions that might result in nystagmus include achromatopsia, albinism, Leber congenital amaurosis, macular hypoplasia, Stargardt dystrophy of the pigment epithelium, and several other types of optic atrophy. Nystagmus may be secondary to X-linked ocular albinism, congenital stationary night blindness, and, occasionally, retinitis pigmentosa. In these cases, 50% of males usually have the condition, and females are carriers. When genetic mechanisms of nystagmus (such as those listed above) are suspected, referral for genetic counseling is necessary (18).

Treatment

Nystagmus is frequently a sign of an underlying pathologic process. Thus, proper care of the nystagmus patient requires that any fundamental pathologic process be properly diagnosed and treated. Table 18.4 lists signs and symptoms associated with pathologic and congenital forms of nystagmus (36). After ruling out the need for (or arranging) medical management of any underlying pathology, management of nystagmus follows the sequential considerations described in Chapter 3. Management is directed at reducing the manifestations of nystagmus by improving visual acuity and enhancing binocularity. Because many forms of nystagmus have latent components, in which the nystagmus frequency or amplitude, or both, increases with decreased binocularity, enhancing binocular vision can often dramatically decrease the nystagmus. Management that can improve nystagmus includes optical measures such as (a) use of refractive correction, (b) added lenses, and (c) prism. Vision therapy procedures and certain medications (37) can assist development of nystagmus control. Finally, ocular muscle surgery will help in selected cases (38) by aligning the eyes, lessening the nystagmus, improving function through an expanded relative null (which allows clearer vision over a wider area of the field without a head turn), and reducing head turn.

REFRACTIVE CORRECTION

The effects of nystagmus often can be lessened by prescription of the appropriate refractive correction. Because the quality of the retinal image can directly influence the ability to maintain accurate steady fixation, the importance of correcting significant refractive error in the management of nystagmus should not be taken lightly. Applying liberal criteria for prescription is reasonable, since refractive correction will seldom cause any harm—even though it may not improve the condition as much as may be desired. For nystagmus patients, the following criteria should be used to determine when refractive treatment is necessary: greater than 1 to 2 D of hyperopia, 0.50 D or more of astigmatism, or 0.50 D or more of myopia or anisometropia. These amounts are often clinically significant, and optical correction should be the first consideration in management. In some cases, prescription of refractive corrections at the lower end of these guidelines will obviously be of little help, and many clinicians will wish to defer such small corrections.

When there is a reasonable chance that correction of the refractive error will improve the acuity and nystagmus characteristics, the clinician should consider evaluation of the effect of contact lenses on visual acuity and nystagmus control. For some patients, rigid gas-permeable contact lenses have been reported to result in greater control of the nystagmus intensity immediately upon insertion and also over time. This effect may be attributable to two factors. First, there is often undetected astigmatism associated with congenital nystagmus. In these cases, the contact lens gives a clearer retinal image, thereby potentially reducing the nystagmus. Second, as the eyes move, the lenses may cause lid sensations and give feedback information that allows control to be developed. Soft contact lenses probably do not have the same feedback effects but are often preferred for correction of significant refractive errors, such as those occurring after removal of congenital cataracts.

ADDED LENSES

Plus Adds

Added plus can be very useful when there is reduced visual acuity and demanding near tasks (Case 18.1). Young patients usually hold near work close and use relative magnification to read print of the size required for adequate school performance. However, they often need a near addition to assist them in maintaining accommodation

TABLE 18.4 ASSOCIATED SIGNS AND SYMPTOMS OF PATIENTS PRESENTING WITH NYSTAGMUS AND THEIR APPROPRIATE DIAGNOSIS^a

Signs					
Symptoms	Jerk Movements	Normal	Gaze-evoked	Seesaw	Downbeat
Vertigo	Vestibular origin	Vestibular	Bruns disorder; sedative or anticonvulsant medications	Chiasmal	Cervicomedullary junction lesion
Tinnitus	Acoustic neuroma, mumps, measles, or infectious mononucleosis	Vestibular or eighth nerve	Bruns disorder	—	—
Oscillopsia	Brainstem lesions, vascular demyelination tumor	Vestibular origin; including Ménière disease	If upbeat, consider drug-induced, brainstem, or cerebellar disorder; hemianopia; Bruns disorder	Chiasmal; look for bitemporal field cut	Arnold-Chiari, platybasia
Reduced visual acuity	Congenital, if improved at near; acquired, if visual acuity poor at distance	Cataracts, dense corneal scar, infantile glaucoma, ocular albinism, optic atrophy, Leber optic atrophy	Large acoustic neuroma	Septo-optic dysplasia	Midbrain lesion with associated obstruction of cerebrospinal outflow
Diplopia	Latent nystagmus without suppression	Multiple sclerosis, midbrain disorders, or encephalitis	Bruns disorder; sedative or anticonvulsant medications	Chiasmal lesion	Antiepileptic medication overdose, lesion of posterior fossa, or Wernicke encephalopathy
Nausea	—	Vestibular or cerebellar disorder	Bruns disorder; sedative or anticonvulsant medications	Chiasmal lesion	Chondrosarcoma, fourth ventricle
Headache	—	Cerebellar or midbrain disorder	Look for cranial nerve palsy	If also has diplopia, midbrain trauma	Chondrosarcoma, fourth ventricle; cerebellar tumor or occipital lobe tumor

^aNote that every sign is not always associated with a particular symptom in patients. If any doubt exists in the diagnosis of the patient, the examiner should generate an appropriate referral to a neurologist.

as they get further along in school, where more prolonged studying is required. Older patients, who are losing accommodation, and all patients with very poor acuity may need near additions that are somewhat stronger than normal, especially when significant magnification is needed to improve near acuity.

Case 18.1 High Plus Addition for Near

An 11-year-old boy presented with the chief complaint of not being able to read books easily or see the chalkboard. His parents reported that he had received a visual examination 2 years previously, but he did not wear the prescription. External and internal ocular health was within normal limits. Visual acuity and refraction with cycloplegia were as follows:

OD: +2.75 – 2.75 × 015 20/80 – 1
 OS: +3.00 – 2.25 × 178 20/80
 OU: 20/70 – 1

There was a comitant 1 Δ esophoria at 6 m and orthophoria at 40 cm. Stereopsis was 140 seconds at 40 cm with Titmus circles. There was no suppression. Fixation was central with both eyes. There was pendular nystagmus of about 5-degree amplitude and 1 Hz. Foveations were accurate with 65 ms duration. A +2.50 near addition gave 0.5 M acuity at 35 cm. Distance telescopic spectacles and binoculars were rejected because of appearance.

The cycloplegic refractive finding was prescribed with a +2.50 D near addition. The patient was instructed to return for reevaluation in 1 month. He wore the new lenses full time and felt that his reading was substantially improved. He had been moved closer to the blackboard, which helped his distance performance. Aided visual acuity was as follows:

OD: 20/70 – 2
 OU: 20/60 – 1
 OS: 20/70

Near acuity was 0.5 M at 35 cm through add.

Minus Adds

It is well known that some patients with nystagmus have decreased nystagmus with convergence (along with improved acuity and cosmesis). Thus, some clinicians have suggested the use of added minus lenses that are stronger than the refractive correction in an attempt to lessen the effects of nystagmus. The theory is that the minus power puts a patient into a converged position. In the presence of strabismus and a moderate or high AC/A ratio, a significant change in convergence posture is often possible by making a patient accommodate through added minus lenses. However, when treating patients with heterophoria, this approach suffers from a lack of informed consideration of the interactions among accommodation, convergence, and fusion. If the nystagmus patient has binocular vision and maintains fusion, there is no increase in convergence with added minus because fusional divergence is stimulated to counteract the convergence caused through stimulation of the AC/A. Thus, added minus is of no help in reducing nystagmus for patients with heterophoria and actually makes binocularity worse by causing an esophoria at near and making reading or other sustained close-viewing activities uncomfortable. Decreasing binocularity in this manner can be a detriment if it causes a latent component to become manifest and increases the nystagmus.

PRISM CORRECTION

Prism corrections are used in treatment of patients with nystagmus to improve binocularity and reduce the nystagmoid oscillations. Improving binocularity can be successful in cases of esophoria or hyperphoria if the prism enhances ocular alignment and develops improved fusion. Prism corrections to lessen the nystagmus

probably work by inducing convergence or placing the eyes in the null position. When the intensity of nystagmus decreases with convergence, the effect of base-out prisms on nystagmus intensity should be tested. In these cases, small to moderate amounts of base-out prism will often decrease the nystagmus, with a resulting improvement in acuity. The amount of prism required varies considerably from patient to patient. The total amount, which is typically determined empirically, generally ranges between 10 and 20 Δ base-out. Fresnel prisms are often used for higher prescriptions.

Prism can be prescribed with the bases in the same direction (yoked or conjugate prism) as a method of improving visual acuity or of treating the abnormal head postures that are often associated with nystagmus (Case 18.2). Such a prescription might involve a base-out prism over the right eye and an equal-power base-in prism over the left eye to shift both eyes to the left. If this places the eyes in or closer to the null point, vision will be clearer and a right face turn may be relieved. Although conjugate prisms may eliminate a slight face turn, the prisms are often cosmetically unacceptable because an observer will notice that the eyes appear deviated through the prisms. Conjugate prisms are probably most successfully used when patients have an abnormal head posture of less than 15 degrees. Thus, if a patient has a 15-degree face turn to the right, 10 Δ prisms bases left would reduce the face turn by about 5 degrees. The remaining face turn would probably be within cosmetically acceptable limits. Such small-power prisms can be ground into spectacles with an acceptable edge thickness if the eye size is small and the refractive error is slight. Fresnel prisms are available in amounts up to 30 Δ to manage moderate face turns, but acuity is somewhat degraded with the higher powers.

Case 18.2 Conjugate Prism

An 8-year-old boy presented with the chief complaint of a head turn to the right that was cosmetically noticeable to the extent that classmates were teasing him. He also reported not being able to read easily. His parents reported that he had received a visual examination 3 months previously and that surgery had been recommended for the head turn; they wanted a second opinion concerning the surgery. External and internal ocular health was within normal limits. Allowing the patient to turn his head gave the following visual acuity and refraction with cycloplegia:

OD: $-1.75 - 1.25 \times 010$ 20/30 - 1
 OS: $-1.00 - 0.75 \times 180$ 20/30
 OU: 20/30

Acuity in straight-ahead gaze was 20/70. There was a comitant 1 Δ exophoria at 6 m and 40 cm. Stereopsis was 100 seconds at 40 cm with Titmus circles. There was no suppression. Fixation was central with both eyes. There was jerk right nystagmus of about 6-degree amplitude and 1 Hz, and a 10-degree right head turn. Foveations were accurate and of 80 ms duration. A +1.25 near addition and 8 Δ base-out before the right eye and 8 Δ base-in before the left (conjugate prism, bases-right) was prescribed. The patient was instructed to wear the new lenses full time and return for reevaluation in 1 month. He felt that his head turn was substantially improved and also reported easier reading.

OCCCLUSION

Use of occlusion to improve visual acuity has reduced value in heterophoric patients with nystagmus because of the high incidence of a latent component. If the nystagmus increases with occlusion, the nystagmus will be worsened while the eye is occluded. Thus, treatment of anisometropic amblyopia in patients with latent nystagmus is done using blur as an occluder or through vision therapy that treats the amblyopic eye while both eyes are open (through use of anaglyphs or Polaroids). When blur is used for occlusion, enough plus power is used so that the “good” eye is blurred, but not enough is used so that there is an increase in nystagmus when the amblyopic eye fixates. The power needed is determined empirically but needs to be enough so that the amblyopic eye is forced to assume fixation.

Atropine can be used to implement occlusion in patients with latent nystagmus. Calcutt and Crook (36) reported the results of six patients with esotropia, amblyopia, and latent nystagmus who were treated using

daily administration of 1% atropine in each eye. Latent nystagmus was reduced enough so that total direct occlusion could be used. Bilateral atropine instillation was used 2 weeks prior to the direct occlusion. Atropine use continued throughout therapy. All patients showed significant acuity improvement, and several had permanent reduction in latent nystagmus. Similar findings were reported by Windsor, Burian, and Milojevic (39).

VISION THERAPY

A number of vision therapy procedures can be utilized to lessen or eliminate the effects of nystagmus. These procedures fall into two categories: (a) vision therapy using antisuppression and fusional vergence therapy to enhance fusion and (b) feedback techniques (such as afterimage therapy, intermittent photic stimulation, and auditory biofeedback) to increase voluntary control of the nystagmus and stabilize fixation. Participation in a training program requires sufficient maturity, so active vision therapy is usually deferred until after a patient has reached school age (i.e., age 5 to 7 years). However, provided that sufficient cooperation can be attained, the age of the patient is not a barrier to therapy, and treatment can begin at any age with reasonable results. Thus, given the same nystagmus condition, a patient who is 60 years old has essentially the same prognosis for improvement as one who is 6 years old. The principle is that factors other than age (e.g., motor etiologies have a better prognosis) determine the appropriateness of beginning an active therapy program.

Fusion Enhancement Therapy

Antisuppression Therapy

A frequent clinical observation regarding the intensity of nystagmus is that it lessens as binocular vision is enhanced. Thus, an important initial step in therapy for heterophoria patients with nystagmus is treatment of suppression. Suppression training uses active therapy, including Polaroid or anaglyphic TV trainers, anaglyphic coloring activities, and tranaglyphs or vectograms. Active treatment involves binocular (dichoptic) stimulation of peripheral retinal areas followed by gradual encroachment upon central areas. Attention is drawn to simultaneous perception of suppression clues and clearness of the clues seen by each eye. Finally, physiologic and pathologic diplopia therapy are added.

Sensory fusion should be maximally developed before motor fusion therapy begins. For these heterophoric patients with nystagmus, development of increased facility is more important than training large vergence magnitudes. Programs should be designed that utilize the most natural environment possible, consistent with controlling the therapy, so that an improvement in binocularity is achieved and the gains are transferred to free space situations. This can be accomplished by using the red/green or Polaroid procedures described in Chapter 6 (i.e., tranaglyphs or vectograms) as soon as possible in the therapy program.

Horizontal Vergence Therapy

Horizontal vergence therapy is considered when an existing heterophoria is large enough that it can be causing fusional difficulties (Case 18.3). The ultimate goal of horizontal vergence and accommodative therapy is to increase vergence responses so that the patient maintains comfortable binocular alignment for longer periods of time. Ideally, such improvement lessens the nystagmus and allows an increase in acuity.

Case 18.3 Manifest Latent Nystagmus

An 8-year-old boy presented with the chief complaint of difficulty seeing in school and having nystagmus that was cosmetically noticeable. His parents reported that he had received a visual examination every year since age 2, at which time the nystagmus was first detected. He wore no correction. External and internal ocular health was within normal limits. Visual acuity and refraction with cycloplegia were as follows:

OD: +0.75 – 0.50 × 010	20/80 – 1
OS: ×1.00 – 0.25 × 005	20/100
OU: 20/80	

There was an intermittent comitant 10 Δ exotropia at 6 m and 40 cm. Stereopsis was 200 seconds at 40 cm with Titmus circles. There was alternating suppression. Fixation was central with both eyes. The jerk nystagmus had the fast phase toward the fixing eye and was of about 5-degree amplitude and 1.5 Hz. Foveations were inaccurate and about 45 ms in duration. A +3.00 D near addition gave 0.5 M acuity at 35 cm.

Vision therapy was prescribed to improve binocularity by reducing suppression and improving convergence abilities. After 3 months of therapy, there was an 8 Δ exophoria with good fusion and no suppression. Stereopsis was 30 seconds at 40 cm, and visual acuities were 20/30 in each eye using a vectographic method and 20/25 binocularly. The nystagmus had been virtually eliminated (1-degree amplitude and 0.5 Hz) with binocular viewing, but a large latent component was still present. Acuities were 20/60 in each eye when occlusion was used to eliminate binocularity.

This patient is a classic example of a patient with manifest latent nystagmus, which is defined here as nystagmus that is present because there is compromised or no binocularity as a result of strabismus or suppression or both. When fusion is improved for these patients, the nystagmus becomes latent and dramatically lessens. Many nystagmus patients have such a latent component to their nystagmus, which is why we suggest maximally improving binocularity as a first step to management.

Sensory–motor therapy involves programs designed to affect vergence or accommodation and then to utilize procedures that affect their interactions. Many vision therapy procedures can be used to improve vergence ability; as different as they may seem initially, their similarities are striking. The primary emphasis is on the improvement of the magnitude and especially facility of vergence responses. To this end, many of the vergence techniques described in Chapters 6 through 8 can be used.

Feedback Therapy for Ocular Control

Because there are often significant reductions in the nystagmus after completion of vision therapy programs that enhance binocularity, we recommend that binocularity be enhanced maximally after prescription of the refractive correction and any prism that assists fusion. However, even with development of maximal binocularity, there is seldom perfect control of eye movements unless the latent component of the nystagmus was very high initially. As a result, most nystagmus patients will also benefit from additional therapy using feedback to increase control of ocular movements (Case 18.4).

Case 18.4 Biofeedback Therapy

A 20-year-old albino woman presented with the chief complaint of difficulty seeing in college and having nystagmus that was cosmetically noticeable. She had received a visual examination every few years since age 2, at which time the nystagmus was first detected. With the exception of albinism and a hypopigmented macula, external and internal ocular health was within normal limits. Visual acuity and refraction with cycloplegia were similar to her current correction:

OD: +3.75 – 4.50 \times 178 20/80 – 1
 OS: +4.50 – 4.25 \times 004 20/100
 OU: 20/80

There was a constant 10 Δ esotropia at 6 m and 40 cm. There was alternating suppression and no stereopsis at 40 cm with Titmus circles. Fixation was central with both eyes. There was pendular nystagmus of about 7-degree amplitude and 1.75 Hz. Foveations were very inaccurate and about 35 ms in duration. A +3.00 D near addition gave 0.5 M acuity at 35 cm.

Biofeedback therapy was prescribed to reduce the nystagmus amplitude and improve foveation abilities. After 2 months of therapy, the nystagmus had reduced to a cosmetically acceptable 3-degree amplitude and 0.75 Hz. Acuity had improved to 20/60 +2 in each eye. Foveations were more accurate and remained about 30 to 50 ms in duration.

Therapy to increase eye movement control is based on the premise that the quality of the eye movements directly affects the visual acuity in nystagmus. Basic research has demonstrated that subjects with longer and more accurate foveations typically have better acuity (40). We have observed that patients who have foveations that are very short (less than 20 ms) or very inaccurate (seldom on target) have a better prognosis for improved acuity with treatment. Thus, we habitually recommend therapy to increase foveation accuracy and control toward the end of fusion enhancement therapy.

Generally, a nystagmus patient has no awareness that his or her eyes are oscillating. Except in acquired cases, the visual world appears stable—without apparent image movement (oscillopsia). As a result, therapy to enhance control of eye movements must provide some form of feedback to the patient that the eyes are moving. Success in therapy then assumes that control of the nystagmus can be enhanced via the therapy used. The most commonly used therapies are discussed below; these range from afterimage therapy through vertical line counting. Although auditory biofeedback is fairly successful, it is a technique that is not readily available to most clinicians. Probably the most successful clinically available techniques are two visual feedback techniques, namely, intermittent photic stimulation and vertical line counting.

Afterimages

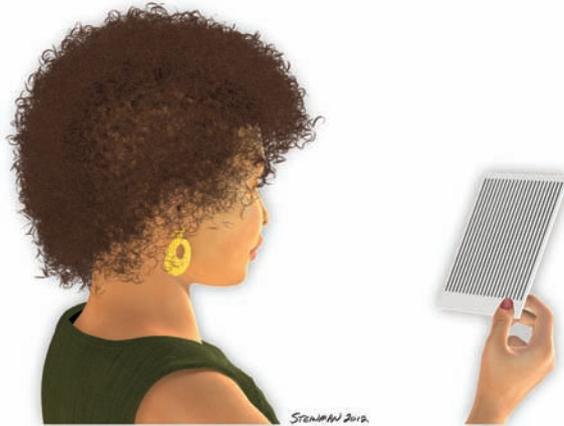
The use of afterimages is a practical therapy procedure that can improve the steadiness of fixation in patients with nystagmus. The theory is that afterimages provide visual feedback regarding the intensity of nystagmus oscillations. An afterimage can be generated using a camera flash located about 40 cm from the eyes at the null position. Typically, the afterimage is binocular so that a latent nystagmus component is not uncovered during the occlusion needed to generate the afterimage. However, a monocular afterimage can be used if there is no significant latent component. A blinking light in the background is used to intensify perception of the afterimage, and the patient notes the movement of the afterimage while viewing a blank screen. Subsequently, targets are introduced and the patient's task is to reduce the intensity of the afterimage movements and resolve the detail of the target. Theoretically, the null region can also be expanded to the primary position by having the patient gradually move his or her head toward the primary field of gaze while attempting to maintain reduced nystagmus (41).

The afterimage technique has satisfactory success when the patient has a null point with a significant reduction in nystagmus intensity. However, afterimage therapy is somewhat less valuable when there is significant nystagmus or the patient has no null point. In these cases, the afterimage is often not generated on (or even near) the fovea. Because the goal of therapy is to improve fixation, and the fovea is the retinal area that drives fixation, generating the afterimage in the peripheral retina reduces the success of the technique.

Auditory Biofeedback

The principle behind auditory biofeedback is that, through feedback, the patient can alter the motor output and stabilize the eyes. In this technique, the eye position and movements are monitored using infrared eye movement monitors and converted into an audible tone. This tone is either a continuous tone (with the pitch changing as the eyes oscillate) or utilizes a "dead zone" so that there is no sound when the eyes are on target and a signal occurs when fixation strays (42). In each of these cases, the feedback allows the patient to "hear" the nystagmus.

Patients typically learn to lessen the amplitude of their nystagmus quite rapidly. Kirschen (42) used the dead-zone approach in treating three subjects and achieved 41% to 73% reduction of nystagmus amplitude with 1 hour of training. The frequency of oscillations was not greatly affected. Long-term effects of these treatments are moderate. Ishikawa et al. (43) reported that one-third of their 29 patients maintained complete improvement, one-third had moderate long-term improvement, and the remainder complained of poor results.



■ **Figure 18.6** The vertical line counting task described by Leung, Wick, and Bedell (44) consists of a number of dark high-contrast lines of equal separation. The patient's task, which is complicated by his or her nystagmus, is to count the lines. As ability improves, the task is made more difficult by moving the lines further away, decreasing the line separation, or decreasing the contrast of the lines.

Auditory biofeedback has rapid short-term success for treating nystagmus patients. However, if long-term results are desired, it is likely that other forms of therapy need to be used prior to (or concurrently with) auditory biofeedback in order to maximize the gains that may be achieved via the biofeedback. Further, there is no commercially available clinical biofeedback system. It is necessary to purchase a research model or an eye movement monitor, a computer, a data acquisition board, and a speaker, and to hire a computer programmer.

Line Counting

The line counting technique described by Leung, Wick, and Bedell (44) consists of stimulating each eye monocularly for 15 to 20 minutes with a target consisting of vertical lines separated by a uniform amount (Fig. 18.6). The patient's task is to count each line on the target located at 30 to 40 cm. As ability improves, the lines are located at greater distances or the line separation is decreased. Patients initially notice considerable difficulty maintaining fixation accurately enough to comfortably count the lines. With practice on a large variety of line separations and contrasts, precision of fixation and visual acuity are improved.

Vertical line counting appears to result in impressive and appreciated benefits for many patients (Case 18.5). It is inexpensive and readily performed by almost any patient. It is appropriate to introduce this technique in the management of nystagmus when binocular therapy has been completed.

Case 18.5 Vertical Line Counting

A 16-year-old boy presented with the chief complaint of difficulty seeing and reading in school and having failed his driver's license examination. His parents reported that he had received a visual examination every couple of years since age 4, at which time the nystagmus was first detected. He had glasses, but seldom wore them. External and internal ocular health was within normal limits. Visual acuity and refraction with cycloplegia were as follows:

OD: +1.75 – 1.50 × 005 20/80 – 1
 OS: +2.00 – 2.25 × 170 20/100 + 1
 OU: 20/80

There was a comitant 8 Δ exophoria at 6 m and 40 cm. Stereopsis was 200 seconds at 40 cm with Titmus circles. There was intermittent alternating suppression. Fixation was central with both eyes.

The jerk nystagmus had about 5-degree amplitude and a frequency of 1.5 Hz. Foveations were very inaccurate and about 25 ms in duration. A +3.00 near addition gave 0.5 M acuity at 35 cm.

Vision therapy was prescribed to improve binocularity by reducing suppression and improving convergence abilities. After 2 months of therapy, there was good fusion, no suppression, and acuity had improved to 20/60. Vertical line counting was introduced to his therapy regimen. After 2 additional months of binocular enhancement and line counting therapy, stereopsis was 30 seconds at 40 cm, and visual acuities were 20/30– in each eye using vectographic testing.

Intermittent Photic Stimulation

The flashing technique described by Mallett (30) is a modification of an amblyopia training technique (Case 18.6). The treatment is appropriate for all patients except those who are epileptics and may be sensitive to flashing lights. Typically it is done on a synoptophore, although any background that has a variable flash rate could be used. Therapy sessions consist of stimulating each eye monocularly for 15 to 20 minutes, with the target flashing at 3 to 4 Hz. The patient's task is to identify and count detailed targets, such as groups of dots, lines, and letters or numbers (Fig. 18.7). All targets have a red background on the theory that red tends to promote foveal fixation. Patients initially have considerable difficulty accurately shifting fixation between the target details. Approximately six to eight therapy sessions are reported to develop the precision of fixation and improve visual acuity for patients of all ages. To prevent regression, patients should train for an additional six sessions after acuity has stabilized.

Case 18.6 Intermittent Photic Stimulation

An 18-year-old woman presented with a desire to have an unrestricted driver's license. Her last visual examination had been 2 years previously. External and internal ocular health was within normal limits. Visual acuity and refraction with cycloplegia were similar to her current correction:

OD: $-1.25 - 1.50 \times 180$	20/80 - 1
OS: $-2.00 - 2.25 \times 180$	20/80
OU: 20/80	

There was comitant 4 Δ esophoria at 6 m and 40 cm. Stereopsis was 140 seconds at 40 cm with Titmus circles. There was intermittent alternating suppression. Fixation was central with both eyes. The jerk nystagmus had about 6-degree amplitude and a frequency of 1.5 Hz. Foveations were very inaccurate and about 20 ms in duration. A +3.00 D near addition gave 0.5 M acuity at 35 cm.

Intermittent photic stimulation was prescribed as office therapy, and vertical line counting was used for home therapy. After 2 months of therapy, visual acuities were 20/30– in each eye using vectographic testing.

Photic stimulation is a valuable addition to treatment of nystagmus and seems to elicit some impressive and appreciated benefits. For example, Mallett (30) reported that the technique improved acuity to better than 20/40 after only 12 weeks of therapy for 83% of his 54 patients. The technique should be included in the long-term management of congenital nystagmus as soon as binocularity has been maximally enhanced.

PLEOPTICS

Pleoptic methods have been advocated by some authors. See Shapiro (45) for a detailed description of pleoptic techniques. Stegall (41) observed that direct occlusion was effective when the amblyopic eye viewed targets through a Kodak No. 92 red filter. Foveal fixation may be stimulated if latent nystagmus is reduced by



■ **Figure 18.7** The target designed by Mallett has a number of small, detailed tasks on a red background. Using a major amblyoscope, the target is flashed at 3 to 4 Hz for 15 to 20 minutes. The patient's task is to count the targets during the flashing.

this method. The red filter and occlusion amblyopia treatment technique of Brinker and Katz (46) may also be a reasonable consideration for treatment of amblyopia complicated by latent nystagmus.

PHARMACOLOGIC THERAPY

The visual sensation of movement (oscillopsia) is an especially distressing symptom that is a common sequela of acquired nystagmus. When the etiology of nystagmus is an infectious process, a metabolic or toxic disturbance, or a vascular disorder, systemic medication can play a significant role in management. For example, medications are sometimes effective in treatment of the symptoms of oscillopsia and vertigo associated with vestibular nystagmus, downbeat nystagmus, and, on rare occasions, congenital nystagmus. Currie and Matson (47) described ten patients with vertical oscillopsia and downbeat nystagmus who were treated successfully with 1 to 2 mg of clonazepam. The symptoms were reduced for 2 to 6 hours per dose, and one patient experienced 72 hours relief per dose. Side effects of the medication, such as drowsiness and sedation, limit the long-term benefit.

Baclofen, which inhibits the excitatory neurotransmitter system, has been used to decrease oscillopsia in some cases of congenital nystagmus (48), periodic alternating nystagmus (PAN), and seesaw nystagmus. The side effects include dizziness, drowsiness, hypotension, nausea, and weakness. Since most congenital nystagmus patients do not suffer from oscillopsia, this expensive medication is not used often. Baclofen therapy is generally reserved for patients who do not have increases in acuity with the treatments listed above.

In a 56-day randomized, double-masked, placebo-controlled study, Shery et al. (37) demonstrated that pharmacologic agents such as memantine and gabapentin can improve visual acuity, reduce nystagmus intensity, and improve foveation in congenital nystagmus. Patients were randomized into either a memantine ($n = 16$), gabapentin ($n = 16$), or placebo group ($n = 15$). Mean visual acuity improvements showed a significant effect between treatment groups ($p = 0.004$), with improvement in both memantine and gabapentin groups. Eye movement recordings showed an improvement in nystagmus intensity ($p = 0.001$) and foveation ($p = 0.0007$). Participants subjectively reported an improvement in vision after memantine and gabapentin treatment more often than in the placebo group ($p = 0.03$). There were no significant differences between the treatment groups with visual function (VF-14) or social function questionnaires.

SURGERY

A frequent cosmetic consequence of nystagmus is a face turn, head tilt, chin elevation, depression, or a combination of these. The patient assumes a head position that moves the eyes into a field of gaze where the nystagmus is lessened or visual acuity improves. Kestenbaum (49) designed a surgical technique to move

all horizontal rectus muscles, using an identical amount of resection and recession. Successful surgery shifts the null point to the primary position, and any existing face turn is eliminated. Occasionally, there is also increased visual acuity in the primary position, a lessening of the nystagmus intensity, and an increase in the null position over a wider range of gaze (50). Modifications of Kestenbaum's procedure have also been used. For example, when a patient has a vertical head turn, the four vertical rectus muscles are operated on simultaneously (51). The success of these procedures in reducing face turns to within 15 degrees of the primary position is reported to be about 80%.

In a prospective, noncomparative, interventional case series of ten adult patients, Hertle et al. (38) investigated the results of horizontal rectus tenotomy in patients with congenital nystagmus. Simple tenotomy of all four horizontal recti with reattachment at the original insertion was performed, and search-coil eye movement recordings and clinical examinations were performed. One year after surgery under binocular conditions, nine of the ten patients had persistent, significant postoperative increases in the expanded nystagmus acuity function of their fixing (preferred) eye. Average foveation times increased in all nine fixing (preferred) eyes. Binocular visual acuity measured with the ETDRS chart increased in five patients and was unaffected in five.

There are four main points to discuss when counseling patients regarding the value of surgical intervention for a head turn secondary to congenital nystagmus. First, most authorities only recommend surgery when the face turn is greater than 15 degrees (31). Smaller amounts of anomalous head position are managed with conjugate prisms. Second, consideration is given to both the location of the null point and the amount of head turn. For older patients, these positions may not be the same because social pressure often causes the patient to adopt a helpful, but less than optimum, head position (52). In these cases, surgery is designed to place the null point in the primary position, rather than eliminating the abnormal head position per se. Third, the best surgical results are reported in patients older than 4 years. Overcorrections more commonly result when children are younger than 4 years. Fourth, when the head turn patient has strabismus as well as nystagmus, surgery is typically performed on the dominant eye because a change in head position will be mediated by the fixating eye. Surgery is simultaneously or subsequently performed on the other eye to correct the strabismus. The prognosis for a successful result decreases slightly for these more complicated cases.

The esotropia associated with nystagmus blockage syndrome is usually surgically treated after occlusion to eliminate amblyopia and develop normal ocular motility. There is a fair cosmetic prognosis, with apparent alignment in the primary position about 50% of the time. There are few functional cures reported, although about 25% have microtropia with some binocular function. Either the Faden operation with a small recession or bimedial rectus recessions are used. Surgical results are typically not as good as those in congenital esotropia. Overcorrections and undercorrections are frequent, and the number of reoperations is more than 50%.

Summary

Nystagmus can present a difficult diagnostic challenge. In addition to pathology, the etiologic factors include developmental and genetic anomalies (53). Nystagmus is often caused by (or associated with) afferent and efferent visual defects. Acquired nystagmus, such as opsoclonus, seesaw, vestibular, and many others, requires immediate diagnosis and management of the underlying disease to reduce the long-term consequences. The severity of visual impairment is not always dependent on the etiology (54). Indeed, for many patients visual functioning is worse than predicted from assessment of the retinal image motion (nystagmus), suggesting an additional sensory loss (56). Presumably, this additional loss is a form of bilateral amblyopia resulting from abnormal early visual experience produced by incessant retinal image motion and (frequently) large amounts of astigmatic blur (57); conditions that are treatable using the sequential management steps listed below.

Although nystagmus generally cannot be cured, we recommend that the clinician aggressively treat nystagmus patients. Using sequential management, the prognosis for functional and cosmetic improvement is often quite high in patients with heterophorias. Treatment consists of (a) correction of the refractive error, using spectacles or contact lenses, (b) prisms to induce convergence or correct a head turn, and (c) vision therapy to enhance fusion and reduce suppression. After binocularity is maximally improved, vision therapy to improve fixation stability is used if needed. Medications and surgery play a role in selected cases.

Study Questions

1. Why is a slit lamp helpful in nystagmus diagnosis?
2. What is a foveation and why might it be important to a nystagmus patient?
3. What are the characteristics of periodic alternating nystagmus?
4. What are important additional case history questions to ask a patient or parent regarding nystagmus?
5. How can you test visual acuity in a patient with latent nystagmus?
6. Describe voluntary nystagmus.
7. Convergence may reduce nystagmus; base-out prism can cause convergence. Support or refute this statement: Base-out prism is the treatment for nystagmus.
8. Why might prism base-right in each eye help a patient with nystagmus?
9. Describe how vision therapy for suppression might help a patient with nystagmus.
10. Compare the treatment technique and overall treatment goals of line counting and intermittent photic simulation in treatment of the patient with nystagmus.

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Aniseikonia

There are few subjects that have been developed with greater care or are supported by more extensive research than that of aniseikonia. However, even though it is relatively common in clinical practice to encounter patients with symptoms of aniseikonia, iseikonic lens designs are seldom prescribed. As a result, it often becomes difficult to recall the procedures needed for diagnosis and treatment. This chapter briefly describes the condition of aniseikonia and presents a simplified method for design of iseikonic corrections.

Definitions of Aniseikonia

Aniseikonia, which means “not-equal images” (1), is defined as a condition of binocular vision in which there is a relative difference in the size or shape, or both, of the ocular image of the two eyes (2). A size difference that causes symptoms (generally 0.75% or more) is defined as *clinically significant aniseikonia* (3). Smaller amounts of image size difference are usually not clinically significant, although they are relatively common. Even large amounts of image size difference do not cause aniseikonic symptoms for some patients.

The size of each ocular image depends on the retinal image formed by the dioptric systems of the eye, the distribution of retinal receptive elements, and the physiologic and cortical processes involved in vision. As a result, the two ocular images are seldom, if ever, equal. There are normal differences in image size when looking at objects in left or right gaze and when objects are located at different distances from the eyes (4). These normal image size disparities form the basis of stereopsis and provide a signal representing where one object is with respect to another.

STATIC VERSUS DYNAMIC ANISEIKONIA

Aniseikonia can be considered to be composed of two different, but related, magnification-induced problems—static and dynamic aniseikonia (5). Measures of static aniseikonia assess the actual difference in image size between the eyes; it is these measures, rather than the normal or physiologic differences in image size, that we are typically concerned with in clinical determinations of aniseikonia. The amount of dynamic aniseikonia is determined by analyzing differences in induced phoria that occur when a patient looks in various fields of gaze through an anisometropic correction (6). A patient can have either static aniseikonia or dynamic aniseikonia, or both problems at the same time. For example, a patient with emmetropia or ametropia (with no difference in the refractive correction of each eye) could have measured aniseikonia. This would be static aniseikonia. Another patient, corrected with spectacle lenses for a large myopic anisometropia, would be expected to have dynamic aniseikonia because of the difference in spectacle lens powers. Obviously, contact lens correction is the preferred method of minimizing dynamic aniseikonia.

Historical Perspective

Prior to 1945, theoretical and clinical courses in aniseikonia were given at the Dartmouth Eye Institute, and a clinician had to be certified by that institute in order to obtain an eikonometer (7). As instrumentation was simplified and techniques for measuring aniseikonia were improved, the obligatory Dartmouth courses were discontinued. However, the initial investigations of the Dartmouth group provided the technical and clinical papers that underlie instruction in professional schools and discussion of aniseikonia in textbooks.

Differences in the retinal image size may result from correction of refractive errors, including antimetropia and anisometropia. Donders (8) described the difference in the relative size of the images of the two eyes due to correction of anisometropia and suggested that these differences may interfere with binocular vision. Lippincott (9), Green (10), Friedenwald (11), and Koller (12) also discussed changes in the retinal images resulting from correction of ametropia. Hess (13) believed that symptoms that occur with lens correction of anisometropia are caused by prismatic effects in the lens periphery. Von Rohr (14) calculated image size differences occurring in unilateral aphakia and high anisometropia. Erggelet (15) pointed out that astigmatic corrections also introduce size differences between the retinal images. He considered these size differences unimportant, since they rarely exceed 4% or 5%. Earlier, Erggelet (16) had considered the possibility that a physiologic image size difference might result from unequal distribution of the retinal elements in the two eyes. The correctness of this conjecture is illustrated by the statistical analysis of Carleton and Madigan (17), which showed that aniseikonia occurs in bilateral emmetropia and isoametropia as well as anisometropia.

KNAPP'S LAW

For some clinicians, confusion results from too liberal an application of Knapp's law, which states that the corrected eye with axial ametropia has a retinal image equal in size to that of an emmetropic eye of equal power, provided the lens is placed at the anterior focal point of the eye (2). However, there are a substantial number of patients with axial anisometropia who cannot comfortably wear spectacle lens corrections, suggesting that Knapp's law is more useful as a guideline than a "law." The ultimate determinant of the retinal image size is based on the separation of retinal photoreceptors and on the registration of these in the visual cortex, not solely on the power or form of the refractive correction. As a result, Knapp's law fails in many cases, because simply correcting the anisometropia and providing clear retinal images has a more beneficial effect on binocular fusion than the detrimental effect of the potentially unequal image sizes.

Diagnosis

It is not generally difficult to decide whether a patient has aniseikonia. A careful review of the case history and a few basic clinical tests should give sufficient information to make a tentative diagnosis on nearly all of the patients suspected of having aniseikonia. After reviewing the patient's symptoms, consider the refractive state and corneal curvature. If these do not allow accurate diagnosis, then a period of diagnostic occlusion or an iseikonic clip-on or both should lend further diagnostic support.

The definitive diagnosis of aniseikonia is done by measuring the image sizes with an instrument (such as the space eikonometer or Aniseikonia Inspector), if one is available in the office or on referral. When a measurement device is not available, the aniseikonic correction may be estimated from the refractive correction required or from comparison of the images seen by the two eyes.

HISTORY

The symptoms that the patient experiences are important in the diagnosis of aniseikonia. Symptoms of aniseikonic patients are similar to those of patients with uncorrected ametropia and heterophoria. The incidence of symptoms reported by 500 aniseikonic patients is listed below. Although local eye discomfort (asthenopia) and headaches are the most frequent symptoms, there are a variety of conditions that may produce symptoms similar to aniseikonia (18). As a result, we recommend that other possible causes for a patient's complaints be investigated and treated before considering iseikonic correction.

Symptoms of aniseikonia patients include the following:

Asthenopia	67%
Headaches	67%
Photophobia	27%
Reading difficulty	23%
Nausea	15%
Motility difficulty	11%
Nervousness	11%
Dizziness	7%
General fatigue	7%
Distortion of space	6%

To conduct the examination, it is important to determine the patient's primary symptom, along with its duration and frequency. Begin by having the patient describe the current symptoms using questions such as "In what way do your eyes bother you most?" Directing the patient to give an accurate description of his or her difficulties requires tact and judgment, because some patients are anxious to report any visual phenomenon or relate their numerous visits to various specialists and it is easy to lose track of the problem that brought them.

The most important symptoms are those present when the refractive correction is worn. Ocular symptoms can conveniently be grouped under the term *asthenopia*. Typical ocular symptoms include those directly associated with the eyes, such as aching, burning, eye pain, itching, pulling sensations, and tiring. These symptoms may also include subjective observations, such as blurred or doubled vision and even slanting or tipping of level surfaces. Visual experiences such as these may or may not be accompanied by any ache, pain, or other discomfort, but they often greatly concern the patient. Ocular symptoms are usually related to the use of the eyes and are frequently due to uncorrected ametropia, heterophoria, or aniseikonia. As such, they are often readily relieved by properly prescribed visual correction.

Referred symptoms include dizziness, headaches, nausea, and nervousness. Such symptoms are seldom definitively related to the use of the eyes and, when they exist, a refractive or iseikonic correction is less likely to bring relief. These symptoms, which frequently seem to be of ocular origin, prompt patients to consult with an eye specialist in the hope that the headaches may be due to the eyes and that the eye doctor can "cure" them. However, careful questioning by the clinician may reveal that the headaches are due to other causes, such as allergies or sinus conditions. It is the clinician's task to determine whether referred symptoms have an ocular etiology or whether the patient should be advised to consult other specialists.

The length of time that symptoms have been present should also be considered. Long-standing symptoms that have been previously investigated without success tend to strongly suggest aniseikonia. This is because a patient with long-standing symptoms has usually sought a variety of treatments. If all previous treatments have been unsuccessful, it tends to rule out other possible causes for the symptoms and increase the chances for aniseikonia.

REFRACTIVE CONDITION

There are a few patients with equal or no refractive error who have aniseikonia and symptoms (19,20). Many of these patients are those who have had unilateral cataract extraction and are pseudophakic in one eye after cataract surgery (21). However, in patients who have not had refractive or cataract surgery, the likelihood of aniseikonia is generally not high unless the patient is anisometropic. Once the anisometropia is corrected, aniseikonia becomes a definite possibility. Aniseikonic symptoms occur infrequently in the presence of uncorrected anisometropia because one of the ocular images is usually so blurred that the patient uses only one eye and aniseikonic symptoms are not present.

CORNEAL CURVATURE

A difference in the corneal power of each eye indicates that at least a portion of the anisometropia is refractive. Generally, corneal shapes are equal and differences are uncommon. However, unequal corneal shapes frequently happen after refractive surgeries, including LASIK or PRK. Postsurgically induced unequal corneal shapes often cause aniseikonia. Thus, it is important during history to question the patient regarding prior refractive surgery treatments. When correcting such patients with spectacles, a difference in image size will result. Astigmatism is virtually always of corneal or, occasionally, lenticular origin. Either type of astigmatism can be considered a refractive problem, in which spectacle correction will result in aniseikonia. In refractive anisometropia, correction of refractive errors with contact lenses rather than spectacle lenses will minimize these differences in image size, especially when the anisometropia is not very high (less than 6.00 diopters [D]) and the difference in corneal power matches the amount of anisometropia. The other advantage of contact lens correction for anisometropic patients is the reduction of the amount of variable prism power induced by versional eye movements.

When prescribing spectacle correction for a patient with anisometropia and equal corneal curvatures, there should be minimal problems with static aniseikonia, provided the lenses do not produce undesired shape magnification. This can be avoided by prescribing equal front curves and center thickness. However, the theory behind equalizing the lens front curves and center thickness assumes that the anisometropia must result from a difference in axial length when the corneal curvatures are equal. Unfortunately, this is not always the case, because the anisometropia may be due to a refractive difference associated with the lens or the back

surface of the cornea. Aniseikonia cannot be definitely ruled out simply because the corneal curvatures are equal. Further, the problem of dynamic aniseikonia induced by the spectacle lenses is often a significant deterrent to binocular visual function. In general, these factors suggest that contact lenses should be the initial prescription consideration.

RETINAL CONDITIONS

There are retinal conditions currently being successfully treated (e.g., epiretinal membrane) that could not be effectively treated in the past. These treatments often restore vision, but sometimes either the treatment or the underlying condition causes the photoreceptors of the eye to assume different relative locations than they initially had. This monocular change in retinal photoreceptor location can cause a rather debilitating asymmetric aniseikonia that can also be very large (many times greater than 15%). The patient complains of one image being significantly larger than the other, *and* the image size difference may vary in different portions of the retina. This image size difference is often not correctable with any iseikonic prescription lens—the overall image size is often too great to correct (6–7% is about the maximum that can be made in glasses) and there is not a lens that can provide a variable correction across the field. Fortunately, many times a partial iseikonic correction can help (see Case 19.1). In cases where iseikonic correction is not

Case 19.1 Use of the Aniseikonia Inspector

A 67-year-old man had a right macular epiretinal membrane 2 years previously. After removal of the membrane, he subsequently had a retinal detachment. After repair of the detachment and cataract surgery with an intraocular lens (IOL) implant in that eye, his primary complaint was blurred vision at distance and near in the right eye, vertical diplopia, and an image size difference, with the right image being about 20% smaller than the left. In addition to the right image being smaller, he also reported that it varied in size from the top of the field to the bottom, presumably a result of asymmetric stretching of retinal elements from the membrane or its removal. Vision with the spectacles was not satisfactory because of vertical diplopia and retinal image size difference. Refractive error was as follows:

OD: +1.25 c – 1.50 × 105 6/8
 OS: –1.25 c – 0.25 × 090 6/6 +2
 OU: 6/6 +2

Keratometric readings were as follows:

OD: 43.25 at 173; 43.00 at 083
 OS: 44.00 at 001; 43.87 at 091

Measures of eye alignment were 6.5 base-down on the right (a moderately comitant right hyperopia that did not increase significantly on right and left gaze or on right or left head tilt). There was fair sensory fusion with intermittent right suppression (determined using the American Optical [AO] vectographic adult slide).

There was a clear, well-centered posterior chamber IOL in the right eye and early nuclear sclerotic lens changes in the left eye. Interocular pressures were 18 (right eye) and 16 (left eye) as determined by Goldmann applanation tonometry. There was a mottled macula on the right, with a retinal detachment repair and a normal fundus appearance on the left.

Because of the large reported image size difference, the patient was assessed using the Aniseikonia Inspector. The right image was found to be about 16% smaller than the left, with significant variation in response, presumably due to the variation in retinal elements and instability of the initial correction of the vertical deviation. The problem with his aniseikonia is that it cannot be corrected fully with conventional optics because the total image size is too great *and* there is variable image size across the vertical meridian. Iseikonic spectacle correction was ordered that maximally increased the right image

(only about 7% could be achieved in spectacle correction) and incorporated a total of 6.5 base-down before the right eye (OD, 3.5 base-down; OS, 3.0 base-up).

The patient returned after adapting to the lenses for 3 weeks. He had noticed reduced symptoms during the adaptation period. His acuities were as follows:

OD: 6/7.5 –1

OS: 6/6 –1

At 6 m, there was no suppression. He was fusing well with the prism, and stereopsis was 3 minutes of arc (AO vectographic slide). At 40 cm, he was fusing well and stereopsis was 80 seconds of arc (AO near card series). Repeat assessment with the Aniseikonia Inspector with his new glasses on revealed about 4% residual aniseikonia. In spite of the residual aniseikonia, the patient was happy with his vision, had improved visual comfort for reading, and generally had fewer binocular problems than might be expected with residual aniseikonia of this amount.

successful, other “solutions” might be helpful; these generally involve making the patient increasingly monocular in successive steps until the symptoms are tolerable. These steps include:

1. Focusing one eye for distance and the other for near. This can be done by simply holding up a plus trial lens over one eye of the best distance correction and seeing if the patient has reduced symptoms. If so, single-vision lenses that focus one eye for distance and the other for near (spectacle monovision) can be prescribed. If this is not successful, try:
2. Defocusing the poorer-seeing eye for both distance and near. Again, using a trial lens to blur the vision in the poorer-seeing eye, add to the distance correction about -1.50 (for these typically presbyopic patients). This will often blur the central vision enough that the image size symptoms are minimized and, if successful, can be prescribed in bifocal form. If this is unsuccessful, consider:
3. Blocking central vision of one eye (typically the most distorted one). This can be done with a small circle (about 25 mm diameter) of clear contact paper. This type of partial monocular occlusion is often cosmetically and visually acceptable. If not, use:
4. Occlusion of the full field (clear contact paper)

When iseikonic correction is not possible and you consider the steps above, it is clinically important to involve the patient in the decision making. The patient comes wanting their to the problem solved (and *solved* often means back-to-normal as it was before the condition and surgical treatment) and this is often not possible. If necessary, demonstrate to the patient why you cannot make an iseikonic correction (*your vision has different image sizes in different portion of your vision*) and describe the reasons “regular” glasses will not work (*there is not a lens available that can correct your full image size difference/there is not a lens that can provide variable magnification across the visual field*). Show how “monocular” vision can reduce symptoms (*notice how focusing one eye for near/blurring one eye reduces your symptoms*) and then work together to determine which type of monocular correction works best. Failure to include the patient in these decisions may result in both the patient and doctor being unnecessarily frustrated.

OCCLUSION

Occlusion may be useful as an aid in the diagnosis of aniseikonia. If the patient’s symptoms are eliminated by wearing a patch, they are probably due to a binocular problem. Once all other binocular problems have been treated or ruled out, aniseikonia is left as the probable cause of the symptoms.

CLIP-ON ANISEIKONIC CORRECTION

A clip-on iseikonic correction is often useful to diagnose aniseikonia. Such lenses have plano power, with magnification based on the combination of front curve and center thickness used in their manufacture. When the clip-on reduces the symptoms, aniseikonia is very likely to be the problem. To further test the assumption,

TABLE 19.1 SPECIFICATIONS FOR PLASTIC SIZE LENSES^a

Percentage Magnification	Lens Thickness (mm)	Power of First Surface	Power of Second Surface
0.5	3	+2.50	-2.50
1.0	3	+5.00	-5.00
1.5	3	+7.50	-7.62
2.0	4	+7.50	-7.75
2.5	4	+9.37	-9.62
3.0	5	+9.00	-9.25
3.5	5	+10.50	-10.87
4.0	6	+10.00	-10.50
4.5	6	+11.25	-11.75
5.0	6	+12.50	-13.12

^aBecause size lenses are not commercially available, they must be custom fabricated using the parameters listed.

the clip-on can be placed in front of the other eye. If symptoms are exacerbated, the diagnosis is complete. Unfortunately, when a clip-on lens does not help, aniseikonia may still be the problem, since symptoms may result from the weight and additional reflections caused by the clip-on lens. Table 19.1 shows the lens thickness and curve combinations for various iseikonic clip-on lenses (22).

Determination of the Presence of Aniseikonia

Several methods can be used to determine whether aniseikonia is present. These include estimation of the image size between the two eyes simultaneously using diplopic images or sequentially using the alternate cover test, Turville testing, or the Maddox rod and double-light technique. Assessment can also be made using tests such as the New Aniseikonia Test or space eikonometry. Although each of these techniques has clinical use, the space eikonometer is probably the most accurate and practical.

SIZE COMPARISON OF DIPLOPIC IMAGES

Comparison of double images is a simple, albeit relatively insensitive, test of the image sizes between the two eyes that can be used to estimate horizontal, vertical, or overall aniseikonia.

1. The patient wears the appropriate spectacle correction and views a square target that is doubled, using vertical prism of about 5 Δ . The target will be seen horizontally displaced if any horizontal phoria is present.
2. The patient compares the perceived horizontal extent of the top target with the perceived horizontal extent of the bottom target. A difference suggests horizontal aniseikonia.
3. To estimate the horizontal aniseikonia, a size lens (Table 19.1) is placed in front of the eye with the smallest image. The percentage magnification of the size lens is changed until the two targets appear to be of equal horizontal lengths.
4. The process is repeated for the vertical dimensions.
5. The results are recorded, indicating the magnification needed to equalize the perceived images (e.g., 2.0% on OD horizontal, 1.0% on OS vertical; 1.5% on OD overall).

ALTERNATE COVER TEST

Brecher (23) proposed using the alternating cover test to detect and estimate the magnitude of aniseikonia.

1. Have the patient wear the appropriate spectacle correction and fixate a distance square target that is alone in the visual field.

2. Occlude each eye alternately and ask the patient to compare the horizontal size of the target seen with each eye. The cover paddle should be moved quickly between eyes and held for about 1 second in front of each eye to facilitate comparison of the two images.
3. If there is a difference in perceived size, repeat the test with a size lens in front of the eye with the smaller perceived image. Change the size lens until the image seen with each eye appears to be the same size as the cover paddle is alternated.
4. The process is repeated for the vertical dimensions.
5. The results are recorded, indicating the magnification needed in each meridian to equalize the perceived images of the two eyes.

TURVILLE TEST

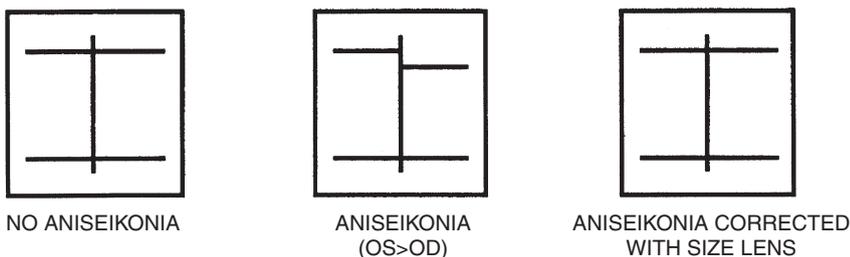
The Turville test can be used for detecting and measuring aniseikonia in the vertical meridian using the slide with two horizontal lines that Morgan developed (24) (Fig. 19.1).

1. Position the septum so that the patient sees the right half of the target with the right eye and the left half of the target with the left while wearing the appropriate spectacle correction.
2. Have the patient compare the vertical separation of the two lines on the right target with the separation of the two lines on the left target. A difference in the perceived vertical separation of the lines on the right side suggests vertical aniseikonia.
3. Aniseikonia can be measured using a size lens in front of the eye with the smallest separation and changing the size lens to equalize the perceived vertical separation of the lines on both sides.
4. This measure of the vertical aniseikonia should be recorded.

MADDOX ROD AND TWO-POINT LIGHT SOURCES

Testing with a Maddox rod and two light sources is performed as follows:

1. Two small light sources are placed about 60 cm away from the patient, with a horizontal separation of about 20 cm. The patient wears the appropriate spectacle correction and views the lights through a Maddox rod in front of only one eye, with the axis at 180 degrees. One eye sees the two light sources, and the other (behind the Maddox rod) sees two vertical luminous lines.
2. Have the patient compare the relative separation of the lights with the relative separation of the luminous streaks. A difference in the separation suggests aniseikonia. Prism can be used to align the light and line on one side if a lateral heterophoria makes the judgment difficult by causing a displacement of the streaks from the light sources.
3. A size lens in front of the eye that perceives the smallest separation (lights or streaks) can be used to measure aniseikonia. Change the power of the size lens to equalize the separation between the lights and the streaks.
4. The test can be repeated with the light sources separated vertically and the Maddox rod at axis 90 degrees placed in front of only one eye to determine the presence and measurement of vertical aniseikonia.
5. The size lens that produces the same distance between the lights and the luminous streaks is recorded as a measure of aniseikonia.



■ **Figure 19.1** The slide developed by Morgan for Turville testing appears as two parallel horizontal lines emanating from a central vertical line. The patient's task is to report the relative separation of the horizontal lines on either side of the vertical line. Report of an unequal separation of the lines can be neutralized with a size lens, providing an estimated amount of magnification to prescribe.

THE NEW ANISEIKONIA TEST

The procedure for the New Aniseikonia Test (25) is as follows:

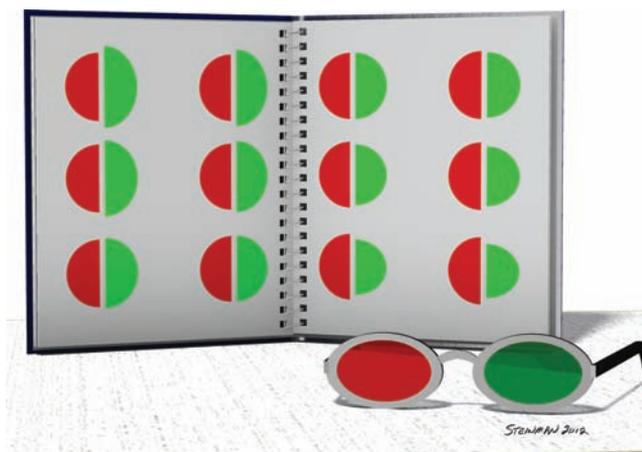
1. The patient wears red and green filters over the appropriate spectacle correction.
2. Have the patient compare the red and green half-moons in the booklet (Fig. 19.2) to determine the half-moons that seem to have identical vertical diameters.
3. Rotate the booklet to a horizontal position and repeat the test.
4. The percentage of aniseikonia that is present in each meridian is recorded. This test tends to provide a smaller estimate of the aniseikonia present than the amount measured using a space eikonometer.

THE ANISEIKONIA INSPECTOR

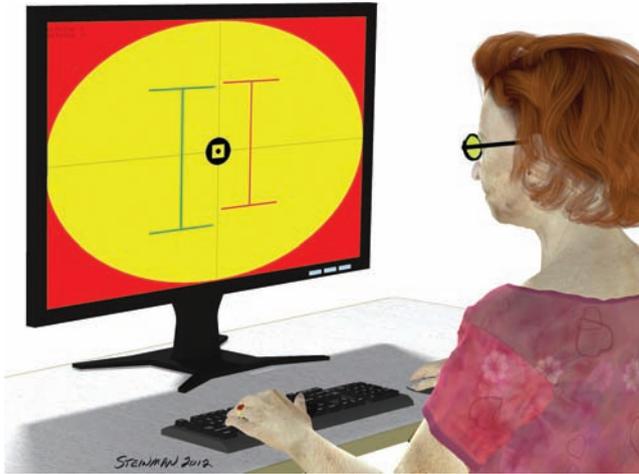
The aniseikonia test of the Aniseikonia Inspector program is based on direct-comparison eikonometry (26) which, although it tends to underestimate aniseikonia (27,28), can have a sensitivity of less than 0.5%. Although underestimation could be a concern, the large range (up to 25%) of the Aniseikonia Inspector (29) is often a substantial advantage when testing patients with new-onset aniseikonia caused by conditions such as unilateral aphakia, retinal detachment, and epiretinal membrane (e.g., Case 19.1). Many of these patients have developed significant aniseikonia as a result of treatment to preserve their vision. The aniseikonia is often so large in magnitude that it cannot easily be assessed by other means, including the space eikonometer (which will only measure up to 5% image size difference). This large measurement range and clinical availability (compared to the space eikonometer) makes the Aniseikonia Inspector a very useful clinical test.

When assessing aniseikonia using the Aniseikonia Inspector:

1. The test is performed with the patient sitting 2 to 6 ft from the computer monitor.
2. The patient looks at the computer monitor screen through red/green glasses so that each eye sees a separate portion of the screen (typically the red lens is in front of the right eye, although the program allows the examiner to determine which eye will have the red lens).
3. An aniseikonia setting is made by changing the size of one of two half-circles (Version 1) or bars (Version 2 or 3) with keys on the keyboard or with the mouse until the two targets appear equal in size (Fig. 19.3).
4. The aniseikonia is measured in the vertical, the horizontal, and the diagonal direction. In each direction, the measurement is done twice, once starting with -25% preset aniseikonia and once starting with $+25\%$ preset aniseikonia.
5. The average of the two measurements is taken as the aniseikonia value and the total amount of aniseikonia is automatically determined by computer calculations of the results.
6. The potential aniseikonia correction can be simulated by the computer to verify that the patient's symptoms are reduced. The aniseikonia correction can also be manipulated to refine the correction for maximal patient satisfaction.



■ **Figure 19.2** The New Aniseikonia Test consists of a book with a number of pairs of red/green half-moons. When viewed with red/green glasses, one of the half-moons is seen by the right eye and the other is seen by the left eye. The patient's task is to determine which pair of targets contains half-moons with the same vertical diameter on each side. This gives an estimate of the amount of magnification to prescribe.



■ **Figure 19.3** The Aniseikonia Inspector is a computer program with either pairs of red/green half-moons (Version 1) or red/green bars (Version 2). When viewed with red/green glasses, one of the half-moons (bars) is seen by the right eye and the other is seen by the left eye. The patient uses the keyboard or mouse to make the targets have the same dimension on each side. The task is done twice in each of three meridians (vertical, horizontal, and oblique), and the average of each set of measures gives the aniseikonia in that direction. The computer program then calculates the overall amount of magnification to prescribe.

This test tends to provide a smaller estimate of the aniseikonia present than the amount measured using a space eikonometer (28).

THE SPACE EIKONOMETER

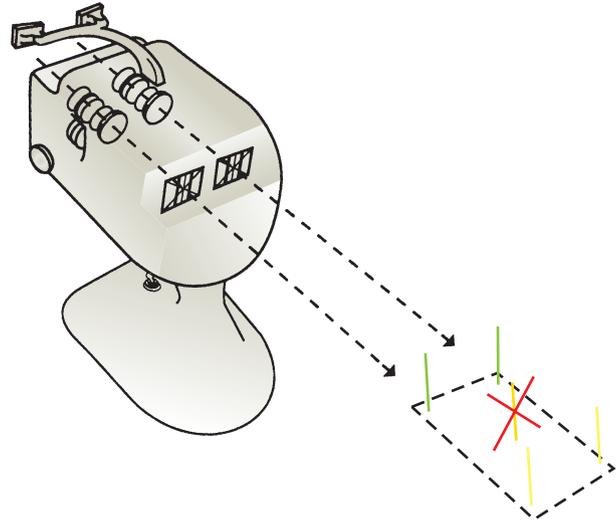
The most accurate prescribing for aniseikonia is based on measurement of the image size differences, rather than guessing at the amount of aniseikonia present. From a clinical standpoint, measurement of aniseikonia provides the best means of determining whether a patient's symptoms are related to aniseikonia. Very accurate measurements of up to 5% image size difference can be made using the space eikonometer. Using an eikonometer also facilitates prescription of noniseikonic corrections. For example, practitioners are sometimes reluctant to prescribe an anisometropic correction that might induce aniseikonia. However, the full correction of significant spherical anisometropia does not always result in significant aniseikonia. A solution to this dilemma is to use an eikonometer more frequently when aniseikonia is suspected. When the patient's response to the refractive correction is measured with the eikonometer, it is often a pleasant surprise to find little or no aniseikonia. Evaluating the patient's responses to a tentative refractive correction with the eikonometer also allows the clinician to modify the refractive correction to minimize induced aniseikonia when the visual needs of the patient permit the sacrifice of optimum acuity and binocular function for the sake of comfort or expense.

The space eikonometer is extremely accurate—perhaps the most accurate clinical measurement of a binocular function. The test is also soundly based in physiologic optics research on single binocular vision and stereopsis. The space eikonometer is no longer currently available for purchase as a new instrument. However, there are a substantial number of used eikonometers available, with an increase in the numbers as practitioners retire. Because this is the only readily available instrument, and many clinicians are not familiar with its use, we have included this short section on use of the eikonometer so that the practitioner who acquires one can more easily become acquainted with the idiosyncrasies of using it to measure aniseikonia.

Target

The target of the space eikonometer appears as two bright white (or yellowish) vertical lines behind a red cross with two dull green vertical lines in front of the cross (Fig. 19.4). The appearance of this target is varied by altering the positions of the controlling levers. The $\times 90$ lever at the top of the instrument (Fig. 19.5) moves the position of the left side of the outside lines closer for right eye magnification or farther for left eye magnification.

■ **Figure 19.4** The space eikonometer target appears as two bright white (or yellowish) vertical lines behind a red cross with two dull green vertical lines in front of the cross. The patient's task during measurement of aniseikonia with the eikonometer is to report the relative positions of the line targets as changes in the magnifications of each are achieved by moving the controlling levers. The test is complete when the patient reports that all portions of the target are equidistant.

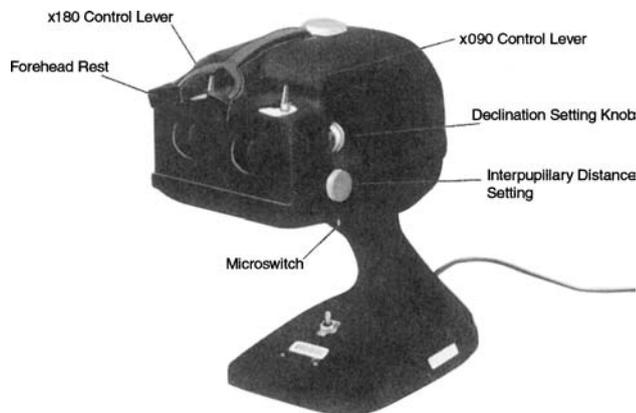


The $\times 180$ lever moves the relative position of the right sides of the red cross closer for right eye magnification or farther for left eye magnification. The declination wheel rotates the top of the red cross toward the observer for plus settings and away for minus settings. The clinician should familiarize himself or herself with the phenomena described in this section by looking into the instrument both monocularly and binocularly.

The patient's task during measurement of aniseikonia with the eikonometer is to report the relative positions of the line targets as changes in the relative magnifications of each are made by moving the controlling levers. The test is complete when the patient reports that all portions of the target are equidistant.

Making Eikonometer Settings

Position the patient comfortably in front of the eikonometer, with the refractive correction in place and the interpupillary distance set on the instrument (Fig. 19.5). Have the patient observe the target and report the position of the lines when all settings are on zero. Call attention to the outer lines first. By using a bracketing technique, the $\times 90$ wheel can be moved until the outer lines are seen equidistantly. Extinguishing visibility



■ **Figure 19.5** The appearance of the space eikonometer target is determined by altering the positions of the controlling levers. The $\times 90$ lever at the top of the instrument moves the position of the left side of the outside lines closer for right eye magnification or farther for left eye magnification. The $\times 180$ lever moves the relative position of the right side of the red cross closer for right eye magnification or farther for left eye magnification. The declination wheel rotates the top of the red cross toward the observer for plus settings and away for minus settings. Between changes in the controlling levers, visibility of the target is extinguished by using the switch at the bottom of the eikonometer.

of the targets with the micro switch (Fig. 19.5) between changes of the lever setting allows for more accurate findings. The measurement procedure is then repeated for the sides of the red cross, using the $\times 180$ lever, and for the tilt of the red cross, using the declination wheel. The method of limits is applied for determining the final location of the levers and declination wheel. The sensitivity of the patient to the three parts of the test is estimated by one-half the range within which alignment of the targets is reported. The manual provided with the instrument provides more detail concerning the testing procedure for routine cases.

Determining Image Size

After the settings have been determined, the aniseikonic correction is obtained from the three measurements ($\times 90$, $\times 180$, and declination) by using magnification tables. The decision to prescribe a full, partial, or no aniseikonic correction is based on the measurements and professional judgment regarding the availability of the correction, the cost, and the likelihood that the patient will have successful relief of symptoms. These points will be discussed further in a later section. Next, however, we discuss some of the difficulties experienced during aniseikonic examination with the eikonometer.

Aniseikonic Examination Difficulties

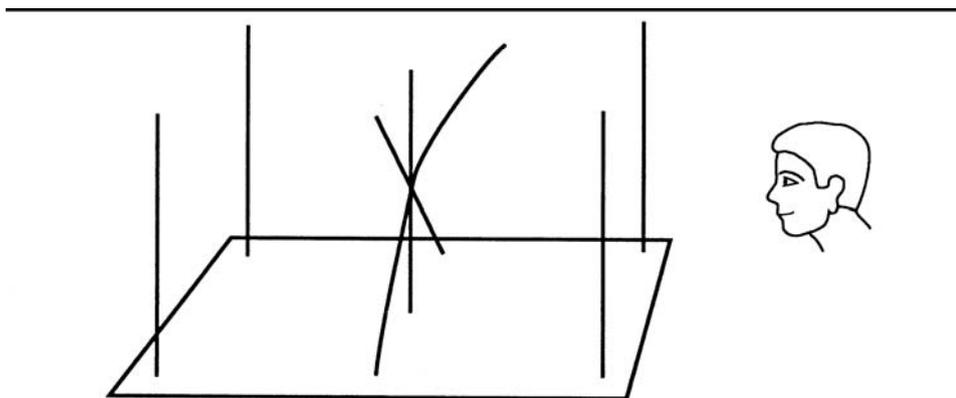
Monocular Suppression

Patients who lack sufficient stereopsis to respond during eikonometry report that the space eikonometer target appears flat. Other indications of monocular suppression are patient reports that the bright white (yellowish) vertical lines appear in front of the red cross or that the dull green vertical lines appear behind the red cross. These reports indicate that the patient is using the monocular clue of brightness, rather than stereopsis, to evaluate the appearance of the target.

If there is a question as to whether an eye is being suppressed, have the patient observe the target with one eye and then the other. With the right eye, the two right vertical lines are closer together than the two left vertical lines. With the left eye, the left vertical lines appear closer together than the right lines. Thus, with both eyes open, the suppressing eye can be determined by asking the patient whether the right or left vertical lines appear closer together.

Heterophoria

For some patients with good fusion and stereopsis, the space eikonometer test indicates the presence of small amounts of heterophoria, most frequently hyperphoria. When there is even as little as 0.5Δ uncorrected hyperphoria, one of the oblique lines of the cross in the target often appears in front of the other (Fig. 19.6). If this observation is reported, fixation disparity testing should be done to determine the vertical prism



■ **Figure 19.6** When there is an uncorrected hyperphoria, the space eikonometer target may appear to be distorted, and one limb of the cross will tilt toward the observer. Reports of this phenomenon should alert the examiner to place small amounts of vertical prism in front of the hyperphoric eye to restore the perception of a symmetrical cross so that more accurate judgments of the position of the cross can be made.

required to reduce the fixation disparity to zero (Chapter 15). Then, determine (by the method of bracketing) that the prism ensures exact coincidence of the oblique lines. This is done by placing a 0.5 Δ prism alternately base-down and then base-up before one eye. If there is no remaining hyperphoria, one oblique line will appear in front of the other (and vice versa) as the prism is flipped from base-down to base-up. The proper power prism (it may require more than 0.5 Δ) is then placed in a trial frame and the aniseikonic test is continued.

Management

Prescribing iseikonic corrections requires similar clinical judgment to that used when prescribing refractive and heterophoric corrections. Factors to be considered include the age of the patient, the nature of the previous corrections and the patient's reaction to them, the type of work and hobbies done by the patient, the patient's temperament and concern about the appearance and expense of the correction, and, above all, the nature of the symptoms and the likelihood of their elimination or reduction by iseikonic correction.

PRACTICAL CONSIDERATIONS

In designing iseikonic prescriptions, it is easy to allow the desire to solve the optical problem to overshadow the problems that the patient may have with the correction being prescribed. Remember the primary complaint of the patient and attempt to solve that problem without creating a new one. A prescription that is optically correct might be considered unwearable by the patient. In certain instances, it is preferable not to prescribe the full refractive findings, but rather to modify them instead of ordering bitoric lenses. A slight change in cylinder axis or power may only reduce the acuity slightly and be preferable to an expensive prescription with unacceptable appearance or weight. In almost all instances, common sense dictates use of the simplest solution and determines the difference between success and failure of management.

LENS PRESCRIPTION

Although there are no hard and fast rules for prescribing aniseikonic corrections, we recommend considering the following factors when deciding whether or not to recommend an iseikonic correction.

Factors that suggest not prescribing include the following:

- Inconsistent or variable measurements of the size difference on repeated trials
- Poor depth perception
- Aniseikonia in reverse to that expected from the anisometropia
- Symptoms that are not related to use of the eyes or have not been improved by refractive or heterophoric corrections
- A patient who is comfortable, even with a significant aniseikonia. This can occur if a partial refractive correction for one eye has been worn for several years

Factors that suggest prescribing include the following:

- Aniseikonia that can be measured with a sensitivity smaller than the size difference measured (e.g., 1.0% \pm 0.50% rather than 0.75% \pm 1.5%)
- Definite symptoms related to the use of the eyes
- Relief of symptoms with monocular occlusion when there is no significant lateral or vertical heterophoria
- Improvement of symptoms while wearing a temporary size lens clip-on for 1 to 2 days
- Anisometropia, where the full refractive correction causes (or is likely to cause) discomfort
- Failure of other corrections to provide relief of the symptoms

PRESCRIPTION DECISIONS REGARDING PATIENTS WITH ANISEIKONIA

The issues in designing aniseikonic corrections are composed of two slightly different points of view—eliminating all estimated magnification difference between the two eyes or eliminating all measured magnification difference between the two eyes. Both of these philosophies have merit, and the fact that each works clinically indicates that iseikonic lens design is often not an exact science and is frequently more of an art of patient management.

Estimated Magnification Prescriptions

When prescribing to eliminate all estimated magnification difference between the two eyes (30), the actual aniseikonia is generally not measured, but it is assumed to be related to the difference in the spectacle magnification of the lenses. In practice, this technique is often used when instruments such as the space eikonometer are not available. Clinically, practitioners who prescribe using this philosophy generally choose to prescribe less magnification than that which would be expected to reduce the magnification difference between the lenses to zero. Typically, around 1.0% per diopter of anisometropia is used to estimate the amount of magnification to prescribe. Unfortunately, this technique tends to be less accurate when prescribing for patients with anisometropic myopia. In general, however, prescriptions designed from this philosophy contain slightly more magnification than those prescribed based on actual measures of the aniseikonia.

Measured Aniseikonia Prescriptions

When the aniseikonia present is measured with, for example, the Aniseikonia Inspector or a space eikonometer, a prescription can be designed that eliminates the measured magnification difference between the two eyes. In this technique, measurements are usually taken through a patient's best spectacle correction. From knowledge of the parameters of the old spectacle correction (eyewire distance, front curve, thickness, and index of refraction), an iseikonic correction is designed by altering these parameters to reduce the measured magnification difference to zero. As long as aniseikonia can be measured, this technique is equally satisfactory for both anisometropic hyperopia and anisometropic myopia. Prescriptions that are designed based on this philosophy usually have slightly less magnification than those that are based on estimates derived from the calculation of possible aniseikonia from differences in spectacle lens power.

Regardless of the philosophy of prescribing for patients with aniseikonia, the tables in this chapter can be used to design iseikonic corrections. When prescribing to eliminate an estimated difference in magnification, simply decide how much residual magnification you wish to leave and design a lens that achieves this requirement. If aniseikonia is measured, it is very easy, using the tables, to design an iseikonic correction that reduces the measured difference to zero. The issue of dynamic and static aniseikonia is also not a problem when the aniseikonia is measured and the measurement includes both static and dynamic components of aniseikonia. The designed iseikonic correction will then be the correction required.

Iseikonic Lens Design

The process of designing lenses to correct aniseikonia, combined with refractive correction (known as *translation*), does not have to be a complex task. If the Aniseikonia Inspector is used, different prescription parameters that affect the magnification of spectacle lenses (e.g., base curve, lens thickness, refractive index, and vertex distance) can be changed using slider bars. The resultant aniseikonia is shown in real time when changing the prescription, making it simple to design an iseikonic prescription. The Aniseikonia Inspector provides images of the lenses to help determine whether the lenses will fit the frame and to evaluate the cosmetic implications of the correction.

If the practitioner will be designing lenses to correct aniseikonia, changes in the dimensions of the patient's current spectacle lenses (front curve, thickness, and position from the eye) can be made to introduce the desired iseikonic correction. This procedure makes it unnecessary to consider the magnification properties of trial lenses and simplifies the design of iseikonic lenses. When patients are already wearing spectacle lenses, the only thing that has to be determined is the amount of magnification needed.

After iseikonic lens design, but before lens fabrication, two steps should be tried. Each of these has merit and together they eliminate the need for many iseikonic corrections. First, prescribe contact lenses whenever possible. Many times a contact lens correction that eliminates the problem of dynamic aniseikonia will allow comfortable binocular vision in the presence of a moderate to large amount of static aniseikonia. The success of this premise is illustrated by Case 19.2.

Case 19.2 Contact Lenses to Treat Aniseikonia

A 39-year-old woman had radial keratotomy (RK) 2 years previously on her right eye. She did not have the left eye done because of displeasure with the visual results of the first procedure. Her primary complaint was blurred vision at distance and near. She had been about 1 D myopic before RK and had worn spectacles occasionally. She had never worn contact lenses. She had post-RK spectacles, but had broken them. Vision with the spectacles was not satisfactory, due to frequent fluctuations of vision. Refractive error was as follows:

OD: +7.25 c – 2.50 × 080 6/7.5
 OS: –1.25 c – 0.25 × 090 6/6 +2
 OU: 6/6 +2

Keratometric readings were as follows:

OD: 33.25 173, 30.00 at 083 Badly distorted mires
 OS: 39.00 173, 38.87 at 083

Because of the large anisometropia, contact lenses were advised. The contact lens for the right eye was fitted to vault the RK-flattened (30.00 D) central cornea, using a front curve of 9.0 mm (38.50 D). This resulted in a high plus refractive tear film, which, combined with the contact lens, corrected the refractive error. The power ordered was determined by trial fitting and overrefraction, as is frequently necessary because of the unreliability of post-RK central keratometry readings.

The patient returned after adapting to the lenses for 3 weeks. She had no trouble during the adaptation period. With the contact lenses, her acuities were as follows:

OD: 6/6 +1 Overrefraction: OD: plano
 OS: 6/6 –1 OS: –0.50 6/6

At 6 m, there was no suppression. She was orthophoric, and stereopsis was 2 minutes of arc. At 40 cm, she was orthophoric and stereopsis was 80 seconds of arc (with the AO vectographic slide and near card series). Space eikonometry with her contact lenses in place revealed little or no aniseikonia, in spite of the anisometropia. She was happy with her vision and had none of the binocular problems that might be expected with anisometropia of this amount. She was advised to continue to increase her wearing time and return in 1 month or as needed.

When a patient either does not want to, or cannot, wear contact lenses, judicious changes in the prescription may reduce the potential problem. Thus, our second recommendation is to consider small axis or power alterations for older patients who might be expected to have difficulties with space perception or the moderate changes in astigmatism axis or power that frequently occur. Modification of the correction, when needed, will minimize patient dissatisfaction with a new correction that causes perceptual distortion. Such modifications often alleviate the need to prescribe bitoric iseikonic bifocal lens. Case 19.3 illustrates these tenets.

Case 19.3 Small Axis or Power Alterations

H.B., a 61-year-old man, was seen for a routine evaluation. He complained of a slight reduction in distance acuity and some problems reading over the past few months. He was noticing that he could see slightly better at distance when he raised his chin to look through his trifocal. He had glaucoma con-

trolled with Propine (dipivefrin hydrochloride, 0.1%), which he started taking after developing severe systemic side effects to Timoptic (timolol maleate, MSD, 0.25%). His current spectacles were as follows:

OD: +0.50 DS	20/40 +2	+2.25 add
OS: +0.25 c – 0.25 × 90	20/40	50% trifocal

There was a normal fundus appearance, with very slight early senescent nuclear lens changes in each eye. Interocular pressures were 20 (right eye) and 21 (left eye) according to the American Optical non-contact tonometer (AONCT). Visual fields were full and normal. Refractive error was as follows:

OD: +1.25c – 1.00 × 75	20/20 +2
OS: +1.00c – 0.75 × 109	20/15 –2

There was a 6 exophoria at 6 m and 14 exophoria at 40 cm through the add. There was no fixation disparity at 6 m and 240 degrees of stereopsis (AO vectographic adult slide). A +2.50 add was required for near. Near stereopsis was 200 degrees (Randot), and there was no suppression.

The patient reported clear vision with the new correction in a trial frame, but he noticed that the table-top slanted and he felt that he had trouble judging where to place his feet when he walked. Modifying the lens correction to change the cylinder axis to 90 degrees and reducing the cylinder power gave satisfactory acuity and eliminated the perceptual distortions. These changes were discussed with him, along with the option for iseikonic lenses to give the clearest acuity and eliminate the distortions. The patient preferred not to spend the money for an iseikonic correction. The final prescription was as follows:

OD: +1.25 c – 0.50 × 90	20/20 –2	+2.25 add
OS: +1.00 c – 0.50 × 90	20/20 –1	50% trifocal

The patient returned for a progress evaluation in 2 weeks and reported clear vision with no perceptual distortion with the new correction. Because of the clear acuity without symptoms with a modified conventional correction, no further aniseikonic evaluation was considered.

Fear of potential aniseikonia is *not* appropriate as a rationale for withholding or reducing the power of corrections required by patients with binocular anomalies, such as those who have anisometropic amblyopia that can be successfully treated when they wear the full correction (Chapter 17). For these patients, the benefits of full correction almost invariably outweigh the possible detriments that might occur from induced aniseikonia.

Our third recommendation applies to the commonly seen patient who does not want to wear contact lenses, but who needs the full prescription for clear vision and best binocularity. In these cases, we suggest prescribing spectacles that best correct the refractive error. This is done for two reasons:

1. Some people readily adapt to almost anything (explain a 20 Δ esophoria and a 5 Δ esotropia); and if the patient adapts comfortably to a conventional correction, the difficulty of designing an iseikonic correction is averted.
2. If the patient cannot adapt to conventional spectacle lenses, then there is a basis for testing, and the parameters of the spectacle lenses can be altered to produce the necessary magnification changes. Usually, 2 to 4 weeks are sufficient to determine whether the lens correction will be satisfactory. If severe symptoms remain after this time, aniseikonic correction will probably be required.

There are three general rules to follow when altering the dimensions of a patient's spectacle lenses in order to arrive at an approximate correction for aniseikonia (31,32):

1. A change in vertex distance (h) of a lens results in a change in magnification.
2. An increase in the front surface curvature (D_1) of a lens results in an increase in magnification.
3. An increase in the thickness (t) of a lens increases magnification.

There are physical restrictions in the amount of change that can be made in any single variable (e.g., t cannot be reduced to below about 1.5 mm without compromising lens strength). As a result, when designing iseikonic lenses, make small changes in all relevant variables rather than attempting to produce desired magnification changes by modification of only one parameter.

lenses closer to the eyes will increase the magnification of each lens, but it will be more for the right than the left because of its greater power. This is independent of the fact that no change is made in the front curves and center thicknesses. If the lenses are moved nearer to the eyes by 3 mm (to an eyewire distance of 11.5 mm), the magnification change (Table 19.2) will be +1.8% for the right lens and +0.6 for the left lens. The difference [(+1.8%) - (+0.6%)] is +1.2% more magnification for the right lens, approximately the desired change.

Bevel Changes

The thicker edges of minus lenses make it possible to change magnification by shifting the bevel of the right and left lenses. Table 19.3 shows magnification changes realized by changing from a center bevel to a $\frac{1}{3} - \frac{2}{3}$ or a $\frac{2}{3} - \frac{1}{3}$ bevel. A $\frac{1}{3} - \frac{2}{3}$ bevel moves a lens nearer to the eye and increases the magnification of minus lenses, whereas an anterior bevel ($\frac{2}{3} - \frac{1}{3}$) moves a lens away and decreases the magnification of a minus lens.

The effects of bevel changes are apparent when considering the patient wearing the following:

OD: -8.00 DS (center bevel)

OS: -8.00 DS

The amount that a bevel change can vary lens position (h) is then calculated and used in the formula $m\%$ (change in magnification in percent) = $V_o(h)/10$ (Table 19.2) to calculate the change in magnification that can be realized from a bevel change.

The smallest measurement of the frame determines the amount of effect in magnification that bevel alteration will give for minus lenses (the opposite is true for plus lenses). For a frame that measures 44 × 40 mm, the 40 mm measurement determines the amount the bevel can be varied and, thus, the magnification change for a minus lens.

Adjusting the bevels so that the right lens is moved closer ($\frac{1}{3} - \frac{2}{3}$ bevel) and the left farther ($\frac{2}{3} - \frac{1}{3}$ bevel) causes a magnification change of nearly 2.0% (1.92%) for a 52-mm eye size frame.

MAGNIFICATION BY CHANGING BASE CURVE

The change in magnification of a lens when the front surface power (D_1 —front curve) is changed is shown in Table 19.4. This table is based on a 2.1-mm minimum lens thickness. The magnification gains of increasing lens front curve are greatest for patients wearing plus (hyperopic) corrections. Myopic corrections with

TABLE 19.3 APPROXIMATE MAGNIFICATION (PERCENT) CHANGES BY CHANGING LENS BEVEL FROM CENTER TO $\frac{1}{3} - \frac{2}{3}$ OR $\frac{2}{3} - \frac{1}{3}$ (2.1 mm CENTER THICKNESS)^a

Eye Size (mm)	Power (D)					
	-1.00	-2.00	-4.00	-6.00	-8.00	-10.00
36	0.03	0.10	0.22	0.37	0.56	0.77
38	0.03	0.10	0.23	0.40	0.61	0.84
40	0.04	0.10	0.24	0.43	0.67	0.92
42	0.04	0.10	0.25	0.46	0.72	1.05
44	0.04	0.10	0.26	0.49	0.78	1.13
46	0.04	0.11	0.28	0.52	0.82	1.19
48	0.04	0.11	0.29	0.54	0.87	1.26
50	0.05	0.11	0.30	0.57	0.92	1.36
52	0.05	0.11	0.31	0.60	0.96	1.44

^aMinus lens: moved closer to the eye, increases magnification; moved farther from the eye, decreases magnification.

Based on calculating lens edge thickness:

Where: 2.1 = lens center thickness (millimeters)

V_o = lens vertex power (diopters [D])

h = lens radius (millimeters)

n = the index of refraction of the lens material (glass = 1.523) minus the index of refraction of air (1.000).

TABLE 19.4 APPROXIMATE MAGNIFICATION (PERCENT) CHANGES ASSOCIATED WITH VARIOUS LENS POWERS AND CHANGES IN FRONT SURFACE CURVATURE*

Δ Base Curve (D1)	Power (D)												
	-10 $t = 2.1$	-8 $t = 2.1$	-6 $t = 2.1$	-4 $t = 2.1$	-2 $t = 2.1$	-1 $t = 2.1$	0 $t = 2.1$	+1 $t = 2.6$	+2 $t = 3.1$	+4 $t = 4.1$	+6 $t = 5.1$	+8 $t = 6.1$	+10 $t = 7.1$
-4	+1.46	+1.04	+0.64	+0.24	-0.16	-0.36	-0.56	-0.90	-1.23	-1.90	-2.56	-3.24	-3.88
-2	+0.72	+0.52	+0.32	+0.12	-0.08	-0.18	-0.28	-0.45	-0.61	-0.95	-1.28	-1.62	-1.94
+2	-0.72	-0.52	-0.32	-0.12	+0.08	+0.18	+0.28	+0.45	+0.61	+0.95	+1.28	+1.62	+1.94
+4	-1.46	-1.04	-0.64	-0.24	+0.16	+0.36	+0.56	+0.90	+1.23	+1.90	+2.56	+3.24	+3.88
+6	-2.18	-1.56	-0.96	-0.36	+0.24	+0.54	+0.84	+1.35	+1.84	+2.85	+3.84	+4.86	+5.82
+8	-2.92	-2.08	-1.28	-0.48	+0.32	+0.72	+1.12	+1.80	+2.46	+3.80	+5.12	+6.48	+7.76

*Based on: $\Delta m\% = \Delta D_1 \left[\frac{t}{15} + 0.05V_0 \right]$

Where: $\Delta m\%$ = change in magnification (percent)

ΔD_1 = the change in lens front surface curve (diopters [D])

t = lens center thickness (millimeters)

15 = a corrected constant; made up of the index of refraction of glass corrected for the fact that magnification is expressed in percent and lens thickness is expressed in millimeters

0.05 = 1 the change in vertex distance (approximate) for a change in front surface curvature of ΔD_1

V_0 = lens vertex power (diopters).

powers greater than -2.50 D have a decrease of magnification with an increase in front curve (if other parameters remain the same), because the front curve increase moves the lens vertex farther from the eye. The magnification change from an increased vertex distance with increased front curve is additive for hyperopic corrections. For minus lenses, the increase in magnification from a front curve increase is offset by a magnification decrease due to vertex distance changes.

As an example of modifying lens front curve to increase magnification, consider a patient wearing the following:

OD: $+3.00$ DS $+ 7.50$ front curve
 OS: $+5.00$ DS $+ 9.50$ front curve

Magnification of 1.5% is to be added to the right lens. From Table 19.4, a $+4$ D increase in the front curve of the right lens (to $+11.50$) will be enough to give approximately the desired 1.5% increase. A 4 D front curve change for a $+2.00$ D lens would give a 1.13% increase, while changing a $+4.00$ D lens would give 1.9%. Thus, about 1.57% is achieved for a $+3.00$ D lens: $(1.13 + 1.9)/2 = 1.57$. Because the table goes in 2 D power steps, results for intermediate changes must be determined by interpolation.

MAGNIFICATION BY CHANGING LENS THICKNESS

Tables 19.5 and 19.6 show the magnification changes that result from a change in thickness (Δt) of a lens of specific front curve and power when other factors (bevel, vertex distance, etc.) are held constant. These tables also represent the fact that a change in vertex distance (Δh) results from an increase in Δt .

To use Tables 19.5 and 19.6, consider the patient wearing the following:

OD: plano/ $+6.25$ front curve/ 2.1 mm thickness
 OS: -2.00 DS/ $+4.50$ front curve/ 2.1 mm thickness

A 0.75% increase in magnification is desired on the left lens. To use the tables requires subtraction of the value from Table 19.6 from that in Table 19.5 to determine the percentage change in magnification. Increasing thickness increases magnification, and, to achieve our desired magnification, the thickness of the left lens must be increased. From Table 19.5, for a front curve of $+4.50$ and a thickness increase of $+2.0$ mm, the value is $+0.600\%$. From Table 19.6, for a lens power of -2.00 and a thickness increase of $+2.0$ mm, the value is -0.20 . The $+0.80\%$ [$A (+0.600) - B (-0.20)$] change in magnification achieved approximates the $+0.75\%$ desired.

Increasing lens thickness gives a corresponding increase in edge thickness. This increased edge thickness can be used by changing the bevel to gain a change in magnification. Table 19.7 shows changes in magnification that result from a bevel change after the lens thickness has been increased. This effect is most significant when lens vertex power is greater than -4.00 or $+6.00$ D or when a significant increase in thickness has been prescribed.

CONSIDERATIONS FOR ISEIKONIC PRESCRIPTIONS

A $+2.0$ mm thickness increase and a front curve increase of $+4$ D both represent large changes. As a result, all three variables—eyewire distance (h), front curve (D_1), and thickness (t)—should be altered to achieve desired magnification changes. In this manner, smaller changes can be made to each, and the resulting prescription will be more cosmetically satisfactory. Table 19.8 summarizes the effects that can be realized by changing the various parameters. However, in spite of all precautions, very steep front curves or very thick lenses, or both, are sometimes needed to achieve desired magnification effects. To achieve the most cosmetically appealing result, care should be taken to use lens coatings and a minimum frame size.

ANTIREFLECTIVE COATING AND LENS EDGE COATING

Steep front curves and/or increased lens thickness can cause unwanted internal reflections, as well as resulting in a rather strange-looking pair of spectacles. Antireflective coatings are a useful technique that can be used

TABLE 19.5 MAGNIFICATION CHANGES THAT RESULT FROM A CHANGE IN THICKNESS AND FRONT CURVE

Δ Thickness (mm)*	Base Curve															
	0.50	1.50	2.50	3.50	4.50	5.50	6.50	7.50	8.50	9.50	10.50	11.50	12.50	13.50		
-1.5	-0.05	-0.15	-0.25	-0.35	-0.45	-0.55	-0.65	-0.75	-0.85	-0.95	-1.05	-1.15	-1.25	-1.35		
-1.0	-0.03	-0.10	-0.17	-0.23	-0.30	-0.37	-0.43	-0.50	-0.57	-0.63	-0.70	-0.77	-0.83	-0.90		
0.5	-0.02	-0.05	-0.08	-0.17	-0.15	-0.18	-0.22	-0.25	-0.28	-0.32	-0.35	-0.38	-0.42	-0.45		
+0.5	+0.02	+0.05	+0.08	+0.17	+0.15	+0.18	+0.22	+0.25	+0.28	+0.32	+0.35	+0.38	+0.42	+0.45		
+1.0	+0.03	+0.10	+0.17	+0.23	+0.30	+0.37	+0.43	+0.50	+0.57	+0.63	+0.70	+0.77	+0.83	+0.90		
+1.5	+0.05	+0.15	+0.25	+0.35	+0.45	+0.55	+0.65	+0.75	+0.85	+0.95	+1.05	+1.15	+1.25	+1.35		
+2.0	+0.06	+0.20	+0.33	+0.47	+0.60	+0.72	+0.87	+1.00	+1.13	+1.26	+1.40	+1.52	+1.66	+1.80		
+2.5	+0.08	+0.25	+0.42	+0.58	+0.75	+0.92	+1.08	+1.25	+1.41	+1.58	+1.75	+1.92	+2.08	+2.25		
+3.0	+0.10	+0.30	+0.50	+0.70	+0.90	+1.10	+1.30	+1.50	+1.70	+1.90	+2.10	+2.30	+2.50	+2.69		
+3.5	+0.11	+0.35	+0.58	+0.82	+1.05	+1.28	+1.52	+1.75	+1.98	+2.21	+2.45	+2.68	+2.91	+3.14		
+4.0	+0.13	+0.40	+0.67	+0.92	+1.20	+1.46	+1.73	+2.00	+2.26	+2.52	+2.80	+3.06	+3.33	+3.59		
+4.5	+0.14	+0.45	+0.84	+1.03	+1.35	+1.65	+1.95	+2.25	+2.54	+2.84	+3.15	+3.48	+3.74	+4.03		

*+, thickness increase; -, thickness decrease.

TABLE 19.6 MAGNIFICATION CHANGES THAT RESULT FROM A CHANGE IN THICKNESS FOR A GIVEN LENS POWER*

Δ Thickness (mm)	Lens Power (D)										
	-10	-8	-6	-4	-2	0	+2	+4	+6	+8	+10
-1.5	+0.75	+0.60	+0.45	+0.30	+0.15	0.0	-0.15	-0.30	-0.45	-0.60	-0.75
-1.0	+0.50	+0.40	+0.30	+0.20	+0.10	0.0	-0.10	-0.20	-0.30	-0.40	-0.50
-0.5	+0.25	+0.20	+0.15	+0.10	+0.05	0.0	-0.05	-0.10	-0.15	-0.20	-0.25
+0.5	-0.25	-0.20	-0.15	-0.10	-0.05	0.0	+0.05	+0.10	+0.15	+0.20	+0.25
+1.0	-0.50	-0.40	-0.30	-0.20	-0.10	0.0	+0.10	+0.20	+0.30	+0.40	+0.50
+1.5	-0.75	-0.60	-0.45	-0.30	-0.15	0.0	+0.15	+0.30	+0.45	+0.60	+0.75
+2.0	-1.00	-0.80	-0.60	-0.40	-0.20	0.0	+0.20	+0.40	+0.60	+0.80	+1.00
+2.5	-1.25	-1.00	-0.75	-0.50	-0.25	0.0	+0.25	+0.50	+0.75	+1.00	+1.25
+3.0	-1.50	-1.20	-0.90	-0.60	-0.30	0.0	+0.30	+0.60	+0.90	+1.20	+1.50
+3.5	-1.75	-1.40	-1.05	-0.70	-0.35	0.0	+0.35	+0.70	+1.05	+1.40	+1.75
+4.0	-2.00	-1.60	-1.20	-0.80	-0.40	0.0	+0.40	+0.80	+1.20	+1.60	+2.00
+4.5	-2.25	-1.80	-1.35	-0.90	-0.45	0.0	+0.45	+0.90	+1.35	+1.80	+2.25

*A and B = Δm% for a given base curve, thickness change, and lens power.

$$\text{Based on } \Delta m\% = -\frac{\Delta f D_1}{15} + \frac{2V_0}{10}$$

This holds true when the level of a lens is centered and lens thickness is increased without changing lens curvature or eyewire distance.

Where: Δm% = change in magnification (percent)

Δf = change in lens thickness (millimeters)

D₁ = lens front surface curve (diopters [D])

V₀ = lens vertex power (diopters)

15 = a corrected constant; made up of the index of glass corrected for the fact that magnification is expressed in percent and lens thickness in millimeters

10 results from changing meters to millimeters and expressing magnification in percent

To calculate Δm%, the data from Table 19.5 is labeled "A" and is subtracted from the data from Table 19.6 (labeled "B").

TABLE 19.7 APPROXIMATE CHANGES IN MAGNIFICATION (PERCENT) BY CHANGING LENS BEVEL FROM CENTER TO $\frac{1}{3}$ - $\frac{2}{3}$ OR $\frac{2}{3}$ - $\frac{1}{3}$ WHEN THE THICKNESS HAS BEEN CHANGED IN FIXED STEPS FROM STANDARD (2.1 MM MINIMUM) THICKNESS (BASED ON 46 MM EYE SIZE MINUS LENSES)^a

Δ Thickness (mm)	Power (D)												
	-10	-8	-6	-4	-2	-1	0	+1	+2	+4	+6	+8	+10
-1.5	0.94	0.62	0.36	0.18	0.05	0.02	0.00	0.01	0.02	0.04	0.06	0.08	0.10
-1.0	1.02	0.68	0.41	0.21	0.07	0.03	0.00	0.02	0.04	0.07	0.11	0.14	0.18
-0.5	1.11	0.75	0.46	0.24	0.09	0.04	0.00	0.03	0.05	0.11	0.16	0.22	0.27
+0.5	1.28	0.89	0.56	0.31	0.12	0.05	0.00	0.04	0.09	0.18	0.26	0.35	0.44
+1.0	1.36	0.95	0.61	0.34	0.14	0.06	0.00	0.05	0.10	0.21	0.31	0.42	0.52
+1.5	1.45	1.02	0.67	0.38	0.15	0.07	0.00	0.06	0.12	0.24	0.36	0.48	0.60
+2.0	1.52	1.09	0.71	0.41	0.17	0.08	0.00	0.07	0.14	0.28	0.41	0.55	0.69
+2.5	1.61	1.16	0.77	0.44	0.19	0.09	0.00	0.08	0.16	0.31	0.46	0.62	0.77
+3.0	1.68	1.22	0.82	0.48	0.20	0.09	0.00	0.09	0.17	0.34	0.51	0.68	0.85
+3.5	1.78	1.29	0.87	0.51	0.22	0.10	0.00	0.09	0.19	0.38	0.56	0.75	0.94
+4.0	1.85	1.35	0.91	0.54	0.24	0.11	0.00	0.10	0.20	0.41	0.61	0.82	1.02
+4.5	1.94	1.42	0.96	0.57	0.26	0.11	0.00	0.10	0.21	0.44	0.66	0.89	1.10

^aMinus lens: moved closer to the eye, increases magnification; moved farther from the eye, decreases magnification. Plus lens: moved closer to the eye, decreases magnification; moved farther from the eye, increases magnification.

Based on calculating lens edge thickness:

$$\text{Minus lens edge thickness} = 2.1 - \frac{V_o P^2}{2(\Delta n)} + \Delta t$$

$$\text{Plus lens edge thickness} = 2.1 + \Delta t$$

Where: 2.1 = minimum lens thickness (millimeters)

V_o = lens vertex power (diopters [D])

h = lens radius (millimeters)

Δn = the index of refraction of the lens material (glass = 1.523) minus the index of refraction of air (1.000)

Δt = change in lens thickness (millimeters)

The amount that a bevel change can vary lens position (Δh) is then calculated and used in the formula from Table 19.2 to calculate the change in magnification that can be realized from a bevel change.

TABLE 19.8 HOW CHANGES IN LENS PARAMETERS AFFECT LENS MAGNIFICATION

	Strong Minus Lens	Weak Minus Lens	Weak Plus Lens	Strong Plus Lens
Vertex distance				
Further	Decrease	Little effect	Little effect	Increase
Closer	Increase	Little effect	Little effect	Decrease
Bevel				
Forward	Increase	Little effect	Little effect	Decrease
Backward	Decrease	Little effect	Little effect	Increase
Front surface				
Steeper	Small decrease	Increase	Increase	Increase
Flatter	Small increase	Decrease	Decrease	Decrease
Thickness				
Thicker	Increase	Increase	Increase	Increase
Thinner	Decrease	Decrease	Decrease	Decrease
Index			Material	
1.4985			CR-39 plastic	
1.523			Crown glass	
1.556			Hi Lite	
1.577			True-Lite	
1.586			Polycarbonate plastic	
1.601			Glass/plastic	
1.701			High-index glass	
1.805			Index Eight	

to eliminate a number of excessive reflections. An antireflective coating and a frame-matching edge coat on lenses with an edge thickness over 2.6 to 3.1 mm will greatly enhance acceptability of iseikonic prescriptions by reducing internal reflections and improving cosmetic appearance.

Frame Size and Material

Careful consideration to selection of frames for iseikonic prescriptions is very important. A fairly heavy frame that fits well will be a good choice because a small change in eyewire distance has a large effect on magnification, especially for patients with anisometropia. To achieve minimum lens thickness and weight, the frame should have as small an eye size as possible. Thick edges of iseikonic lenses can be better concealed by a zyl frame than by a rimless or metal frame.

EXAMPLES OF LENS DESIGN

The procedures used to achieve desired magnification are complex enough to warrant detailed examples. Two cases, one spherical and one astigmatic, will be discussed (Cases 19.4 and 19.5). To obtain accurate results, use the following sequence (27):

1. Changes in eyewire distance are preferred because they are more acceptable cosmetically. Thus, we recommend maximally changing eyewire distance (Table 19.2) initially, so that as much magnification change as possible can be realized from this change. When the aniseikonic correction is in the same direction as the anisometropia, reduce eyewire distance as much as possible (keeping in mind that 9 to 10 mm is the practical minimum). Increase the eyewire distance as much as possible when the aniseikonic correction is opposite to that expected from the anisometropia.
2. Change front curve (Table 19.4) as much as possible. Very steep or very flat front curves are not cosmetically appealing, so attempt to stay between +10.50 D and +2.00 D. Selecting front curves that correspond to those available from local laboratories will save both time and money.
3. Change the thickness of the lens (Tables 19.5 and 19.6), using the selected front curve from step 2.
4. Make bevel alterations as necessary, using Table 19.3 or Table 19.7 or both.

Case 19.4 Design from Estimation

A 23-year-old woman is referred with complaints of long-standing symptoms of headaches and asthenopia when wearing her spectacle correction. She has tried contact lenses, with relief of the asthenopia, but allergies have forced her to discontinue contact lens wear. Her refractive correction is as follows:

OD: -1.00 DS

2.1-mm minimum (center) thickness +5.25 front curve center bevel

15-mm eyewire distance

OS: -4.00 DS

2.1-mm minimum (center) thickness +3.50 front curve center bevel

15-mm eyewire distance

Keratometer readings are as follows:

OD: 44/50/180 44.75

OS: 46.25/180 46.50

Based on the corneal curvatures, the anisometropia of this patient is at least partially of dioptric origin. Ogle (33) stated that 1.5% aniseikonia per diopter of anisometropia is the usual amount expected. Since anisometropia is usually due (at least partially) to axial length differences, and under-prescribing is the rule rather than the exception, we decided to give 3.0% magnification increase to the left eye rather than 4.5%. To do this, follow the steps set forth earlier:

1. Decrease the eyewire distance (Table 19.2) from 15 mm to 10 mm (either by readjusting the present frame or selecting a new one) to increase magnification +0.5% for the right lens and +2.0% for the left. This is a difference $[(+2.0) - (+0.5)]$ of +1.5%—an increase in magnification relative to the left lens.
2. Change front curve (Table 19.4). Increasing the front curve helps because more magnification can then be gained when thickness changes are made. However, Table 19.4 suggests that little change will occur, and we decided to follow the table and make no front curve change.
3. Change thickness (Tables 19.5 and 19.6). The final desired magnification depends primarily on increasing the thickness of the left lens. For a front curve of +3.50 and a thickness change of +2.5 mm, Table 19.5 equals 0.582; Table 19.6 equals -0.50 when the thickness of a -4.00 D lens has been changed +2.5 mm. Consequently, the magnification change for changing thickness +2.5 mm $[A (+0.582) - B (-0.50)]$ is +1.082%.
4. Changing the bevel (Table 19.7) of a -4.00 DS lens that has had a thickness increase of +2.5 mm to move the lens closer (change from center to $\frac{1}{3} - \frac{2}{3}$ bevel) gives a magnification change of +0.44%.

Alterations of lens parameters have changed the magnification of both lenses to give a net increase of 3.02% magnification overall, left eye. This is determined from the following:

Change eyewire distance	1.50%
Change front curve	No change made
Change thickness	1.08%
Change bevel	0.44%

Final Prescription

OD: -1.00 DS

2.1-mm (center) thickness +5.25 front curve center bevel

10-mm eyewire distance

OS: -4.00 D.S.

4.6-mm (center) thickness +3.50 front curve $\frac{1}{3} - \frac{2}{3}$ bevel

10-mm eyewire distance

Antireflective coat; edge coat

Case 19.5 Design from Estimation

A 19-year-old uncorrected symptomatic woman has a 2 Δ exophoria at distance and near. Her refractive correction and acuity are the same as her current correction. Her current correction is as follows:

OD: +1.00	20/20–	PD = 62
OS: +1.00 c – 2.00 \times 180	20/20	
Front curve: +6.50 OD and +4.50 OS		
Center thickness: 2.6 mm OD and 2.1 mm OS		
Eyewire distance: 14.0 mm		

Twenty-four hours of diagnostic occlusion eliminated the patient's symptoms. No significant lateral or vertical heterophoria was found. Space eikonometry reveals the need for the following:

left 1.25% O.A.c 1.75% \times 180

There are moderate to severe seasonal allergies, and slit lamp examination reveals moderate follicles under both upper lids.

Because contact lens fitting is not appropriate due to the patient's allergies and lid appearance, an iseikonic prescription will be designed. When a meridional correction is required, each principal meridian must be considered separately. For the right lens, the power is the same in all meridians: +1.00 in the 90-degree meridian and the same for the 180-degree meridian. For the left lens, the power in the 90-degree meridian is -3.00 ; in the 180-degree meridian, it is -1.00 .

To design the lenses, follow the steps set forth earlier, but, this time, corresponding principal meridians must be compared.

Horizontal Meridian

1. Change eyewire distance (Table 19.2). Moving a +1.00 lens 4 mm closer decreases magnification in that meridian -0.4% . Moving a -1.00 (left lens, 180-degree meridian) lens 4 mm closer increases magnification $+0.4\%$. This is a difference of 0.8% —a $+0.8\%$ increase in the 180-degree meridian, relative to the left lens.
2. Change front curve (Table 19.4). Because the $+0.8\%$ increase in magnification in the horizontal meridian (left lens) is most of the desired 1.25% change for that meridian, no front curve change will be made until the effect of the thickness change of step 3 is evaluated.
3. Change the thickness (Tables 19.5 and 19.6). From Tables 19.5 and 19.6, increasing the thickness of a -1.00 lens (with a +4.50 front curve) +1.5 mm gives an increase in magnification $[A (+0.450) - B (-0.07)]$ of $+0.52\%$ (left lens, 180-degree meridian).

Vertical Meridian

1. Change eyewire distance (Table 19.2). Eyewire distance was reduced 4 mm in step 1 of the 180-degree meridian, and this reduction must also be used in analysis of the 90-degree meridian. Reducing the eyewire distance from 14.0 to 10.0 mm decreases magnification -0.4% for the right (+1.00/90 degree) and increases magnification $+1.2\%$ for the left ($-3.00/90$ degree) lens. This is a difference of 1.6% —an increase of $+1.6\%$ in the 90-degree meridian, relative to the left lens.
2. Change front curve (Table 19.4). Decreasing the front curve (90-degree meridian) of the right (+1.00) lens by -2 D decreases magnification -0.45% . Previous discussion of increasing the front curve of a lens of -2.50 D or greater showed that a decrease in magnification would result.

However, with a steep front curve, an increase in thickness becomes much more significant. Thus, the front curve of the left ($-3.00/90$) lens should be increased. With a $+4$ D increase in front curve for the -3.00 lens, a decrease in magnification of -0.04% is realized (interpolated from Table 19.3). This gives a relative magnification increase of $+0.41\%$ in the 90-degree meridian of the left lens.

3. Change the thickness (Tables 19.5 and 19.6). Lens thickness was increased $+1.5$ mm when the 180-degree meridian was analyzed, and this thickness change must also be used for calculations in the 90-degree meridian. No change in the front curve was made in the 180-degree meridian with a $+8.50$ front curve (from the $+4$ D increase in step 2). Increasing the thickness of a -3.00 lens (left lens, 90-degree meridian) by $+1.5$ mm gives a magnification increase $[A (0.847) - B (-0.225)]$ of $+1.072\%$ in the 90-degree meridian.
4. Bevel change. No bevel change is made until the effects of the other changes are evaluated. Bevel changes should be made as a final step, in order to achieve additional needed magnification.

The magnification changes are as follows:

	180-degree Meridian	90-degree Meridian
Eyewire distance	0.80%	1.60%
Front curve	No change	0.41%
Thickness	0.52%	1.072%
Bevel	No change	No change
Total	1.32% increase (left lens)	3.082% increase (left lens)

The result is $1.32\% \text{ OA} \times 1.76\% \times 180$, which is quite close to the magnification desired ($1.25\% \text{ OA} \times 1.75\% \times 180$) for the left eye.

Final Prescription

OD: $+1.00$ DS
 2.6-mm center thickness front curve $+6.25/180$; $+4.25/90$
 10.5-mm eyewire distance center bevel
 OS: $-1.00 - 2.00 \times 180$
 3.6-mm center thickness front curve $+4.50/180$; $+8.50/90$
 10.5-mm eyewire distance center bevel
 Antireflective coat; edge coat

Bitoric Lenses

The bitoric lens has different amounts of magnification in different meridians within the same lens. In general, iseikonic bitoric lenses are designed so that the same meridians are used for the front cylinder and for the refractive astigmatic correction. Thus, to correct the refractive error and give the desired magnification, both lenses will typically have cylindrical front and back surfaces, since only one center thickness is possible on a lens. The cylinder axes on the front and back of each lens must be aligned exactly to produce the desired lens power. Even a 0.5-degree misalignment can cause significant power deviation from that required. Bitoric lenses are difficult to fabricate, and few laboratories are equipped to do this type of work. When ordering a bitoric lens from a lab, it is best to simplify the order so that it is more easily understood—for example, by using a power diagram (optical cross). Specify the front curves, center thickness, and total power. The lab will determine the proper back curves. To check the lenses when they are received, simply verify the refractive power (using the lensometer), determine that the center thickness matches your order, and check that the front curves have the proper powers and axes.

INADVERTENT ISEIKONIC CORRECTIONS

If the patient will have no (or minimal) aniseikonia with a spectacle correction, it is important that the new prescription be designed so that it will not create or exacerbate a problem. The primary issue to consider is whether the patient is currently wearing a correction or not. If the patient is already wearing a spectacle correction that is similar to the new one, prescribing front curves and center thickness that are equal to the old correction will generally create few problems. If there is a large change in correction or a first correction, then prescribing equal front curve and center thickness lenses in minus cylinder form will typically be sufficient when the prescription is for hyperopic anisometropia. When both lenses have minus power, it is usually superior practice to order stock lenses rather than equal front curve and center thickness, since stock lenses almost always have equal center thickness. Stock front curve lenses also have the proper corrected curves for the minus refractive powers prescribed. Further, the standard front curves used on stock minus power lenses provide a small amount of magnification to the eye requiring more minus due to the flatter front curve on the more minus lens. If this small amount of magnification is not desired, equal front curves and center thickness should be ordered.

There are other ways that aniseikonia may be inadvertently induced by prescription of a new spectacle correction. This can occur even when the actual change in refractive error is very small or the only change is that a patient chooses a new frame and the lens power is the same. These inadvertent iseikonic corrections occur because of changes in frame eye size, differences in the refractive index of the new and old prescription (e.g., glass lenses in the old correction and polycarbonate lenses in the new one), differences in vertex distance where the new and old glasses sit at different differences from the eyes, and (for strong prescriptions) differences in the adjustment of the frame where the new might have a different face form and/or pantoscopic tilt than the old. To minimize these potential adaptation issues, insure that a new prescription sits the same distance from the eye as the old and that the adjustment is as close to the old as possible (same face form and pantoscopic tilt).

Frame Eye Size Changes

When a new frame is chosen that has a substantially different eye size than the previous correction, aniseikonia may be inadvertently induced. In these instances, the patient experiences a significant change in the magnification of the lens due to the change in vertex distance induced by the change in lens eye size. A larger lens eye size causes the lens to be located farther away, due to the change in lens sag (Fig. 19.8). Table 19.9 shows the changes in sag that occur when lenses of various size and front surface curvature are used. The change in sag causes the lens to be moved to a different distance from the eye and alters the magnification that the patient experiences.

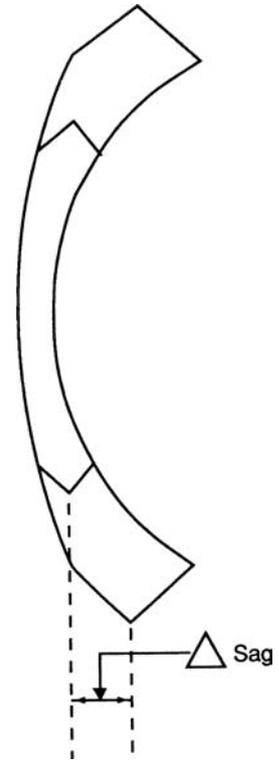
As an example of the usefulness of Table 19.9, consider the patient wearing the following:

OD: +1.00 2.6-mm center thickness 14-mm eyewire distance	+6.50 front curve center bevel
OS: +4.00 4.1-mm center thickness 14-mm eyewire distance	+10.50 front curve center bevel
Frame size: 42 × 40 mm	

There is no change in correction, and the patient wants a new and more stylish frame. No change in lens parameters will be made, but if the patient selects a new 52 × 48 mm frame, the lens sag will be increased for both lenses. Because both lenses are plus, the largest measurement of the frames determines the amount of sag. A +1.00 D lens with a +6.50 D front curve has a -5.50 D back curve. A +4.00 D lens with a +10.50 D front curve has a -6.50 D back curve.

From Table 19.9, the back curve for the right lens is -5.50 and the 42-mm “key” eye size sag is 2.3 mm. When frame eye size is increased to 52 mm, the sag is 3.5 mm. The difference is an increase in sag (vertex distance) of 1.2 mm (3.5–2.3). This causes a magnification increase of 0.12% (Table 19.2). From Table 19.9, the back curve for the left lens is -6.50 when eye size is 42 mm; the sag is 2.7 mm. Increasing the eye size to 52 mm increases sag to 4.2 mm. The difference (4.2–2.7) is an increase in sag (vertex distance) of 1.5 mm. This causes a magnification increase of 0.6% (Table 19.2). Thus, the change in frame eye size alone causes an increase in magnification of 0.48% (0.6–0.12) relative to the left lens. This difference may cause perceptual problems for the patient, with a possibility that he or she could never adjust unless

■ **FIGURE 19.8** An increase in lens eye size causes a change in lens sag. This change in sag places the lens at a different vertex distance and alters the magnification experienced by the patient. As a result of this factor, aniseikonia may be inadvertently induced when a new frame is chosen that has a substantially different eye size than the previous correction.



other changes were made. The simplest change would be readjustment of the frame. If it were adjusted 1.5 mm closer (to an eyewire distance of 12.5 mm), the increase in magnification caused by the larger frame (+0.48%) would be offset by a decrease in magnification from moving the lenses closer to the eyes (-0.45%) (Table 19.2).

The same effect is present in minus corrections. As frame size increases, lens sag (vertex distance) increases and magnification is decreased (Fig. 19.8). For anisometropic corrections, the lens of greatest power has the greatest magnification decrease. This creates a difference in magnification between the two lenses that was not present previously, and it may cause perceptual problems. Again, the method of choice for eliminating this effect is to adjust the frame closer to the eyes.

TABLE 19.9 LENS SAG (MILLIMETERS) FOR VARIOUS LENS SIZES AND SURFACE CURVATURE^a

Eye Size (mm)	Surface Curvature											
	1.50	2.50	3.50	4.50	5.50	6.50	7.50	8.50	9.5	10.50	11.50	12.50
36	0.4	0.7	1.0	1.4	1.7	2.0	2.3	2.6	2.9	3.3	3.6	3.9
38	0.4	0.8	1.1	1.5	1.9	2.2	2.6	2.9	3.3	3.6	4.0	4.3
40	0.5	0.9	1.3	1.7	2.1	2.5	2.9	3.3	3.7	4.1	4.4	4.8
42	0.5	1.0	1.5	1.9	2.3	2.7	3.2	3.6	4.0	4.5	4.9	5.3
44	0.5	1.1	1.5	2.0	2.5	3.0	3.5	4.0	4.4	4.9	5.4	5.9
46	0.6	1.2	1.8	2.2	2.8	3.3	3.8	4.4	4.9	5.4	6.0	6.5
48	0.7	1.3	1.9	2.4	3.0	3.6	4.2	4.7	5.3	5.9	6.5	7.1
50	0.7	1.4	2.1	2.6	3.2	3.9	4.5	5.2	5.8	6.5	7.1	7.8
52	0.8	1.5	2.2	2.8	3.5	4.2	4.9	5.6	6.3	7.1	7.8	8.6
54	1.0	1.7	2.4	3.1	3.8	4.6	5.3	6.1	6.9	7.7	8.4	9.3

^aWith a change in frame size, the type of correction determines the sag effect. For minus lenses, the smaller frame measurement determines the sag effect; for plus lenses, the larger frame measurement determines the sag effect.

Refractive Index Changes

Changes in the refractive index of the lens also can result in inadvertent iseikonic corrections. Typically, the change in magnification that results from a change of refractive index is small. For example, there is a decrease in magnification of about 0.05% for a change from crown glass to polycarbonate plastic. This decrease in magnification means that as the index of refraction is increased, the front curve can be made flatter or the lens thinner, or both, to achieve the same amount of magnification.

A frequent reason for changing to a higher index is to provide improved cosmetic appearance of spectacle lenses. Although the change in magnification is small, many patients complain of altered space perception. This usually results from a combination of the change in material (index of refraction), a decrease in lens center thickness that is often made to minimize edge thickness, and a lack of care in prescribing the front curve of the new prescription. To minimize complaints of altered perception, it is best to make the new minus lens with about 0.50 to 1.00 D more front curve than the old lenses and then to adjust the correction as close to the eyes as possible. Often more face-form (wrap-around) and care that the pantoscopic tilt of the frame is the same as the old pair will also help minimize complaints of perceptual distortion due to inadvertent iseikonic correction.

Summary and Conclusion

Although there are a substantial number of patients with symptoms of aniseikonia, iseikonic lenses are not often prescribed. Careful review of the history and clinical tests will provide sufficient information to make a tentative diagnosis of the probability of aniseikonia. When there may be aniseikonia, we recommend first prescribing contact lenses or spectacle correction to determine whether simply correcting the refractive error will solve the patient's problems. Occasionally, for older patients, a small modification of cylinder axis or power may also alleviate symptoms of aniseikonia and eliminate the need for aniseikonic correction.

When iseikonic corrections are required, they can be designed using our general rules to alter dimensions of a patient's spectacle lenses to correct aniseikonia:

1. Changing vertex distance (h) changes magnification
2. Increasing front surface curvature (D_1) increases magnification
3. Increasing the thickness (t) increases magnification

Recognition of these factors enables the clinician to determine what lens parameters to change and simplifies the design of iseikonic corrections.

Study Questions

1. Why would it be important to differentiate between static and dynamic aniseikonia?
2. What is Knapp's law and why does it not hold true in many suspected cases of aniseikonia?
3. How are symptoms of aniseikonia similar to symptoms of patients with heterophoria?
4. What types of ocular surgery would lead to aniseikonia?
5. What can you do to determine image size difference without an eikonometer or an Aniseikonia Inspector?
6. Why would you decide to prescribe only a partial iseikonic correction? How would this decision influence the doctor-patient interactions?
7. In order to increase lens magnification, you need to change which lens factors in what manner?
8. Why does change in base curve not provide a change in magnification for a minus lens?
9. Why is frame eye size important in designing an iseikonic lens?
10. How can you minimize a patient's symptoms of altered space perception, when prescribing new glasses?

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Binocular and Accommodative Problems Associated with Computer Use

Among the most frequent health-related problems reported by users of computer video display terminals (VDTs) are those related to vision. Working on the computer for long periods can lead to eye discomfort, fatigue, blurred vision, and headaches (1). When patients seek care for complaints related to computer use, it is important to accurately diagnose and treat all of their symptoms, not only the visual problems. Symptoms associated with VDT use can largely be categorized into four primary areas—refractive, binocular vision, ocular and systemic health, and ergonomic. Symptoms resulting from each of these can be resolved with proper care and attention to environmental design.

Etiology and Prevalence of Computer-related Vision Problems

Surveys show that nearly 15% of patients seeking general eye care schedule their visual examination as a result of computer-related visual complaints (2). This is not surprising, as 70 million U.S. households (62%) contained one or more computers in 2003; a number which increased to 91.7 million households (76.7%) by 2010 (3). Surveys indicate that more than 10% of patients present with symptoms primarily associated with monitor use; more than 20% of them could not receive a definitive diagnosis and treatment plan (4). According to the U.S. Census Bureau, in 2010, 68% of Americans aged 15 and older used computers at home, 35% used computers at work, and 15% used computers at school (3).

The problem is not limited to adults. Many children use computers for educational and recreational purposes. The way that children use the computer may make them even more susceptible to development of computer-related vision symptoms. Children often continue performing an enjoyable task, such as playing video games, without breaks until they are near exhaustion. Such prolonged activity can increase eye-focusing problems and eye irritation. An additional issue is that computer workstations are typically arranged for adults. Therefore, a child using a computer on a typical office desk must often look up higher than an adult. This may cause problems with a child's vision, as well as resulting in symptoms of arm, neck, and back discomfort.

Computer Vision Syndrome versus Computer Use Complex

The problems associated with computer use are so frequent and there is so often a visually related symptom that the term *computer vision syndrome* has been suggested as descriptive of the group of problems associated with computer use (5). According to *Stedman's Medical Dictionary* (6), a *syndrome* is a group of symptoms related to a specific disease. This calls into question the term *computer vision syndrome*, because it is likely that symptoms stemming from computer use are not a specific disease related solely to vision. This is especially significant when considering the physical symptoms that also accompany computer use; for example, neck, back, and wrist problems, such as carpal tunnel disease (1), and visual symptoms that are related to lid disease, lack of blinking, or dry eye rather than vision per se (2).

In medicine, a group of diseases or symptoms associated with similar etiologies is called a *complex* (e.g., EHHA complex) (7). Thus, the symptoms associated with computer use are more similar in this respect to a complex than a syndrome. For these reasons, we are using the term *computer use complex* (CUC) to

include all of the visual and physical signs and symptoms associated with computer use. This chapter primarily discusses visually related signs and symptoms related to CUC—what is often referred to as computer vision syndrome (5).

Characteristics

SYMPTOMS

Most symptoms are associated with computer use, although patients also frequently complain of symptoms with reading or other close work. In most cases, symptoms occur when the visual demands of the task exceed the visual abilities of the patient to comfortably perform them. At greatest risk for development of symptoms are patients who spend two or more continuous hours of daily computer use. Common complaints include eyestrain, headaches, blurred vision, diplopia, sleepiness, difficulty concentrating, loss of comprehension over time, a pulling sensation, and movement of the text on the screen.

SIGNS

Visually related symptoms may be associated with any refractive error. Symptoms of presbyopic patients may be related to the binocular state or to the design of the prescription used for computer use. Thus, it is important for the clinician to evaluate the type of correction (bifocal or single vision) and the ways in which the prescription is used.

ANALYSIS OF BINOCULAR AND ACCOMMODATIVE DATA

Patients with visually related computer symptoms often have accommodation-based problems. Although a significant heterophoria at near may be an important finding in many cases, to reach a diagnosis clinicians should use their judgment and generally rely on characteristics in addition to the magnitude of the heterophoria at distance and near.

Direct tests of fusional vergence, including step, smooth, and jump vergences, are important in diagnosis. In addition, tests that indirectly assess fusional vergence should be considered. Tests performed binocularly with minus lenses evaluate the ability to stimulate accommodation and control binocular alignment using negative fusional vergence (NFV) (e.g., positive relative accommodation [PRA] and binocular accommodative facility [BAF] testing with minus lenses). A characteristic finding in patients with visually related computer use symptoms is a report of blur, rather than diplopia, as the endpoint on PRA and BAF testing.

Reduced PRA or BAF results may stem from inability to stimulate accommodation or from reduced NFV. The differential diagnosis is based on the assessment of accommodation under monocular conditions. Simply cover one eye after the patient reports blur on the PRA test; if blur persists, the problem is usually accommodative (accommodative insufficiency or ill-sustained accommodation). If the vision clears, the problem is associated with binocular vision (NFV). Normal monocular accommodative ability on accommodative facility testing suggests reduced NFV.

Another important indirect test of NFV is monocular estimation method (MEM) retinoscopy (8). It is not unusual to find an abnormal result on this test on patients with visually related CUC symptoms. An MEM finding of greater plus than expected suggests that the patient is using as little accommodation as possible to decrease the use of accommodation or accommodative convergence.

Differential Diagnosis

It is typically not necessary to consider serious underlying etiology in cases of visually related CUC symptoms. As with other conditions, differential diagnosis (Table 20.1) depends on the nature of the patient's symptoms. Visual conditions associated with serious underlying disease almost always have an acute onset, with associated medical problems or neurologic symptoms. Typically, patients with visually related CUC symptoms present with long-standing chronic complaints. The health history is negative, and although the patient may be taking medication known to affect accommodation (e.g., allergy-related medications such as loratadine [Claritin]), the symptoms usually are not easily related to use of the medication. The primary functional disorders that typically must be differentiated are basic heterophoria (eso-, exo-, and/or hyperphoria),

TABLE 20.1 SYMPTOMS AND SIGNS OF VISUALLY RELATED COMPUTER USE PROBLEMS

Symptoms	
These symptoms are related to computer use, although there may also be symptoms with use of the eyes after reading or other near tasks:	
Eyestrain	Difficulty concentrating on reading material
Headaches	Loss of comprehension over time
Blurred vision	A pulling sensation around the eyes
Double vision	Movement of the print
Sleepiness	
Signs: Exophoria	Signs: Esophoria
Receded near point of convergence	Receded near point of convergence
Basic exophoria	Basic esophoria
Greater exophoria at near than at distance	Greater esophoria at near than at distance
Low AC/A ratio	High AC/A ratio
<i>Direct measures of positive fusional vergence (PFV)</i>	
Reduced smooth vergence	
Reduced step vergence	
Reduced fusional facility	
<i>Indirect measures of PFV</i>	
Low negative relative accommodation	
Low monocular estimation method retinoscopy finding	
Difficulty with plus lenses during binocular accommodative facility (BAF) testing	
<i>If accommodative excess is also present</i>	
Difficulty with plus lenses during monocular accommodative facility (MAF) testing	
<i>If accommodative insufficiency is also present</i>	
Difficulty with minus lenses during MAF and BAF testing	
Low positive relative accommodation	
Low amplitude of accommodation	
Possible improvement in near point of convergence testing with plus lenses	

convergence insufficiency, vergence infacility, and visual discomfort secondary to various accommodative anomalies (e.g., infacility, inaccuracy, or insufficiency).

Most visually related CUC symptoms result from benign conditions, with no serious consequences other than visual symptoms (Table 20.1). It is relatively easy to differentiate the binocular vision disorder present. To do so requires a careful analysis of all accommodative and binocular vision data. Cases 2.1 to 2.4 in Chapter 2 provide examples of the analytical process that the clinician should follow.

Ocular inflammation, such as blepharitis and meibomitis, can cause ocular symptoms of blurred vision after near work. This suggests that slit lamp evaluation is an important test in the differential diagnosis of apparent binocular symptoms related to CUC.

General Treatment Strategies for Visually Related Symptoms of Computer Use Complex

SEQUENTIAL MANAGEMENT CONSIDERATIONS

The concepts discussed previously for the sequential management considerations of binocular vision disorders also apply to problems related to computer use (Table 20.2). In the case of visually related symptoms of CUC, the important issues relate to the following:

- Correction of ametropia
- Added lenses
- Prism
- Vision therapy
- Ocular health
- Ergonomic issues

TABLE 20.2 SEQUENTIAL CONSIDERATIONS IN THE MANAGEMENT OF COMPUTER USE COMPLEX

Optical correction of ametropia	Vision therapy for sensory motor function
Added lens power	Horizontal prism
Vertical prism	Surgery
Occlusion for amblyopia	Ocular health management
Vision therapy for amblyopia	Ergonomic issues

CORRECTION OF AMETROPIA

Asthenopia and accommodative fatigue are frequent sequelae of uncorrected refractive errors such as hyperopia and astigmatism. For example, a patient with uncorrected hyperopia must accommodate for the computer working distance, as well as an additional amount to overcome the uncorrected hyperopia. Muscular fatigue resulting from prolonged (and occasionally excessive) accommodation may result in accommodative symptoms. Small amounts of uncorrected astigmatism and anisometropia also often result in visual symptoms. Some myopic patients experience discomfort when working on the computer while wearing eyeglasses. Each of these symptoms may be due to accommodative fatigue and accurate refractive correction must be considered in any management plan. The first management consideration, therefore, is the correction of refractive error.

In some cases patients who do not require correction for other daily activities may benefit from glasses prescribed specifically for computer use. In addition, persons already wearing corrective lenses may find that a prescription prescribed for general use may not be satisfactory for computer work; lenses may be need to be prescribed to meet the unique visual demands of computer viewing. Special lens designs, lens powers or lens tints, or coatings may help to maximize visual abilities and comfort. To properly correct the refractive error of any patient, including computer users, we recommend the prescribing criteria discussed in Chapter 3.

ADDED LENSES

Added plus lenses play a very important role in the treatment of visually related symptoms of CUC. Of course, patients with a high AC/A ratio in whom there is a significant esophoria at near (e.g., convergence excess) benefit from added plus lenses. In addition to the obvious near vision problems that result from the onset of presbyopia, various accommodative problems associated with pre-presbyopia, such as accommodative insufficiency and ill-sustained accommodation, cause CUC-related symptoms that can frequently be treated with added plus lenses. Accommodative problems in which the difficulty is with relaxation of (or frequent changes in) accommodation (accommodative excess and accommodative infacility) respond less well to added plus lenses and generally respond better to vision therapy treatments (Chapter 12).

When prescribing bifocals for computer users, it is important to recognize the difficulties that computer users often have with conventional bifocals which are typically designed for distance and near viewing; the computer monitor distance is often at an intermediate (50–75 cm+) rather than a near (40 cm) distance so that the general-use bifocal is too strong for monitor viewing. Because conventional bifocals or progressive lenses are not designed for looking at a computer monitor, some people are forced to tilt their heads at odd angles or bend toward the screen to see the monitor clearly. These postures can result in muscle spasms or pain in the neck, shoulder, or back.

PRISM

Prism, which is important in cases of binocular vision disorders, is used for visually related CUC symptoms when there is an associated binocular problem. Thus, esophoric patients and patients with a vertical heterophoria should have prism considered as part of the sequential management for their CUC vision-related problem. See Chapters 11 and 15 for prism recommendations for patients with esophoria and vertical heterophoria, respectively.

VISION THERAPY

The final binocular vision–related treatment consideration is the use of vision therapy to restore normal binocular function. Vision therapy is generally an important step in the management of accommodative and vergence problems. In many cases, vision therapy is critical in treatment of the binocular difficulties that accompany CUC vision-related problems.

SURGERY

Surgery, which is a consideration for some binocular vision problems when there is a very large heterophoria, typically has no role relative to CUC-related vision problems.

OCULAR HEALTH

Eyelid health and tear film integrity are very important causes of symptoms in CUC. Because of the intensity of the viewing task, computer users tend to blink less frequently. Studies by Yaginuma et al. (9) and Patel et al. (10) demonstrate a diminished blinking frequency in computer users. Most people blink approximately 18 times per minute; Patel et al. found that computer users blink as few as 4 times per minute (10).

The reduced blinking rate of computer users may be part of an effort to gaze attentively at the computer monitor. In some patients, this decreased blink rate can compromise visual comfort after even a few minutes of computer work, especially in the presence of eyelid disease or dry eye (11). Further, some office buildings have excessively dry environments that cause increased dry eye symptoms in the presence of reduced blinking. Thus, it is often important to carefully assess eyelid health with the biomicroscope. Evaluate tear integrity and break-up time (BUT) at the same time. In appropriate cases it is important to implement treatment of dry eye using artificial tears, nutraceuticals, other drops to improve tear health or volume (e.g., Restasis), and/or punctal plugs as needed.

ERGONOMIC ISSUES

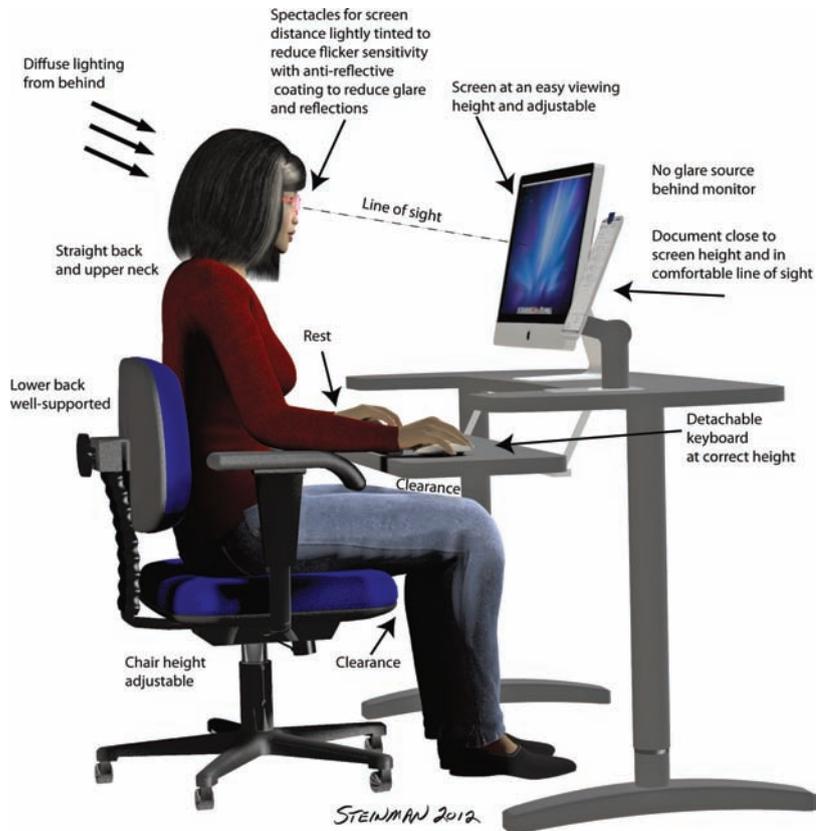
While examining patients suspected of having CUC-related visual symptoms, it is important to accurately evaluate how they use the computer. This is important because, for many patients, preventing or reducing the symptoms of CVS has to do with modifying how the computer is used. Figure 20.1 depicts some important details of the ergonomic setup. These include lighting conditions, glare, other working distances, chair comfort, location of reference materials, position of the monitor, use of rest breaks, time allotments to various tasks, and viewing angles.

Of course, it is possible to develop a rough estimate of viewing distance simply by asking a patient to indicate the computer screen distance with his or her arms. This inexact appraisal of the actual working distance may provide an idea of the monitor's distance and position that is useful to help make decisions as to visual correction and added near lens type, power, and style. It is generally more efficacious, however, to have the patient complete a symptoms-based questionnaire (Appendix 20.1) and then address all of the deficiencies and problems that have been identified.

LIGHTING CONDITIONS AND GLARE

In most work areas there are several causes of light-induced eyestrain, including glare on walls and finished surfaces, reflections from the computer monitor, and excessively bright light from both outside and inside the room. It is important to position the computer screen to avoid glare, particularly from overhead lighting or windows. Exterior light and reflections can often be reduced or eliminated by closing drapes or blinds.

- When using computers, lighting should be about half that used in most offices. Reduce lighting by using fewer or lower intensity bulbs. Change the lighting to reduce glare on the computer screen. Be sure that room windows do not cast glare onto the monitor by moving the monitor and/or closing the blinds until the glare is minimized. It is sometimes necessary to install a dimmer switch for overhead lights (if they are too bright) or to use a desk lamp with a moveable shade that distributes light more evenly over the work area.



■ **Figure 20.1** Evaluation of the use of the computer requires a number of measurements. In addition to those listed in the figure, it is also important to consider the amount of time spent on computer-related tasks.

- If glare from light sources cannot be reduced, consider using a screen glare filter. These filters decrease the amount of light reflected from the screen. For conditions where outside light cannot be reduced, a computer hood can reduce glare and reflections. In most cases anti-reflective coating applied to the patient's lenses will help reduce glare and reflections.

OTHER WORKING DISTANCES AND POSITIONS

Most people find it more comfortable to view a monitor when their eyes are looking downward. The optimal monitor position is 15 to 20 degrees (about 4 or 5 inches) below eye level as measured from the center of the screen and 20 and 28 inches from the eyes. At that position and location, most people do not have to stretch their neck and have corrected visual acuity that is adequate to resolve the material on the screen.

Reference materials should be located above the keyboard and below the top of the monitor. A document holder can be placed beside the monitor to locate the reference materials as close to the screen as possible. The goal is to position the documents so the patient needs to use minimum eye movements and does not need a head movement to look from the document to the screen. This lessens the need to constantly refocus the eyes as well as minimizing head movements, both of which decrease muscle fatigue, headaches, and eye strain.

SEATING POSITION

Chairs should be comfortably padded and conform to the body. The height of the chair should be adjusted so the patient's feet rest flat on the floor. If the chair has arms, they should be adjusted to provide arm support while typing and the keyboard should be adjusted so that the patient's wrists do not rest on it when typing.

COMPUTER MONITORS

Viewing a computer monitor is different than reading a printed page. Often, especially for PC-based monitors, the letters on the computer screen are not as sharply defined, the level of contrast of the letters to the background is reduced, and the presence of glare and reflections on the screen can compromise viewing.

The *refresh rate* (or frequency) refers to the number of times per second that the video board redraws the entire screen. For many monitors the refresh rate is 60 Hz, a speed that can cause a flicker that makes the screen appear to roll. The flicker may also stimulate the eye to accommodate, tiring the visual system. It may be necessary to adjust the brightness, contrast, and font size to the best settings for clear comfortable vision. To solve these potential problems, reset the font sizes and clarity and modify the refresh rate of the monitor to 70–85 Hz. (Verify from the monitor or computer hardware instruction manual that the monitor is capable of this setting.)

To change the computer monitor definition and refresh rate:

- Turn on ClearType in Microsoft Windows XP.

ClearType delivers improved font display quality over traditional forms of font smoothing or anti-aliasing. It improves readability on color LCD displays with a digital interface, such as those in laptops and high-quality flat panel displays. Readability on CRT monitors can also be improved.

- Increase the Monitor Refresh Rate.

Monitors often flicker which can cause eye strain. Many users adapt to the monitor flicker or their eyes are not sensitive enough to detect it. Higher refresh rates are less likely to cause eyestrain.

CHANGING THE REFRESH RATE

In Windows XP

Go to Control Panel>Display

In Settings> Advanced>Monitor

1. Check the box for “Hide modes that this monitor cannot display” to avoid hardware disputes.
 - This will give a drop down list of refresh rates that the monitor safely supports so that it can be set up without error.
 - It may also be necessary to check the manufacturer’s documentation for information about the settings that the monitor supports.
2. Increase the monitor’s refresh rate to 75 Hz or more.

REST BREAKS

It has been suggested that, to reduce eyestrain, the patient should “rest their eyes” during extended periods of computer use. There are no studies that definitively provide the amount of time that should be recommended and it is not known for certain that “rest” even helps. However, many patients report improved comfort during computer use with rest periods. A convenient recommendation is the “20-20-20 rule”: every 20 minutes focus the eyes on an object 20 ft (6 m) away for 20 seconds. This basically provides a convenient distance and timeframe for the patient to follow and, until there are research studies that provide a better recommendation, we suggest that full-time computer users “rest their eyes” on this schedule. Part-time users should follow the same timetable when viewing their monitor for more than 1 hour.

Computer Use Questionnaire

Optimal assessment of ergonomic issues can best be accomplished with a questionnaire that addresses each of the possible problems (Appendix 20.1, Computer Use Questionnaire). It is best to have the patient complete this questionnaire prior to the visual examination; this can be done at the patient’s home or office, where he or she has access to all of the measurements and other data required. When the patient tries to fill out the questionnaire during the examination, he or she frequently tries to guess at the distances and often does so inaccurately, making it more difficult to effectively treat symptoms. At times, it may even become necessary for the clinician to visit the workplace to completely resolve the problem.

COURSE AND PROGNOSIS

There have not been studies documenting the overall efficacy of treatment for improving visually related symptoms of CUC. However, as discussed above, treatment of CUC is tied to treatment of refractive errors and binocular vision and accommodative dysfunction, management of eyelid disease and dry eye symptoms, and development of proper ergonomics. Because each of these conditions can typically be successfully treated, it is likely that the symptoms of CUC can be resolved for most patients, provided that each underlying problem that causes symptoms is identified.

Treatment of refractive errors, binocular vision disorders, and accommodative dysfunction is outlined in this chapter and detailed throughout this book. Following a sequential treatment approach for each condition typically leads to successful resolution of the condition, with subsequent lessening of the visually related symptoms of the CUC sufferer. Successful management of eyelid disease and dry eye is almost always possible with a combination of lid hygiene, medications, and lacrimal occlusion. After faulty ergonomic conditions have been identified (using the questionnaire in Appendix 20.1), management can be initiated.

SUMMARY OF KEY POINTS IN TREATING PATIENTS WITH SYMPTOMS OF COMPUTER USE COMPLEX

An important feature in the sequential management of the visual symptoms of CUC is the emphasis on proper optical correction and added lenses. Because so much of the problem is associated with prolonged near work, provision of clear vision at distance (best correction) and near (added plus lenses) often has a substantial effect on reducing the symptoms. For the CUC patient, prism (horizontal and vertical) and vision therapy are also important treatment alternatives. Vertical prism is effective when needed to correct a small hyperphoria, and vision therapy is best for treatment of symptoms that result from convergence insufficiency and accommodative dysfunction. Ocular health (specifically eyelid and lash health, along with tear film quality and quantity) needs to be evaluated and any problems treated; such treatment can substantially improve visually related CUC symptoms. The patient's ergonomic computer use should be evaluated and recommendations made to improve any problem areas.

Clinical Evaluation

HISTORY AND SYMPTOMS

In addition to the visual history related to binocular vision and accommodative problems described in Chapter 12, it is important to ask appropriate questions in order to gain the information necessary to make critical judgments regarding the patient's working situation. We recommend questioning every patient regarding these issues. Appendix 20.1 documents the important issues related to computer use. This questionnaire is organized to assess symptoms (visual and physical) and ergonomic issues. When a patient cannot complete the questionnaire prior to an examination, address the appropriate questions during the examination. It is important to ask all patients about computer usage; in addition to the obvious job-related computer use, it is common for children and retired adults to be avid computer users.

WORKSTATION

While examining patients, assess the ergonomics of how they use their computer. For example, Part II (Work Practices and Environment) of the questionnaire in Appendix 20.1 provides detailed information about viewing distance, along with the monitor's location. The questionnaire also addresses other environmental working issues, including lighting conditions, glare, other working distances, time allotments for various tasks, and viewing angles.

The questionnaire allows the clinician to quickly assess whether workstation issues are a likely source of visually related symptoms of CUC. A workstation that is poorly designed, whether too high or low or with an improperly adjusted chair, can cause substantial symptoms (Fig. 20.1). In addition, a dry office environment or poor indoor air quality can aggravate a marginal dry eye problem to the point that

symptoms result. The problem of inadequate or poorly directed lighting should not be underestimated. Proper lighting is one of the most overlooked and underemphasized components of our indoor environment. Lighting should be designed to prevent problems, not cause them with reflections and sources of glare.

EVALUATION

The customary battery of tests for general binocular vision evaluation, listed in Chapter 3, provides the majority of information required for diagnosing the cause of visually related symptoms of CUC. It is important to consider information gathered via the questionnaire concerning the lighting used and the computer workstation setup when determining whether any modification in testing might be required. For example, special consideration may need to be given to testing accommodation and vergence under standard 40-cm test conditions, as well as at the computer work distance and under the lighting conditions used by the patient. Modification of the test is frequently needed when making diagnostic decisions based on testing vergence ranges and accommodative accuracy.

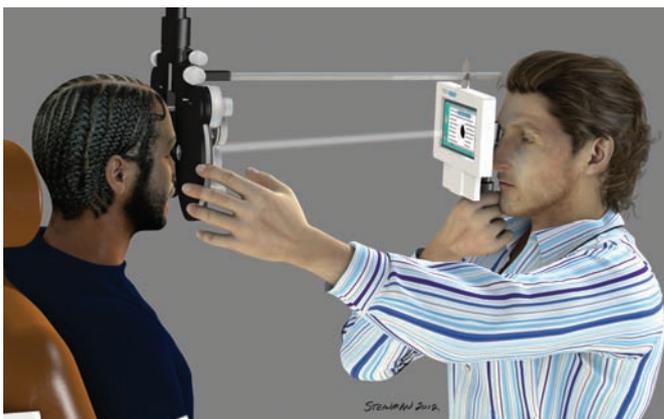
Accommodative Ranges (NRA/PRA)

Normal range values have been developed for accommodative assessment of pre-presbyopic patients. However, the norms, which were made for a 40-cm test distance, may not apply to the VDT working distance which is often substantially further away. A solution is to make measurements at the 40-cm distance and again at the VDT distance; the findings at the VDT distance should be similar to those at 40 cm. An abnormal finding at 40 cm, or an obvious discrepancy between the two findings, indicates a potential problem in this area.

Accommodative Accuracy

Determination of the accuracy of accommodation with MEM retinoscopy (8) is very valuable. This objective test allows measurement of the patient's active accommodative state at 40 cm and under test conditions (room illumination, horizontal gaze, viewing distance, etc.) that closely approximate the VDT environment. When testing at the VDT working distance, use letters that approximate the size of letters on the screen (as determined from questionnaire information). Typically, these are about 20/60 size, although there may be large individual variation.

The PRIO instrument,^a which is designed to simulate the workstation demand, can be used at the appropriate test distance to determine the accuracy of accommodation with MEM retinoscopy (Fig. 20.2). To use the PRIO, determine the patient's computer work distance (from the answers to Appendix 20.1) and



■ **Figure 20.2** Near retinoscopy by the monocular estimation method can be important when determining a near prescription for computer use. The PRIO instrument provides a target that is similar to the computer screen and allows the clinician to test at the appropriate working distance. Tests such as the PRIO may improve patient confidence in the resulting prescription.

perform MEM retinoscopy at that distance. An abnormal finding can be used as the basis for prescribing a near correction that will yield a more focused computer correction. The PRIO finding is typically a 0.25 to 0.50 D greater lag than the finding with traditional MEM retinoscopy using the appropriate letter size and test distance, consistent with basic research that objectively demonstrates that the accommodation to a VDT is about 0.33 D less than the accommodation to an identical paper task (12). An additional advantage of the PRIO instrument is that the patient feels that a “special test” is being done that is specifically designed to help visually related CUC symptoms. Such patient impressions are often invaluable.

Other Testing Factors

Pupil Size

While using a computer, a patient needs to view the monitor in normal room illumination (or slightly dimmer). If there is not enough light, a larger pupil will result that can exaggerate distortions of screen letters and decrease depth of focus to the point of distortion. Caution patients of this possibility and make appropriate recommendations concerning VDT brightness and room illumination. Differences in illumination between the monitor and the background should be less than 3:1. Patients will need to monitor this by estimation, because they will seldom be able to measure exact brightness.

Ocular Health

Eye health, specifically tear film integrity, is critical for VDT users. Because of the intensity of the viewing task, computer users tend to blink infrequently. Always evaluate eyelid health and perform a tear BUT if you question tear integrity.

Sequential Management Protocol

BEST REFRACTIVE CORRECTION

A clear trend has not been identified in the literature in regard to the amount of refractive error that needs to be treated in CUC. Small astigmatism correction, particularly against the rule or oblique, seems to be significant for many patients, as do small hyperopic corrections. These factors confirm that the most important first step is to prescribe the best lens correction for the patient. This single step can solve many of the vision-related problems of CUC. The effects of the best correction and the importance of lens design are illustrated by Case 20.1.

Case 20.1 Added Lenses For Near

Samantha, a 30-year-old office worker, presented with complaints of eyestrain and blurred vision after approximately 4 hours of computer use. These problems started when she was required to spend more time working on the computer at work. She had never had an eye examination. Her medical history was negative, and she was taking Claritin as needed for allergic symptoms (generally in the fall).

Computer Use Questionnaire

Samantha reported frequent episodes of blurred near vision and headaches, both of moderate severity. She worked on the VDT for 7 hours per day, with regular breaks. The viewing distance from the eye to keyboard was 17 in., and the distance from the eye to the computer monitor was 23 in. Her workroom was medium bright, with fluorescent lighting.

Examination Results

VA (distance, uncorrected):	OD: 20/20 OS: 20/20
VA (near, uncorrected):	OD: 20/20 OS: 20/20
Near point of convergence	
Accommodative target:	1 to 2 in.
Penlight:	1 to 2 in.
Cover test (distance):	Orthophoria
Cover test (near):	4 esophoria
Subjective:	OD: plano, 20/20 OS: plano, 20/20
Distance lateral phoria:	Orthophoria
Base-in vergence (distance):	X/7/4
Base-out vergence (distance):	14/21/15
Near lateral phoria:	5 esophoria
−1.00 gradient:	12 esophoria
Gradient AC/A ratio:	7:1
Calculated AC/A ratio:	8:1
Base-in vergence (near):	X/8/1
Base-out vergence (near):	11/25/18 Δ
Negative relative accommodation (NRA):	+2.50 D
PRA:	Diplopia with −1.75
Accommodative amplitude (push-up):	OD: 15 D; OS: 15 D
Monocular accommodative facility (MAF):	OD: 12 cpm; OS: 12 cpm
BAF:	Diplopia with −2.00
MEM retinoscopy:	+1.50 OD and OS

Pupils were normal, all external and internal health tests were negative, the deviation was comitant, and color vision testing revealed normal function. Eyelid and lash health was normal, as was the tear BUT.

Case Analysis

Based on the small esophoria at near, the best way to approach this case is to analyze the NFV group data. This is especially true because there are no apparent contributory eye health problems. For Samantha, the direct and indirect findings that investigate NFV are abnormal. The direct finding, NFV at near, is moderately reduced. The indirect tests—PRA, BAF, and MEM retinoscopy—also suggest an esophoria or low NFV problem. The distance orthophoria and the high calculated and gradient AC/A ratios all suggest a diagnosis of convergence excess with normal tonic vergence.

Management

Because there was no refractive error, our initial approach in this case was to prescribe added lenses for near. To determine the amount of plus to prescribe, consider the AC/A ratio, NRA/PRA relationship, fusional vergence findings, and MEM retinoscopy. In this case, the NRA/PRA relationship suggests the need for a near addition of about +1.00, as does MEM retinoscopy. The calculated AC/A ratio suggests that an addition of +1.00 would reduce the near phoria to slightly more than 2 exophoria. We prescribed plano distance correction with a near addition of +1.00 OD and OS in progressive bifocal form for all near work.

This case illustrates the frequent scenario of ophthalmic correction for CUC. In the absence of significant distance refractive error, most lens corrections are prescribed for near correction because of a problem with accommodation, esophoria, or presbyopia. When prescribing for visually related symptoms of CUC, an important decision the clinician must make when prescribing added plus lenses is whether to recommend single-vision lenses or bifocals.

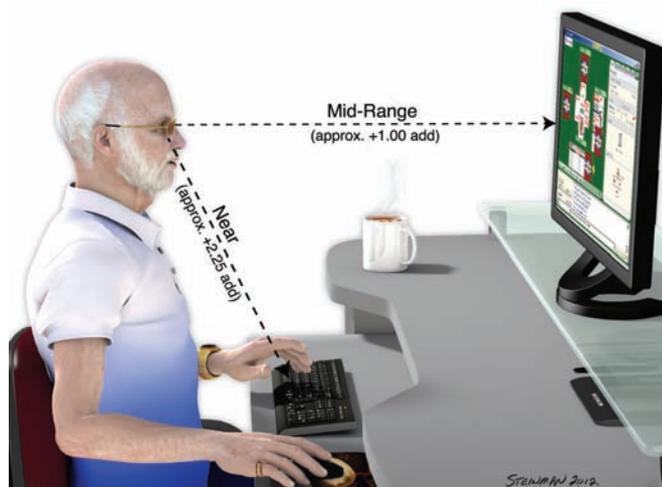
We typically suggest a computer and near bifocal prescription so that the patient does not have to remove his or her glasses when looking up from the computer. Although there are frequent exceptions, in our experience CUC patients wearing single-vision near lenses often become disillusioned with their glasses because of the continual need to remove them for clear distance vision.

Although a bifocal is our first recommendation for computer use, we sometimes encounter resistance from patients, especially pre-presbyopic young adults, about wearing a bifocal. When this occurs, we review and demonstrate the benefits of a bifocal and, if the patient remains unconvinced, prescribe a single-vision near correction. The patient can always change to a bifocal design later, and often will after he or she personally experiences the problems associated with frequently having to remove the single-vision correction.

ISSUES OF LENS DESIGN, COATINGS, AND MATERIALS

In general, for CUC patients, there is a problem with common flat top bifocal designs in which the bifocal height is at or below the lower lid margin. The flat top bifocal requires the patient to raise his or her chin to use the bifocal when looking at the computer. With prolonged computer use, this head position causes frequent neck and back pain, ultimately reducing work efficiency. This problem can be somewhat relieved by the use of progressive addition lenses (PALs) in which the progressive addition is started fairly high in the frame (at the center of the pupil). As long as the near addition is equal to or less than +1.50, most patients can assume a head position that allows them to look at the computer and still use the PAL with minimal head and neck symptoms. For Samantha, we recommended a PAL with the progressive addition starting at the center of the pupil.

As the patient ages (advancing presbyopia), specialized PALs or intermediate/near power bifocals become very important considerations. For advanced presbyopia, the standard PAL tends to have an intermediate corridor of narrow width (or, if the corridor is wide, the near portion is too low in the frame to be easily used). Of course, these issues are related to the amount of time spent using the computer. For advancing presbyopic patients who spend more than 2 hours per day on the computer, a PAL with the top portion having an intermediate power for computer use and the lower portion with the appropriate near power for reading is generally the lens of choice. For example, when an absolute presbyope needs a prescription of plano at distance with a +2.50 near addition, a useful computer prescription might be a computer-designed intermediate/near lens (e.g., +1.25 with a +1.25 near addition) in PAL form (Fig. 20.3). When less than 1 to 2 hours per day is spent on computer use, the advanced presbyopic patient often elects to get by with a less than optimal



■ **Figure 20.3** When the presbyopic patient needs a visual correction while using the computer, the lenses are designed so that the bottom portion contains the total near power needed, with the top portion reduced in power so that the focus is on the computer screen. Either a flat top bifocal or Progressive addition lens design can be used.

correction because of the costs involved when more than one pair of lenses is needed. An inexpensive option for the presbyopic patient who cannot afford a specific computer correction is the PC Peeker,^b a +1.12 lens designed to fit behind the spectacle correction and focus the computer monitor.

Lens coatings, such as ultraviolet (UV) protection and antireflective (AR) coatings, are often considered in treatment of visually related symptoms of CUC patients. In general, there is probably no particular need for UV protection for CUC patients who wear their correction only for computer use; however, if they also wear the correction outdoors, the protective issues of UV protection apply. There is little UV radiation from a computer monitor, so UV protection, although it does not hurt, probably does not provide any significant benefit. There are anecdotal reports that lenses which block the “blue” spectrum of light from the monitor may help protect the macula. These can be considered if there is concern by the patient of doctor regarding current or future macular issues. AR coatings can be helpful for improving vision, especially with large luminance ratios. An AR coating does not reduce screen reflections, but does reduce reflections from room lighting and windows so there are times when an AR coating will solve problems. Thus the AR coating combined with the proper lens prescription (such as added lenses) and design (PALs or computer-designed intermediate/near lenses) can be of value.

Generally, color filters, such as yellow or pink lenses, are mostly cosmetic and considered to be of little significant benefit with the advent of color monitors. However, Kundart et al., in a study of 36 participants, found significant improvements in irritation or burning of the eyes, tearing, or watery eyes, dry eyes, and tired eyes, comparing filtering lenses versus placebo lenses (12,13). This suggests that selected patients may benefit from using filters. Samantha’s PAL lenses included AR coating without filters.

In Samantha’s case, a follow-up visit after 4 weeks revealed that she was doing well with the glasses and had complete relief of symptoms. No additional treatment was recommended.

PRISM

Prism is occasionally required for CUC patients, as illustrated in Case 20.2.

Case 20.2 Prism Correction

Diane, a 24-year-old swimming pool designer, presented with a complaint of intermittent double vision when looking up at clients after working on the computer. She had noticed this problem since high school (for at least 7 years), but had not received any treatment. Her health was normal and she was not taking any medication.

Computer Use Questionnaire

Diane reported frequent episodes of double vision. She worked on the VDT for 2 to 3 hours per day, with regular breaks. The viewing distance from the eye to the keyboard was 17 in., and the distance from the eye to the computer monitor was 24 in. Her workroom lighting was variable, because she traveled to client’s homes to demonstrate pool designs on her laptop.

Examination Results

Interpupillary distance (IPD):	58 mm
VA (distance, uncorrected):	OD: 20/20
	OS: 20/20
VA (near, uncorrected):	OD: 20/20
	OS: 20/20
Near point of convergence:	1 to 2 in.
Cover test (distance):	7 esophoria
Cover test (near):	6 esophoria
Subjective:	OD: +0.25, 20/20
	OS: +0.25, 20/20

Cycloplegic:	OD: +0.50 OS: +0.50
Distance lateral phoria:	7 esophoria
Base-in vergence (distance):	Diplopia; needs 5 base-out to fuse
Base-out vergence (distance):	Diplopia; needs 5 base-out to fuse, breaks at 26 base-out, and recovers at 18 base-out
Near lateral phoria:	6 esophoria
-1.00 gradient:	10 esophoria
Gradient AC/A ratio:	6:1
Calculated AC/A ratio:	5:1
Base-in vergence (near):	X/8/-1
Base-out vergence (near):	X/23/18
NRA:	+2.50
PRA:	-1.25
Accommodative amplitude (push-up):	OD: 12 D; OS: 12 D
MAF:	OD: 10 cpm; OS: 10 cpm
BAF:	Intermittent diplopia with -2.00
MEM retinoscopy:	+0.50 OU

Fixation disparity testing with the American Optical (AO) vectographic slide at distance revealed an associated phoria of 4 base-out. Pupils were normal, all external and internal health tests were negative, the deviation was comitant, and color vision testing revealed normal function. Eyelid and lash health was normal, as was the tear BUT.

Case Analysis

Because there are no contributory eye health problems, the entry point into analysis of the data, in this case, is the moderate magnitude esophoria at distance and near. NFV findings at both distance and near are slightly reduced, with diplopia on base-in testing at distance. Diagnosis of basic esophoria is suggested by the equal magnitude esophoria at distance and near, reduced NFV, and normal AC/A ratio.

Management

Even though the management sequence in Table 11.3 suggests first considering best correction, the distance correction would be of little use; correction of this small amount of hyperopia would obviously have little influence on the angle of deviation. Because the best lens correction is of little value, Diane's treatment would have to consist of prism or vision therapy. After considering the options, Diane decided that she did not have sufficient time to devote to vision therapy. Therefore, based on the fixation disparity results, we prescribed a total of 4 Δ base-out prism. The final prescription was OD +0.25 and OS +0.25, with a 2 Δ base-out in each eye. Diane wore these glasses at work for 4 weeks and returned for a reevaluation. She reported complete relief of symptoms, so no further treatment was necessary. After 2 years of wearing the prism correction, she decided to undergo a vision therapy program.

VISION THERAPY

Vision therapy is often important for treatment of CUC patients (Case 20.3). The need for vision therapy is often related to heterophoria problems or accommodative or fusional vergence problems.

Case 20.3 Vision Therapy

Jack, a 36-year-old stockbroker, presented with complaints of eyestrain and blurred vision after about 2 hours of computer trading. He had experienced these problems for several years, but his previous reading glasses had not been of help to him and he had stopped wearing them after about 4 weeks. His medical history was negative, and he was not taking any medication.

Computer Use Questionnaire

Jack reported frequent severe episodes of eyestrain and blurred vision. He worked on the VDT for more than 12 hours per day, with irregular breaks. The viewing distance from the eye to the keyboard was 17 in., and the distance from the eye to the computer monitor was 24 in. His workroom lighting was fluorescent.

Examination Results

Previous prescription:	+0.50 +0.50
Interpupillary distance (IPD):	62 mm
VA (distance, uncorrected):	OD: 20/20 OS: 20/20
VA (near, uncorrected):	OD: 20/20 OS: 20/20
Near point of convergence	
Accommodative target:	2 to 4 in.
Penlight:	2 to 4 in.
Cover test (distance):	Orthophoria
Cover test (near):	3 exophoria
Subjective:	OD: +0.25 – 0.25 × 180, 20/20 OS: +0.25 – 0.25 × 180, 20/20
Cycloplegic:	OD: +0.75 – 0.25 × 180, 20/20 OS: +0.75 – 0.25 × 180, 20/20
Distance lateral phoria:	Orthophoria
Base-in vergence (distance):	X/4/2
Base-out vergence (distance):	6/10/6
Near lateral phoria:	3 exophoria
–1.00 gradient:	1 esophoria
Gradient AC/A ratio:	4:1
Calculated AC/A ratio:	4.8:1
Base-in vergence (near):	4/8/6
Base-out vergence (near):	6/10/2
NRA:	+1.50
PRA:	–1.25
Accommodative amplitude (push-up):	OD: 9 D; OS: 9 D
MAF:	OD: 11 cpm; OS: 11 cpm
BAF:	2 cpm
MEM retinoscopy:	+0.25

Pupils were normal, all external and internal health tests were negative, the deviation was comitant, and color vision testing revealed normal function. Slit lamp evaluation revealed normal lids and lashes, with no evidence of dry eye or abnormal tear film.

Case Analysis

The normal phoria at both distance and near, normal lids and lashes, and lack of a dry eye condition suggested that an accommodative disorder was the most likely cause for Jack's symptoms. Accordingly, the entry into analysis of this case was the data related to accommodative testing, which revealed a normal amplitude, facility, and accommodative response. The NRA and PRA were both low, and accommodative function was normal, suggesting a fusional vergence problem. PFV and NFV were reduced on direct and indirect tests. Diagnosis of fusional vergence dysfunction is supported by the low NRA and PRA and the reduced BAF.

Management

We advised Jack that his ametropia was considered insignificant; because there was no vertical deviation, glasses were not prescribed. His ocular health was normal, indicating no need for treatment in this area either; rather, we suggested a program of vision therapy to normalize fusional vergence findings and eliminate symptoms.

Because he was unwilling to come into the office for therapy, Jack was given vision therapy procedures to practice at home. We followed the sequence outlined in Table 11.8, and six in-office vision therapy progress visits were necessary to evaluate Jack's progress and make changes in his therapy. At the end of therapy, Jack reported that he was able to work on the computer for a full 12 hours without discomfort.

Reevaluation at completion of therapy revealed the following findings:

Base-in vergence (distance):	X/8/6
Base-out vergence (distance):	X/20/16
Near lateral phoria:	2 exophoria
Base-in vergence (near):	14/26/22
Base-out vergence (near):	20/32/28
NRA:	+2.50
PRA:	-2.50
BAF:	10 cpm

The maintenance program suggested in Table 9.10 was recommended. Reevaluation was scheduled in 6 months; Jack returned in 9 months. He revealed that he had stopped maintenance therapy after 3 months. After his symptoms resumed, Jack initiated therapy again on his own. He was again comfortable, and his findings remained normal.

MEDICAL TREATMENT

Many patients who have CUC-related symptoms have ocular health problems that interfere with their vision and cause symptoms. Sometimes the symptoms may seem to come from either a binocular vision or an ocular health problem, and occasionally the symptoms are related to both conditions (Case 20.4).

ERGONOMIC ISSUES

Many patients who have CUC-related symptoms have ergonomic issues related to a computer workstation design that interferes with their work and causes symptoms. Sometimes the symptoms may seem to come from either a binocular vision or an ocular health problem, but the ergonomics of CUC use must be considered in virtually all cases, as illustrated in Case 20.5.

Case 20.4 Medical Treatment

Jeremiah, a 15-year-old high school sophomore, presented with complaints of eyestrain and blurred vision after about 20 minutes of computer work. He had had these problems for 2 years, but his previous visits to eye doctors had not yielded relief. His previous (1-year-old) reading glasses had not helped, and Jeremiah had stopped wearing them. His medical history was positive for “eyelid problems,” but he was not taking any medication.

Computer Use Questionnaire

Jeremiah reported frequent episodes of moderate eyestrain and intermittent double vision when reading or working on the computer, and he felt that these symptoms were worse when he did computer work. Further questioning revealed that the diplopia was a monocular ghosting that remained when he covered either eye. He worked on the VDT for 2 or more hours per day, with irregular breaks. The viewing distance from the eye to the keyboard was 18 in., and the distance from the eye to the computer monitor was 21 in. His workroom lighting was fluorescent.

Examination Results

Previous prescription:	+0.50 D
	+0.50 D
IPD:	62 mm
VA (distance, uncorrected):	OD: 20/20
	OS: 20/20
VA (near, uncorrected):	OD: 20/20
	OS: 20/20
Near point of convergence:	2 cm
Accommodative target:	2 to 4 in.
Penlight:	2 to 4 in.
Cover test (distance):	Orthophoria
Cover test (near):	2 Δ exophoria
Subjective:	OD: +0.25 – 0.25 × 180, 20/20
	OS: +0.25 – 0.25 × 180, 20/20
Cycloplegic:	OD: +0.75 – 0.25 × 180, 20/20
	OS: +0.75 – 0.25 × 180, 20/20
Distance lateral phoria:	Orthophoria
Base-in vergence (distance):	X/6/4
Base-out vergence (distance):	16/21/16
Near lateral phoria:	3 exophoria
–1.00 gradient:	1 esophoria
Gradient AC/A ratio:	4:1
Calculated AC/A ratio:	4.8:1
Base-in vergence (near):	16/21/17
Base-out vergence (near):	16/20/15
NRA:	+2.00 D
PRA:	–1.25 D
Accommodative amplitude (push-up):	OD: 11 D; OS: 11 D
MAF:	OD: 11 cpm; OS: 11 cpm
BAF:	8 cpm
MEM retinoscopy:	+0.25 D

Pupils were normal, all external and internal health tests were negative, the deviation was comitant, and color vision testing revealed normal function. Slit lamp evaluation revealed 2+ blepharitis, with deficient aqueous production in each eye. Tear BUT was 4 seconds in the right eye and 6 seconds in the left.

Case Analysis

Because the phoria was normal at distance and near and accommodative testing was only slightly abnormal, the most likely cause for Jeremiah's symptoms was an ocular health (dry eye) disorder. Analysis of the results of accommodative testing revealed a normal amplitude, facility, and accommodative response. The PRA was low, but, given the normal accommodative function, this probably reflects an aberrant finding rather than a problem with fusional vergence. Another likely hypothesis was fusional vergence dysfunction. PFV and NFV findings were normal on direct measures and indirect tests of fusional vergence. With only a low PRA and normal BAF, the results suggested no problems with fusional vergence; rather, the findings led to a diagnosis of ocular surface health-related CUC problems.

Management

We advised Jeremiah that the previous prescription would not be expected to relieve his problem. The ametropia was considered insignificant and, because there was no vertical deviation, glasses were not recommended. We prescribed a program of eyelid hygiene for 14 days to normalize his lid and tear health and reduce his symptoms: lid scrubs twice a day and Blephamide (prednisolone/sulfacetamide) SOP (sterile ophthalmic preparation) at bedtime.

Jeremiah was seen in 2 weeks. His blepharitis was substantially improved, and he reported that he could read and work on the computer for a longer period of time before experiencing symptoms. Lid scrubs were continued twice a day for 14 days, and the Blephamide was discontinued. After 2 more weeks, the blepharitis was under control and Jeremiah was able to read and work on the computer for as long as he wanted, without any discomfort.

Case 20.5 Ergonomic Issues

Jamal is a 23-year-old man who is experiencing head and neck aches after 2 hours of computer work. He is healthy and is not taking any medication. He has been a patient in your practice for several years, and his most recent examination was 2 years ago. At that time he had no complaints. He recently started a job that requires him to work on the computer for about 6 hours per day. The findings from the previous and current examinations are listed below.

Computer Use Questionnaire and Examination Results

In the previous examination, Jamal had no symptoms. At the current examination, he reported headaches, along with neck discomfort, after 3 hours of working on the computer. He worked on the VDT for 6 or more hours per day, with irregular breaks. The viewing distance from the eye to the keyboard was 15 in., and the distance from the eye to the computer monitor was 15 in. His workroom lighting was fluorescent.

Test	Previous Examination	Current Examination
Near point convergence	4 to 6 in.	4 to 7 in.
Amplitude of accommodation	15 D	15 D
Distance phoria	Orthophoria	Orthophoria
Near phoria	5 exophoria	6 exophoria
Calculated AC/A ratio	4:1	3.6:1
Base-out (near)	10/18/10	14/20/14
NRA	+2.50	+2.50
PRA	-2.50	-2.75
BAF	12 cpm	13 cpm
MEM retinoscopy	+0.25 OU	+0.50 OU
IPD	58 mm	58 mm

In both examinations, the pupils were normal, all external and internal health tests were negative, the deviation was comitant, and color vision testing revealed normal function. Slit lamp evaluation revealed normal lid health and good aqueous production in each eye. Tear BUT was normal.

Case Analysis

The key findings for the differential diagnosis are the normal binocular vision and ocular health findings. In CUC, these findings may be normal, but the patient may still have symptoms. Given normal binocular vision and ocular health, the CUC-related symptoms that Jamal described are likely to be related to ergonomic issues. The Computer Use Questionnaire revealed that the top of Jamal's 15-in. computer monitor was 9 in. above eye level. He had bright fluorescent room illumination, no glare filter on the screen, and a window behind the monitor. In addition, his work distance was abnormally close (15 in. from the monitor and keyboard). These ergonomic flaws are likely to be contributory to Jamal's symptoms.

Management

This case illustrates the importance of proper workstation design to the treatment of CUC-related symptoms. Of course, we want to manage existing binocular vision problems and treat ocular surface disease. However, it is equally important to treat all of the patient's symptoms. This frequently requires considering the effects of the computer workstation. Carefully check the height and arrangement of the computer. The patient's physical stature should determine how the monitor and keyboard are positioned. While sitting in a working position, the top rim of the monitor should be at (or below) eye level. We suggested that Jamal reposition his computer monitor (lower it by about 5 in.) and himself (raise his chair about 2 in.) so that he looked down at the center of the monitor. We also had him increase his working distance to at least 18 in.

The importance of appropriate lighting is frequently overlooked. It is important to monitor the lighting for glare on the computer screen. Windows or other light sources should not be directly visible when sitting in front of the monitor. In Jamal's case, he had problems in both areas—the room illumination was bright and there was a window behind the computer monitor. The American Optometric Association (AOA) has evaluated and accepted a number of glare screens that can be added to a computer, and we suggested that Jamal obtain one of these. We then recommended that Jamal rearrange his workroom so that the computer was in front of a wall without a window. It was not possible to reduce the amount of lighting in the room.

Usually, the room lighting should closely match the light generated by the computer screen. This is typically easier in the home, where a smaller light can be substituted for the bright overhead light, than in an office, where existing room illumination may not be compatible with a recently added computer

design or location. In most offices, it is easier to move the computer to remove backlighting than to change room illumination. When Jamal's computer monitor was lowered, a glare screen added, and the backlighting controlled by moving the monitor to a wall without a window, he reported that his neck strain was substantially reduced and he no longer had headaches.

Summary and Conclusion

Patients with CUC generally present with bothersome symptoms that interfere with school or work performance. The symptoms frequently occur, and management of these conditions can be a satisfying aspect of optometric care. We have stressed the importance of assessing all aspects of binocular vision, ocular surface health, and ergonomic issues. Once the specific diagnosis for the CUC-related symptoms has been reached, treatment is almost always successful. For binocular vision issues, lenses, added lenses, and vision therapy are used. Ocular surface disease requires medical management. Workstation issues are treated by ergonomic redesign.

Study Questions

1. Symptoms associated with VDT use are typically associated with what primary causes?
2. How would symptoms of presbyopic patients be related to the design of the prescription used for computer use?
3. Why is it typically not necessary to consider serious underlying etiology in cases of visually related CUC symptoms?
4. What are the primary functional visual disorders that typically must be differentiated in cases of visually related CUC symptoms?
5. Why might blink rate and eyelid health influence the reports of symptoms for computer users?
6. What tests are used to evaluate the ocular health of computer users?
7. Why is it important to accurately evaluate how patients suspected of having CUC-related visual symptoms use the computer?
8. What is the influence of workstation design on symptoms?
9. Vergence range measurement norms, which were made for a 40-cm test distance, may not apply to the VDT working distance. How can the clinician deal with this dilemma?
10. Describe the advantages and disadvantages of the PRIO when testing computer users.

SOURCES OF EQUIPMENT

- (a) Available from PRIO Corporation, 8285 SW Nimbus Avenue, Suite 148, Beaverton, OR 97008.
 (b) Available from PC Peekers, 13321 North Meridian, Suite 110, Oklahoma City, OK 73120.

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Appendix 20.1

Computer Use Questionnaire

Part I: Symptoms

VISUAL

Rate the frequency and severity of any symptoms you experience during or after VDT work.

	Work		Home	
Blurred distance vision	Frequent	Never	Frequent	Never
	1 2 3	4 5	1 2 3	4 5
	Severe	None	Severe	None
Blurred near vision	1 2 3	4 5	1 2 3	4 5
	Frequent	Never	Frequent	Never
	1 2 3	4 5	1 2 3	4 5
Eyestrain	Severe	None	Severe	None
	1 2 3	4 5	1 2 3	4 5
	Frequent	Never	Frequent	Never
Dry irritated eyes	1 2 3	4 5	1 2 3	4 5
	Severe	None	Severe	None
	1 2 3	4 5	1 2 3	4 5
Double vision	Frequent	Never	Frequent	Never
	1 2 3	4 5	1 2 3	4 5
	Severe	None	Severe	None
Light sensitivity	1 2 3	4 5	1 2 3	4 5
	Frequent	Never	Frequent	Never
	1 2 3	4 5	1 2 3	4 5
Color distortion	Severe	None	Severe	None
	1 2 3	4 5	1 2 3	4 5
	Frequent	Never	Frequent	Never
	1 2 3	4 5	1 2 3	4 5
	Severe	None	Severe	None
	1 2 3	4 5	1 2 3	4 5

PHYSICAL

Rate the frequency and severity of any symptoms you experience during or after

	Work		Home	
	Frequent 1 2 3	Never 4 5	Frequent 1 2 3	Never 4 5
VDT work				
Headaches				
	Severe 1 2 3	None 4 5	Severe 1 2 3	None 4 5
Neck/shoulder/back aches				
	Frequent 1 2 3	Never 4 5	Frequent 1 2 3	Never 4 5
	Severe 1 2 3	None 4 5	Severe 1 2 3	None 4 5
Wrist ache				
	Frequent 1 2 3	Never 4 5	Frequent 1 2 3	Never 4 5
	Severe 1 2 3	None 4 5	Severe 1 2 3	None 4 5

Part II: Work Practices and Environment

WORK PRACTICES

	Work		Home	
Visual correction when working at the VDT	No Bifocal Soft contact lenses (CL)	Single vision Progressive Gas-perm CL	No Bifocal Soft CL	Single vision Progressive Gas-perm CL
Have you been prescribed a correction for working at the VDT that you do not wear?	No Bifocal Soft CL	Single vision Progressive Gas-perm CL	No Bifocal Soft CL	Single vision Progressive Gas-perm CL
Hours per day of VDT viewing				
How often do you clean your display screen?	Frequent 1 2 3	Never 4 5	Frequent 1 2 3	Never 4 5
Work habits:				
a) Intermittent—periods of less than 1 hour				
b) Intermittent—periods of more than 1 hour				
c) Constant—informal breaks, as required				
d) Constant—regular breaks				
e) Constant—no breaks, other than meals				
How long have you done this amount of VDT work?				

WORK DISTANCES

	Work	Home
Distance from eye to VDT screen	_____ in.	_____ in.
Can the monitor be tilted?	N Y	N Y
Can the monitor height be adjusted?	N Y	N Y
Top of VDT screen in relation to eye level	Above/equal/below	Above/equal/below
Viewing distance: eye to keyboard	_____ in.	_____ in.
Viewing distance: eye to hard copy material	_____ in.	_____ in.

Reference material	Work To the side/below the screen. If to the side, is it next to the screen or keyboard? N Y Is this height adjustable? N Y Stand/desk/CPU(computer processing unit) Is this adjustable? N Y _____ in. N Y	Home To the side/below the screen. If to the side, is it next to the screen or keyboard? N Y Is this height adjustable? N Y Stand/desk/CPU Is this adjustable? N Y _____ in. N Y
Monitor supported on:		
Is all of your hard copy material visible without significant head or neck movements? Other (describe):		

WORKSTATION ENVIRONMENT

	Work	Home
Display screen		
Letter color		
Letter/font size		
Background color		
Do you notice screen flicker?		
Do you use ClearType? (Microsoft based CRT)		
What is the refresh rate of your monitor? Optimum 75–80, Low 60		
Glare filter	No Glass Mesh	No Glass Mesh
Lighting type (mark all that apply)		
Fluorescent overhead only		
Incandescent overhead only		
Fluorescent and incandescent overhead		
Fluorescent overhead and incandescent direct		
General illumination (mark all that apply)		
Room brightness	Bright Medium Dim	Bright Medium Dim
Window light	Front Behind Side	Front Behind Side
Window light control		
Curtains	Vertical Horizontal	Vertical Horizontal
Blinds	Vertical Horizontal	Vertical Horizontal
Desk lamp/task light	N Y	N Y
Environment		
Walls	Color? Shiny finish Dull finish	Color? Shiny finish Dull finish
Desk surfaces	Color? Shiny finish Dull finish	Color? Shiny finish Dull finish
Chair	Adjustable? N Y Back support? N Y	Adjustable? N Y Back support? N Y

Binocular and Accommodative Problems Associated with Acquired Brain Injury

The treatment of binocular vision, accommodative, and eye movement disorders related to acquired brain injury (ABI) is one of the more challenging aspects of optometric practice. Patients who survive ABI generally experience multiple problems, including cognitive, psychological, motor, and sensory anomalies. Even when binocular vision, accommodative, and eye movement problems occur in isolation from cognitive and psychological issues, they tend to be complicated. Cyclovertical and noncomitant deviations, sensory fusion anomalies, unequal accommodation, and visual field loss may accompany the basic vision disorder.

The objective of this chapter is to review the diagnosis and treatment of the most common nonstrabismic binocular vision, accommodative, and eye movement disorders associated with ABI. The emphasis is on determining the various factors that should be considered to determine the potential effectiveness of treatment. As we have done in previous chapters, a sequential treatment approach is presented, allowing clinicians to treat these conditions in an organized manner. We also use a series of cases to demonstrate some of the important concepts discussed in this chapter.

This chapter is not intended to be a complete discussion of all vision problems associated with ABI; significant problems such as visual field loss, visual neglect, ocular disease, and visual information processing disorders are not addressed.

Overview of Acquired Brain Injury

ABI is generally used to refer to both traumatic brain injury (TBI) and stroke or cerebrovascular accident (CVA).

TRAUMATIC BRAIN INJURY

Thurman et al. (1) define TBI as an occurrence of injury to the head that is documented in a medical record, with one or more of the following conditions attributed to the head injury:

- Observed or self-reported decreased level of consciousness
- Amnesia
- Skull fracture
- Objective neurologic or neuropsychological abnormality
- Diagnosed intracranial lesion

TBI may result in significant impairment of an individual's physical, cognitive, and psychosocial functioning.

The reported incidence of TBI in the United States is about 175 to 200 per 100,000 population, or about 2 million head injuries each year (2). Over 1.5 million Americans suffer nonfatal traumatic brain injuries each year that do not require hospitalization (1,3). Another 300,000 individuals suffer brain injuries severe enough to require hospitalization, with 99,000 resulting in a lasting disability. A total of 56,000 people die each year as a result of TBI (1). The prevalence of TBI is estimated to be 2.5 to 6.5 million individuals (4).

The number of people surviving TBI has increased significantly in recent years, which is attributed to faster and more effective emergency care, quicker and safer transportation to specialized treatment facilities, and

advances in acute medical management. TBI affects people of all ages and is the leading cause of long-term disability among children and young adults.

Individuals aged 15 to 24 years have the highest risk of TBI (1), and TBI affects males at twice the rate that it affects females. In addition, the mortality rate is higher among males, suggesting that males are more likely than are females to suffer severe injuries (1).

Although the largest group of TBI survivors are young adults in their prime working years, many survivors, particularly those with a severe TBI, do not return to work. Estimates of those who do not return to work vary widely, ranging from a low of 12.5% to as high as 80%. The ability to return to work is highly correlated with the postacute functional limitations of the survivor (5,6).

Severity of TBI is classified as mild, moderate, and severe (7). Mild TBI is a very common injury, resulting in about 300,000 hospital admissions each year (8). Many more people are believed to sustain mild TBI, but they do not require hospitalization. As a result, an accurate estimation of the number of mild TBI cases per year is not available. About 80% of the people admitted to hospital with the diagnosis of TBI have mild TBI (9). Hellerstein, Freed, and Maples (10) studied the vision characteristics of patients with mild TBI and found significant differences between the TBI group and age-matched non-TBI patients. They concluded that the term *mild TBI* is very misleading and does not necessarily translate to “mild functional loss.” This is very significant because most of the optometrists in private practice primarily encounter patients with mild TBI. The more severe injuries require hospitalization and various types of rehabilitative therapy. Once the patient enters this system, he/she tends to receive eye care from ophthalmologists. The patient with mild TBI, however, will most likely return to the family optometrist if visual symptoms occur after the TBI.

STROKE (CEREBROVASCULAR ACCIDENT)

Stroke, or CVA, is a clinically defined syndrome of rapidly developing symptoms or signs of focal loss of cerebral function with no apparent cause other than of vascular origin, but the loss of function can at times be global (11). The syndrome varies in severity from recovery in a day to incomplete recovery and from severe disability to death (11). Stroke cases can now be classified in epidemiology studies by type. Wolf, D’Agostino, Belanger, and Kannel (12) reported that, in the Framingham study, 45% of strokes were classified as atherosclerotic, 19% as cerebral embolism, 19% as transient ischemic attack, 5% as intracerebral hemorrhage, 4% as subarachnoid hemorrhage, and 2% as other, for men aged 55 to 84 years.

Stroke is the third leading cause of death and the leading cause of chronic disability in the adult population of the United States (13). About 750,000 individuals sustain strokes each year, and there are about 3.5 to 4 million survivors of stroke (12). Of these survivors, about one-third have mild impairments, another one-third are moderately impaired, and the remainder are severely impaired. CVA can occur at any age, but it is much more common in the elderly. The death rate doubles every 10 years between the ages of 55 and 85 (13). The incidence of stroke varies with location. For example, the incidence has been reported to be as low as 238 per 100,000 in Dijon, France, whereas it is 362 per 100,000 in Rochester, Minnesota, and 627 per 100,000 in Novosibirsk, Russia (11). In the United States, there have been consistently higher rates of stroke in the southeastern states since the 1930s (14). With the aging of the population, it is likely that CVA will become even more common in the future. Given the high prevalence of vision problems after CVA, optometrists have an important role to play in the vision care of this population.

Optometrist’s Role

Vision problems are common after ABI, and they have a significant negative impact on common activities of daily living, such as reading, writing, shopping, dressing, sports, and driving (10). Historically, optometrists have not been part of the rehabilitation team in hospitals (15). This team typically includes various physicians and rehabilitation professionals, such as occupational, physical, and recreation therapists and speech/language pathologists. Eye care is usually provided by an ophthalmologist, with a primary emphasis on visual acuity and eye disease (16). As a result, it is common for some vision problems associated with ABI to be left undetected or untreated, leaving the patients with significant functional problems (16–20).

In the past decade, however, optometrists have become more involved in management of vision problems associated with ABI (10,15,18,19,21–31). The optometrist’s role includes management of refractive error; binocular vision, accommodative, and eye movement disorders; visual field loss; ocular disease; and other

visual manifestations of ABI. Because of the complexity of ABI, it is important for optometrists to work closely with the rehabilitation team. The nature of this interaction varies with the time frame after the ABI.

ACTIVE REHABILITATION STAGE

During the active rehabilitation stage, it is critical for the optometrist to work closely with the occupational, physical, and speech therapists. Because of the high prevalence of vision problems after ABI, these rehabilitation specialists often encounter patients with vision problems that interfere with the rehabilitation process. Optometrists with staff privileges and working as consultants at these facilities can provide an important service by identifying and managing the vision problems of patients with ABI in a timely manner. During the early phases of rehabilitation, passive treatment (lenses, prism, occlusion) is often prescribed to make the patient as comfortable as possible during rehabilitation. The optometrist should also educate the rehabilitation team about the nature of the vision problems. This education should include information about the effect of these problems on various activities of daily living and how the therapists can modify the environment and tasks to enable the patient to function most effectively.

During this period of time, it is difficult for the optometrist to perform active vision therapy. However, some optometrists do prescribe active vision therapy to be administered in the rehabilitation hospitals by occupational therapists (32). In such a scenario, the optometrist identifies the problem, prescribes and programs the active vision therapy, supervises the therapists who perform the vision therapy, and performs periodic reevaluations. When the active phase of rehabilitation ends and the patient returns home, the optometrist can take full control of the patient's functional vision care. The active vision therapy program would then continue at the optometrist's office.

POSTREHABILITATION STAGE

Other scenarios are also possible. Because the majority of optometrists do not have staff privileges at rehabilitation hospitals, they will more likely be involved with ABI patients who have not required hospitalization (mild TBI) or patients who have completed active rehabilitation. In other instances, the optometrist may not have the opportunity to examine the patient with ABI for months or even years after the problem occurs. The patient may turn to the optometrist as a last resort. Often the patient may have already been to a number of ophthalmic practitioners and been told either that there is no problem or that treatment is not possible (16,17,20). In such situations, the optometrist is the primary caregiver and the sequential treatment approach described in this chapter becomes applicable. If the patient has recently been discharged from a rehabilitation facility, close cooperation with the patient's therapists will still be important.

Ciuffreda et al. (17,19) summarized the potential role that optometrists should play in the treatment of ABI patients:

The provision of full-scope optometric care to this underserved and poorly understood clinic population offers a unique and altruistic opportunity for the profession. By such a comprehensive approach, in conjunction with other members of the rehabilitative team, patients with TBI can more rapidly reenter society and the work force, and once again be productive members of the community.

Common Binocular Vision, Accommodative, and Eye Movement Disorders Associated with Acquired Brain Injury

BINOCULAR VISION DISORDERS

The common nonstrabismic binocular vision disorders described in previous chapters are often associated with ABI. Cyclovertical heterophoria (Chapter 14) occurs more often after ABI than in the general clinical population. In addition, we sometimes encounter a binocular vision problem called *sensory fusion disruption syndrome*, which seems to be unique to ABI (33–35). Sensory fusion disruption syndrome is a condition in which there is only a small heterophoria, yet the patient is unable to fuse images even though they are aligned bifoveally under optimal conditions (33). This inability to fuse is similar to the strabismic entity referred to as *horror fusionis*. The prognosis in such cases is usually poor. Treatment with lenses, prism, vision therapy,

or surgery is generally unsuccessful, although there have been case reports (33,35) suggesting that some of these patients will regain fusion spontaneously or with treatment.

Binocular vision deficits have been reported to be among the most common vision problems occurring in both the civilian and the military populations after traumatic brain injury (15,30,36–40). Gianutsos et al. (15) performed a vision evaluation on a population of 55 severely brain-injured individuals in a rehabilitation facility for individuals requiring long-term treatment. The most common problems found were binocular vision disorders. Cohen et al. (37) found convergence insufficiency in 38% of acute TBI patients and in 42% of patients reevaluated 3 years after TBI. Suchoff et al. (36) examined 62 brain-injured patients who resided in extended-care facilities and found a high occurrence of exodeviations (41.9%), including convergence insufficiency and intermittent and constant exotropia. There were also a number of patients with vertical deviations (9.7%). Ciuffreda, et al. (30) did a retrospective review of 220 patient records with either TBI or CVA. Vergence deficits (56.3%) were most common in the TBI subgroup, while strabismus (36.7%) and cranial nerve palsy (10%) were most common in the CVA subgroup. Convergence insufficiency was the most common dysfunction found in both groups, occurring in 42.5 % and 35% of the TBI and CVA patients, respectively.

Three recent studies (38–40) conducted among the military personnel returning from the wars in Iraq and Afghanistan found a similar pattern after traumatic brain injury. In these studies, convergence insufficiency was found to be the most common visual disorder after TBI, with a prevalence ranging from 30% to 42%.

ACCOMMODATIVE DISORDERS

The pre-presbyopic, civilian, ABI population consists primarily of TBI. Among this population accommodative disorders, such as accommodative insufficiency, accommodative excess, and accommodative infacility, are more common than among the general clinical population (41). Al-Qurainy (42) reported that approximately 20% of people with TBI have an accommodative dysfunction. Suchoff et al. (36), in a study of 62 consecutive patients with TBI, found that about 10% had accommodative problems. Kowal (43) found that 36% of 161 head-injured patients had accommodative problems. In the Ciuffreda et al. (30) study of 220 patient records with either TBI or CVA, accommodative dysfunction was found (41.1%) in patients with TBI, nearly all of them showing accommodative insufficiency. In contrast, only 12.5% of the patients with CVA had an accommodative disorder. Accommodative problems have also been reported in several case studies (10,20,44,45).

In recent studies of military personnel with TBI by Goodrich et al. (39), Brahm et al. (40), and Stelmack et al. (38), accommodative dysfunction was found in 22%, 42%, and 47% of the subjects, respectively.

EYE MOVEMENT DISORDERS

The ocular motor problems present after ABI are different from the developmental eye movement disorders found in the pediatric population (Chapter 22). Saccadic and pursuit anomalies can be caused by abnormalities in the supranuclear control centers for these two functions and their connections to the extraocular muscles. The saccadic and pursuit systems have separate and distinct neurologic pathways (Chapter 13). Because the pathways are separate for saccades and pursuits, ABI can affect one system, leaving the other intact. Thus, if a patient has abnormal pursuit movements with normal saccadic function, a problem in the occipitoparietal supranuclear center should be suspected. Conversely, an abnormality is likely in the frontal eye fields if pursuits are normal but saccades are abnormal. The various types of saccadic and pursuit dysfunction that occur after ABI are summarized in Chapter 13 (Tables 13.2 and 13.3).

In our experience, eye movement disorders are rarely present in isolation after ABI; rather, they are generally found associated with accommodative, binocular, and visual perceptual dysfunctions. As a result, treatment of eye movement deficiencies generally occurs within the context of an overall treatment approach designed to deal with other problems as well.

Suchoff et al. (36) found that about 40% of ABI patients had eye movement disorders. In a study of civilian population with ABI, Ciuffreda et al. (30) found deficits of saccades in 51% of patients after TBI and 57% of patients after stroke. The three recent studies of vision disorders in military personnel after TBI revealed a high prevalence of pursuit and saccadic dysfunction, ranging from 6% to 33% (38–40). Scheiman and Gallaway (20) reviewed treatment results for nine patients after ABI. Two of the nine cases presented had saccadic and pursuit dysfunction. Both of these patients also had binocular vision and accommodative disorders. One of the two cases reported by Cohen (23) had eye movement problems, in addition to an exotropia and

hypertropia. Ciuffreda et al. (18) argued that although gross abnormalities in saccadic and pursuit function can be diagnosed using conventional testing and observation, more sophisticated testing may be necessary for patients after ABI. They suggested that, after ABI, it is important to use objective recordings based on noninvasive infrared technology. The Visagraph (Chapter 1) is an example of the instrumentation that can be used for this purpose. Suchoff et al. (36) reported on a number of common objectively determined ocular motor deficits associated with CVA; examples include saccadic overshooting and undershooting, difficulty in shifting attention, and inability to sustain fixation and maintain attention.

Symptoms of the Vision Problems Associated with Acquired Brain Injury

Most of the symptoms are typical of those experienced by any patient with binocular vision, accommodative, or eye movement disorders and are often associated with reading or other close work (Table 21.1). Common complaints include eyestrain and headaches after short periods of reading, blurred vision, diplopia, loss of place, sleepiness, and difficulty concentrating on reading tasks. In addition, there are some symptoms that are primarily characteristic of patients after ABI. These include poor balance and coordination (10,18,19,46), dizziness (10,19), and light sensitivity (10,19). It is not unusual for patients to report similar symptoms related to distance vision tasks, such as watching television, driving, walking, and sports, particularly in the presence of binocular vision problems such as vertical heterophoria, divergence insufficiency, and cyclophoria. Eye movement and accommodative disorders can also cause symptoms related to distance vision, such as blurred vision, variable vision, and difficulty localizing objects in space.

Evaluation

The customary battery of tests for general binocular vision evaluation, described in Chapter 1 and summarized in Table 21.2, provides the majority of information required for this population. Tests that stress the dynamics of the fusional vergence and accommodative systems and ability to perform well over time are particularly important after ABI. In regard to eye movement testing, Ciuffreda et al. (17) have stressed the importance of using both chair-side subjective tests (the NSUCO test and developmental eye movement [DEM] test) and objective eye movement recordings to assess eye movement skills. In our experience, subtle problems can be overlooked unless tests that probe the ability to sustain performance over time and to perform quickly are used. Because cyclovertical heterophoria is common, diagnostic techniques such as the double Maddox rod test (Chapter 14) to detect image tilt are also important. Fixation disparity testing is helpful when dealing with more subtle binocular vision problems and provides valuable information for determining the appropriate prism prescription when necessary. When a patient is symptomatic yet all other testing is negative, it is always important to prescribe diagnostic occlusion (Chapter 14).

TABLE 21.1 SYMPTOMS OF VISION PROBLEMS ASSOCIATED WITH ACQUIRED BRAIN INJURY

Eyestrain
Headaches
Blurred vision
Double vision
Inability to read
Difficulty concentrating on reading material
Loss of place when reading
Poor balance and coordination
Dizziness
Light sensitivity

TABLE 21.2 RECOMMENDED TEST BATTERY FOR THE IDENTIFICATION OF VISION PROBLEMS ASSOCIATED WITH ACQUIRED BRAIN INJURY

General test battery	
<i>Binocular vision assessment</i>	
Measurement of the phoria, comitancy, and AC/A ratio	Cover test at distance in all diagnostic fields of gaze, at near, and in the reading position
Assessment of positive fusional vergence (PFV) and negative fusional vergence (NFV)	
DIRECT MEASURES	Step vergence testing Vergence facility testing
INDIRECT MEASURES	Negative relative accommodation (NRA) Positive relative accommodation (PRA) Binocular accommodative facility (BAF) Monocular estimation method (MEM) retinoscopy
Convergence amplitude	Near point of convergence
Sensory status	Worth four-dot test Stereopsis testing
<i>Accommodative assessment</i>	
DIRECT MEASURES	Monocular amplitude of accommodation Monocular accommodative facility (MAF) testing
INDIRECT MEASURES	BAF testing NRA/PRA MEM retinoscopy
<i>Eye movement assessment</i>	
	Developmental eye movement test Northeastern State University College of Optometry (NSUCO) eye movement test
Other important testing	
Fixation disparity testing	
Double Maddox rod test	
Objective eye movement recording (Visagraph)	
Diagnostic occlusion	

OTHER SPECIAL TESTING CONSIDERATIONS

Testing can often be more difficult to complete in patients with ABI because of associated neurologic, cognitive, and psychological disorders. Because many binocular vision, accommodative, and eye movement tests are subjective in nature, it is important to keep this in mind when performing tests and interpreting results. For example, Hellerstein, Freed, and Maples (10,18,19) reported several important diagnostic observations for patients after TBI:

- Vergence and accommodative testing may have to be discontinued because some patients complain of nausea during the testing.
- The patient may request that you move the prism bar or Risley prisms more slowly because he/she experiences discomfort or nausea.
- Fusion ranges may be overestimated if the patient has a delayed cognitive response time.

On occasion, we examine patients after ABI who appear to have normal test results yet report discomfort, nausea, and other symptoms during the testing. In such situations, we suggest repeating the tests for measures such as vergence facility, accommodative facility, the near point of convergence, and accommodative amplitude. When repeating these tests, the time limits for the facility testing should be extended. For example, accommodative facility and vergence facility testing should be continued for a full 2 minutes. The tests for measuring the near point of convergence and amplitude of accommodation should be repeated five to ten times. These modifications may help a clinician to detect a subtle accommodative or binocular vision disorder.

Sequential Management Considerations in the Treatment of Disorders Associated with Acquired Brain Injury

Concepts discussed in previous chapters for the sequential management considerations of binocular vision disorders also apply to problems related to ABI (Table 21.3).

Any of the nonstrabismic binocular vision, accommodative, and eye movement disorders described in Chapters 9 to 15 can occur after ABI. The sequential treatment considerations for the ABI population are almost identical to those reviewed in those chapters. The following subsections describe some of the additional considerations for the ABI population.

VARIABILITY OF FINDINGS AND POTENTIAL RECOVERY

One of the factors that differentiate care of a patient with ABI from care of a patient without ABI is the potential for gradual resolution of the binocular vision, accommodative, or eye movement disorder with time. There is some indication in the literature (47,48) that an individual with a recent history of ABI may show some spontaneous improvement over the course of 6 to 12 months. Based on this concept, some clinicians actually choose to initially deny active treatment to patients. They may tell the patient that since the vision condition is likely to improve over the next 6 to 9 months even without treatment, it is best to not actively treat the problem. If diplopia is present, the clinician may simply tell the patient to wear an eye patch. We disagree with this approach and believe that binocular vision, accommodative, and eye movement disorders associated with ABI should be treated aggressively and as early as possible. Certainly, the treatment should coincide with the other rehabilitation efforts. Thus, once a patient is ready for occupational, physical, and speech/language therapy, treatment of any significant vision disorders should also begin.

However, it is very important in the treatment of patients with ABI that the concept of variability and change over time be considered. Even if active vision therapy is not prescribed, frequent follow-up care is necessary to determine whether a change in optical correction, added lenses, prism, or occlusion is appropriate as the patient's underlying medical problems resolve.

COGNITIVE FUNCTION

In addition to the vision problems commonly associated with ABI, cognitive, attention, language, memory, and emotional problems are common among ABI patients (18,49). The presence of such problems has a direct effect on the prognosis for active vision therapy (Chapter 3). Thus, when considering the sequential treatment options described below, it is important to consider the patient's cognitive, attention, and language function as well as his/her emotional state and motivation. In many cases, active in-office vision therapy may not be a viable option, and the clinician will have to use passive devices (lenses, prism, or occlusion) for treatment. In some cases, even if in-office vision therapy is not appropriate, home-based vision therapy can be performed. When in doubt, a trial period of three to five office visits will usually be sufficient to determine whether the patient will benefit from office-based vision therapy.

TABLE 21.3 SEQUENTIAL CONSIDERATIONS IN THE MANAGEMENT OF NONSTRABISMIC BINOCULAR VISION, ACCOMMODATIVE, AND EYE MOVEMENT DISORDERS

Optical correction of ametropia
Added lens power
Horizontal prism
Vertical prism
Occlusion for diplopia
Vision therapy
Surgery

OPTICAL CORRECTION OF AMETROPIA

Small amounts of uncorrected astigmatism, hyperopia, or anisometropia that may be considered inconsequential in the general population could result in visual symptoms after ABI. This may be because of the high prevalence of accommodative disorders after ABI. In addition, we have observed that after ABI some patients may be hypersensitive to small refractive errors and binocular vision and accommodative disorders. Perhaps this is because the individual has multiple problems to overcome, and the otherwise mild vision problems can no longer be tolerated. Thus, young adults and incipient presbyopes who would normally be able to deal with small amounts of uncorrected refractive error become symptomatic. The first management consideration, therefore, is correction of refractive error, and we suggest correcting even small amounts of refractive error (Table 21.4).

ADDED LENSES

Because of the high prevalence of accommodative insufficiency and ill-sustained accommodation, added plus lenses play a very important role. Although the rules described in Chapter 3 (Table 3.2) work well for the general population, we have found that the required add may be higher in the ABI population. We suggest allowing the patient to wear the proposed add in the office for 10 to 15 minutes while engaged in a reading task. If the patient fatigues and blurred vision occurs, the near addition can be increased. Accommodative excess and accommodative infacility respond not so well to added plus lenses and generally require vision therapy treatments (Chapter 12).

When there is a paralysis of accommodation after ABI, added lenses are an important treatment consideration. In some cases, the accommodative paralysis is temporary. In such cases added plus lenses are useful as a temporary solution while treatment of the underlying condition occurs or as the problem gradually resolves. If the underlying cause of the paralysis of accommodation cannot be eliminated and the condition is stable and nonprogressive, then added plus lenses may need to be made permanent. Unequal accommodation (secondary to organic causes) also responds well to added plus lenses. In such cases, it is often necessary to consider prescribing unequal adds.

Of course, patients with a high AC/A ratio in whom there is a significant esophoria at near (e.g., convergence excess) also benefit from added plus lenses.

PRISM

Prism is particularly important in cases of binocular vision disorders associated with ABI. There is a much higher prevalence of vertical heterophoria and noncomitant deviations in this population. In addition, for the reasons stated above, the prognosis for vision therapy may be poor in some cases. Therefore, prism is often the treatment of choice (Chapter 14). As with optical correction of ametropia, we are more likely to prescribe smaller amounts of prism for patients with ABI than those prescribed for the general population. It is important to recommend frequent follow-up care during the first year after the ABI to monitor changes in binocular vision and assess the need to modify the prism prescription.

TABLE 21.4 GUIDELINES FOR CORRECTION OF REFRACTIVE ERROR AFTER ACQUIRED BRAIN INJURY

Condition	Prescribe if:
Hyperopia	+0.50 or more
Myopia	−0.50 or more
Astigmatism	−0.75 × 180 or more −0.50 × 90 or more −0.50 oblique axis or more
Anisometropia	+0.75 or more

OCCLUSION

Occlusion can be used if double vision cannot be eliminated using lenses, added lenses, or prism. It is generally preferable to restore binocular vision, fusion, and stereopsis rather than simply occluding one eye. However, there will certainly be cases in which fusion is not comfortable or simply not obtainable (e.g., sensory fusion disruption syndrome or significant noncomitancy) and the patient is left with intractable diplopia. In such instances, occlusion becomes a very important treatment option. As a long-term solution, it is desirable to find an approach with the least cosmetic effect. The various options are discussed in Chapter 14.

VISION THERAPY

All the concepts of vision therapy described in earlier chapters apply to binocular vision, accommodative, and eye movement disorders associated with ABI. The primary differences that must be considered for this population are the determination of the prognosis for improvement and estimation of the length of treatment.

FACTORS AFFECTING PROGNOSIS FOR VISION THERAPY AFTER ACQUIRED BRAIN INJURY

A number of investigators have described treatment of binocular vision, accommodative, and eye movement problems associated with ABI using lenses, prism, and vision therapy (17,20,23,24,26,28,29,31,37,44,45, 50–56). These reports, all of which were case studies, suggest that vision therapy can be effective in relieving patient symptoms and improving visual function. However, a number of authors have also reported that, in contrast to the treatment of binocular vision, accommodative, and eye movement problems in the general population, the results are more variable and less predictable in the ABI population. When dealing with ABI patients, one of the primary problems faced by clinicians, therefore, is how to predict the prognosis and length of therapy for a particular patient.

Only Krohel et al. (53), Anderson (45), and Candler (57) have discussed the patient characteristics that affected prognosis in their respective case studies. Krohel et al. (53) reported that response to convergence exercises was variable, often incomplete, and unpredictable. He found that patients without serious neurologic sequelae tended to respond slightly better than did those with serious neurologic involvement. However, success could not be reliably predicted on an individual basis from the type or severity of trauma. Also, the severity of the convergence problem did not positively correlate to the severity of the head trauma. Anderson (45) listed binocular status before the head injury, the patient's age, and the time elapsed after injury as important issues to consider. Candler (57) suggested that the intelligence of the patient before ABI is of utmost importance for prognosis.

Scheiman and Gallaway (20) reviewed the literature and used nine case studies to review the various factors that should be considered when determining the potential effectiveness of vision therapy for the treatment of binocular vision, accommodative, and eye movement disorders after ABI. In their study, six of the nine patients achieved excellent outcomes with vision therapy. The four primary factors that significantly affected the results were cognitive and perceptual problems, visual field loss, excyclotorsion, and sensory fusion disruption syndrome (Table 21.5).

TABLE 21.5 FOUR PRIMARY FACTORS AFFECTING TREATMENT RESULTS FOR ACQUIRED BRAIN INJURY POPULATION

Cognitive and perceptual problems
Visual field loss
Excyclotorsion
Sensory fusion disruption syndrome

Cognitive and Perceptual Problems

Five of the cases presented by Scheiman and Galloway (20) had a primary diagnosis of convergence insufficiency. Four of the five achieved good to excellent results. However, the patient with convergence insufficiency who also had cognitive, memory, and attention deficits was unable to even make minimal progress.

Visual Field Loss

Although visual field loss did not limit improvement of fusional vergence ranges, it did prevent full normalization of reading comfort and speed. In one of the cases, a right homonymous hemianopia continued to interfere with reading speed and comprehension even after correction of the convergence and accommodative insufficiencies. However, in another patient with a superior right quadrantanopia the outcome was excellent and the patient achieved good comfort and reading rate. The critical factor in visual field loss is whether the loss affects the functional activity in question. Because a superior quadrantanopia does not affect the reading task, the patient with this problem achieved an excellent outcome. The right hemianopia, which makes finding the next word in the sentence difficult, had a more negative effect on prognosis.

Excyclotorsion

The presence of a comitant vertical deviation is not necessarily a negative factor. In such cases, prism should be used to complement the vision therapy program, but excellent results can be achieved. Unfortunately, a common acquired vertical problem after head trauma is a superior oblique or bilateral superior oblique palsy. These conditions are often associated with excyclotorsion, which was a significant barrier to success in two of the cases.

Sensory Fusion Disruption Syndrome

The final factor that interfered with the vision therapy outcome was the sensory fusion disruption syndrome. When a patient presents with acquired diplopia after ABI, it is critical to demonstrate that fusion is present. An important test to use is one that probes for random dot stereopsis. In our experience, the presence of random dot stereopsis is a strong predictor of the outcome of vision therapy.

Summary

The series of factors affecting prognosis described above also supports the report by Krohel et al. (53), which shows that success cannot be reliably predicted on an individual basis from the type or severity of trauma. In two of the cases in which vision therapy results were poor, the patient had sustained relatively less severe trauma than sustained by those in the other cases.

The following case reports (Cases 21.1–21.5) review the key issues that should be considered in the evaluation and treatment of binocular vision, accommodative, and eye movement disorders associated with ABI.

CASE STUDIES

Case 21.1 Intermittent Exotropia Treated with Vision Therapy

History

T.N., a 34-year-old man, was struck on the back of the head with a piece of concrete weighing 200 lb. Although he did not lose consciousness, he was evaluated at the emergency room. He was released after treatment of the wound. Since that time he has noted blurred vision and frequent headaches after short periods of reading. He also reported intermittent horizontal double vision after reading for more than 15 minutes.

We examined him about 9 months after the head injury. At that time he was wearing soft contact lenses with a prescription of OD -2.00 and OS -2.00 .

Significant Clinical Findings

VA (corrected):	OD: 20/20 OS: 20/20
VA (corrected):	OD: 20/20 OS: 20/20
Near point of convergence:	15 cm break, 22 cm recovery
Cover test (distance, uncorrected):	Orthophoria
Cover test (near, uncorrected):	10 to 12 Δ , intermittent alternating exotropia at near (deviated 1% of the time)
Subjective:	OD: -1.75 , 20/20 OS: -1.75 , 20/20
Near lateral phoria:	10 Δ exophoria
-1.00 gradient:	7 Δ exophoria
Gradient AC/A ratio:	3:1
Base-in vergence (near):	X/14/12
Base-out vergence (near):	X/18/12
Vergence facility:	8 cpm, slow with 12 base-out
Negative relative accommodation (NRA):	+2.50
Positive relative accommodation (PRA):	-0.50
Accommodative amplitude (push-up):	OD: 5 D; OS: 5 D
Monocular accommodative facility (MAF):	OD: 3 cpm; OS: 3 cpm; difficulty with -2.00
Binocular accommodative facility (BAF):	4 cpm, slow with -2.00
Stereopsis:	20 seconds on Wirt circles, 250 seconds of random dot stereopsis

Pupils were normal; all external and internal health tests were negative; the deviation was comitant; and color vision testing revealed normal function.

Diagnosis

The cover test revealed orthophoria at distance and an intermittent exotropia at near, and the direct (step vergence and vergence facility) and some indirect findings of positive fusional vergence (PFV) were low. In addition, the patient had trouble with all tests that probed the ability to accommodate. These findings supported the diagnoses of convergence insufficiency and accommodative insufficiency.

Treatment

We considered prescribing $+1.00$ reading glasses to deal with the accommodative insufficiency. However, because of the intermittent exotropia and diplopia, we decided to start a vision therapy program. We carefully monitored the patient's progress and symptoms over the first four visits. We decided to prescribe the near add if his symptoms did not begin to improve till the first reevaluation. The vision therapy program followed the sequence recommended in Chapter 9 for convergence insufficiency.

Outcome

T.N. required 11 office visits to complete the vision therapy program. At the reevaluation, he reported elimination of all focusing problems, and that he could read for as long as necessary without headaches or eyestrain. The pre- and post-vision therapy results are summarized in Case Table 21.1.

CASE TABLE 21.1 EXAMINATION RESULTS BEFORE AND AFTER VISION THERAPY

Test	Before Vision Therapy	After Vision Therapy
Cover test (D)	Orthophoria	Orthophoria
Cover test (N)	10 Δ, intermittent, alternating exotropia at near (deviated 1% of the time)	6 Δ exophoria
Near point of convergence	15 cm break, 22 cm recovery	4 cm break, 6 cm recovery
Base-in (N)	X/14/12	12/16/14
Base-out (N)	X/18/12	X/35/25
Vergence facility (12 BO/3 BI)	8 cpm	18 cpm
Accommodative amplitude	5 D OD and OS	10 D OD and OS
BAF	8 cpm	8 cpm

D, distance; N, near; BO, base-out; BI, base-in.

Factors Affecting the Outcome

In this case, the outcome was excellent and the result was achieved in a very short period of time. In fact, the number of required vision therapy sessions was typical of the number required for adults with convergence insufficiency in the general population without ABI. The brain injury did not affect the patient's cognitive skills, and he was highly motivated to regain comfortable vision. The characteristics of the binocular and accommodative problems were all positive, including intermittent exotropia without a complicating vertical or cyclophoria component and normal random dot stereopsis. Ocular motor skills were normal, and his visual fields were unaffected.

This patient represents one end of the continuum of ABI patients that optometrists encounter in practice. It is plausible that T.N. had a mild convergence insufficiency before the head injury for which he was successfully compensating. The ABI caused a decompensation of this preexisting condition, thereby precipitating his symptoms. Because all other issues were normal, the treatment results were rapid and excellent.

Case 21.2 Convergence Insufficiency And Vertical Deviation Treated With Prism And Lenses

History

M.I., a 29-year-old female, required surgery to remove two aneurysms from her brain. Postoperatively, she experienced mild expressive dysphasia and difficulty focusing for all close tasks. She had an eye examination about 8 months after the surgery because the focusing problems were not improving. She was diagnosed with an accommodative insufficiency, and reading glasses were prescribed. A 1-month follow-up revealed little improvement with the reading glasses, and she was referred for a vision therapy consultation.

We first examined M.I. about 10 months after the neurosurgery. At that time she was complaining about an inability to focus on near tasks. She described a "weird" feeling when trying to read and headaches if she continued to read. The focusing problem was so bad that in order to read the newspaper, she would sit on a chair and place the newspaper on the floor.

Significant Clinical Findings

Current glasses: OD, +1.25; OS, +1.25
 VA (corrected): OD: 20/20
 OS: 20/20

VA (corrected):	OD: 20/20 OS: 20/20
Near point of convergence:	10 cm break, 25 cm recovery
Cover test (distance, uncorrected):	2 Δ right hyperphoria, in all diagnostic positions of gaze
Cover test (near, uncorrected):	6 Δ exophoria, 4 Δ right hyperphoria, in all diagnostic positions of gaze
Subjective:	OD: plano, 20/20 OS: plano, 20/20
Fixation disparity testing:	1 base-down OD associated phoria
Base-in vergence (near):	X/18/16
Base-out vergence (near):	10/14/8
Fixation disparity testing:	2 base-down OD associated phoria
Vergence facility:	5 cpm slow, with 12 base-out
Accommodative amplitude (push-up):	OD: 3 D; OS: 3 D
MAF:	OD: 3 cpm; OS: 3 cpm; difficulty with -2.00
BAF:	3 cpm, slow with -2.00
Monocular estimation method (MEM) retinoscopy:	+1.50 OD and OS
Stereopsis:	40 seconds of arc on Wirt circles, 250 seconds of arc of random dot stereopsis

Pupils were normal; all external and internal health tests were negative; the deviation was comitant; and color vision testing revealed normal function.

Diagnosis

In this case, the patient had exophoria at near, along with low direct (step vergence and vergence facility) and indirect PFV findings. In addition, we found a right hyperphoria at distance and near, and difficulty with all testing when probing the ability to stimulate accommodation. These findings support the diagnoses of convergence insufficiency, right hyperphoria, and accommodative insufficiency.

Treatment

The previous practitioner either did not detect or decided not to treat the hyperphoria and convergence insufficiency. Because the primary complaints were related to reading, we decided to issue a single vision near prescription. We prescribed $+1.00$, based on the MEM retinoscopy result, and combined this with 1 Δ base-down OD and 1 Δ base-up OS, based on the fixation disparity testing. The glasses provided some relief, but the patient continued to be symptomatic. We therefore initiated a vision therapy program and followed the sequence described in Chapter 9 for convergence insufficiency and accommodative insufficiency. The procedures described in Chapter 14 were followed for hyperphoria.

Outcome

M.I. required 22 office visits to complete the vision therapy program. At the reevaluation, she reported elimination of all symptoms. Wearing the glasses she could then read for as long as necessary without eyestrain and without blur. The pre- and post-vision therapy test findings are summarized in Case Table 21.2.

CASE TABLE 21.2 EXAMINATION RESULTS BEFORE AND AFTER VISION THERAPY

Test	Before Vision Therapy	After Vision Therapy
Cover test (D)	2 Δ right hyperphoria	2 Δ right hyperphoria
Cover test (N)	4 Δ right hyperphoria	4 Δ right hyperphoria
Near point of convergence	10 cm break, 25 cm recovery	4 cm break, 6 cm recovery
Base-in (N)	X/18/16	X/18/16
Base-out (N)	10/14/8	12/22/14
Vergence facility (12 BO/3 BI)	5 cpm	12 cpm
Accommodative amplitude	3 D OD and OS	7 D OD and OS

D, distance; N, near; BO, base-out; BI, base-in.

Factors Affecting the Outcome

This case is similar to Case 21.1, except that a comitant vertical deviation was present. M.I. also experienced mild cognitive and memory problems as a result of the ABI. It is likely that the vertical deviation and the cognitive issues extended the therapy, requiring twice as many visits as for the more simple convergence insufficiency case presented in Case 21.1. It is important to note that this was a comitant vertical deviation without excyclotorsion, and the final outcome was excellent.

Case 21.3 Convergence Insufficiency Complicated by Right Hemianopia

History

J.F., a 19-year-old man, sustained head trauma as a result of an automobile accident about 9 months prior to the examination. He was in a coma for 1 month and subsequently received about 6 weeks of physical, occupational, and speech therapy. He complained of difficulty focusing and concentrating when reading, trouble shifting focus from far to near, and very slow reading speed. He experienced eyestrain, blur, and intermittent diplopia after 10 minutes of reading. While he was in the rehabilitation hospital, J.F. was examined by an optometrist, who prescribed glasses with prism. The prism glasses did not relieve his symptoms. His goal was to improve his reading comfort and speed so that he could return to college.

Significant Clinical Findings

Prescription:	OD: -1.00 with 1 base-in; OS: -1.00 with 1 base-in
VA (corrected):	OD: 20/20 OS: 20/20
Near point of convergence:	20 cm break, 25 cm recovery
Cover test (distance, uncorrected):	Orthophoria
Cover test (near, uncorrected):	10 to 12 Δ, intermittent alternating exotropia at near (deviated 50% of the time)
Subjective:	OD: -1.00, 20/20 OS: -1.00, 20/20
Base-in vergence (near):	16/18/4
Base-out vergence (near):	X/6/-2
Vergence facility:	0 cpm, diplopia with 12 base-out
Accommodative amplitude (push-up):	OD: 8 D; OS: 8 D

MAF:	OD: 0 cpm; OS:0 cpm; cannot clear –2.00
BAF:	0 cpm; cannot clear; fails –2.00
MEM retinoscopy:	+1.75 OD and OS
Stereopsis:	20 seconds of arc on Wirt circles, 250 seconds of arc of random dot stereopsis
DEM test:	Below the first percentile in both speed and accuracy
Visual field analysis:	Right homonymous hemianopia

Pupils were normal; all external and internal health tests were negative; the deviation was comitant; and color vision testing revealed normal function.

Diagnosis

The intermittent exotropia at near, receded near point of convergence (NPC), and low direct and indirect PFV findings supported a diagnosis of convergence insufficiency. In addition, J.F. had difficulty with all tests that probed the ability to stimulate accommodation, suggesting accommodative insufficiency. Ocular motor dysfunction was indicated by the very poor result of the DEM test, and he displayed a significant visual field loss (right homonymous hemianopia).

The combination of findings certainly contributed to the difficulty that he was experiencing with reading, including asthenopia and difficulty navigating the page.

Treatment

J.F. was advised to read without his glasses, and a vision therapy program was recommended. The vision therapy program followed the sequence recommended for convergence insufficiency, accommodative insufficiency, and ocular motor disorders. To help him compensate for the right hemianopia, we advised him to keep the book tilted at an angle of 45 to 90 degrees when reading. This compensatory strategy, suggested by Hellerstein and Fishman (16), is designed to minimize the problems that occur when trying to read from left to right into a scotoma. With a right hemianopia, it is difficult for the patient to initiate saccades when reading because of the field loss to the right. This makes reading from left to right very difficult. Reading vertically allows the patient with a right hemianopia to read more fluently because only vertical saccades are necessary, thereby eliminating the problem of left-to-right saccades.

Outcome

J.F. required 32 office visits to complete the vision therapy program. At the reevaluation, J.F. reported elimination of all focusing problems and that he could then read for as long as necessary without headaches or eyestrain. Although he was comfortable, he continued to experience difficulty with his reading speed and felt that he often lost his place when reading. He reported that holding the book at an angle improved his accuracy, although his reading rate was less than what he wanted. The pre- and post-vision therapy results are summarized in Case Table 21.3.

CASE TABLE 21.3 EXAMINATION RESULTS BEFORE AND AFTER VISION THERAPY

Test	Before Vision Therapy	After Vision Therapy
Cover test (D)	Orthophoria	Orthophoria
Cover test (N)	10–12 Δ, intermittent, alternating exotropia at near (deviated 50% of the time)	6–8 Δ exophoria
Near point of convergence	20 cm break, 25 cm recovery	2 cm break, 5 cm recovery
Base-in (N)	16/18/4	20/25/20

Base-out (N)	X/6/−2	15/25/20
Vergence facility (12 BO/3 BI)	0 cpm	15 cpm
Accommodative amplitude	8 D OD and OS	13 D OD and OS
BAF	0 cpm	8 cpm
MAF	0 cpm	10 cpm
DEM error score	30	4
DEM ratio score	3.10	2.77

D, distance; N, near; BO, base-out; BI, base-in.

Factors Affecting the Outcome

Even though this patient sustained rather severe head trauma, he experienced only mild cognitive deficiencies. He was highly motivated to return to college and had excellent mental and physical stamina and normal memory abilities. His attendance at the therapy sessions was nearly perfect.

The characteristics of his binocular and accommodative problems were also positive. He had a small comitant intermittent exodeviation, with normal random dot stereopsis. He also had equal accommodative skills in both eyes. He and the patient in Case 21.1 had similar binocular and accommodative problems.

In spite of these positive factors, J.F. achieved only partial success because of the significant saccadic fixation problems, which were probably related to the right homonymous hemianopia. Although the number of errors on the DEM decreased significantly (from 30 to only 4), his ratio score (speed) did not significantly improve. The reading difficulties experienced by patients with a right hemianopia may also be related to language-based problems associated with left hemisphere damage. Clearly, the presence of a hemianopia can have a significant effect on the outcome of vision therapy.

Case 21.4 Convergence insufficiency complicated by visual processing deficits

History

D.B., a 44-year-old school superintendent who was just about to finish his doctoral degree, was involved in a serious automobile accident. While waiting at a red light, he was rear-ended and struck on the back of his head by his briefcase, which had been kept on the back seat. He remembers being dazed and disoriented after the injury. Several days later, he began complaining of headaches, neck pain, shoulder pain, left hand paresthesias, photophobia, blurred vision, and double vision. He was evaluated at a local rehabilitation hospital. His x-rays and computerized tomography (CT) scan were negative. He received outpatient physical therapy for the head, neck, and left upper extremity pain. He subsequently began experiencing problems with speech, memory, and concentration; emotional lability; depression; and anxiety.

We first examined him 1 year after his injury. He complained that he was unable to read comfortably even for short periods of time. When he tried to read, he experienced blurred vision, double vision, and headaches. He had been examined within the past 6 months and was given glasses. D.B. did not feel that these glasses helped.

Significant Clinical Findings

Prescription:	OD: +0.25; OS: +0.25; +2.25 add
VA (corrected):	OD: 20/60 OS: 20/60

Near point of convergence:	20 cm break, 60 cm recovery
Cover test (distance, uncorrected):	Orthophoria
Cover test (near, uncorrected):	6 Δ exophoria
Subjective:	OD: plano, 20/20 OS: plano, 20/20
Base-in vergence (near):	X/10/6
Base-out vergence (near):	X/8/6
Vergence facility:	0 cpm, diplopia with 12 base-out
Accommodative amplitude (push-up):	OD: 1 D; OS: 1 D
Stereopsis:	None
DEM test:	Became frustrated, lost place numerous times, and could not complete the test
Visual information processing testing	
Test of Visual Perceptual Skills (TVPS):	Scored below the 15th percentile in all seven subtests
Developmental Test of Visual Motor Integration:	Twentieth percentile

Pupils were normal; all external and internal health tests were negative; the deviation was comitant; and color vision testing revealed normal function. Amsler grid testing was negative.

Diagnosis

Multiple problems were present, and we were unable to correct visual acuity to 20/20. The NPC was significantly receded with low PFV (convergence insufficiency); the amplitude of accommodation was below the normal level for a 44-year-old (accommodative insufficiency); the patient scored below the first percentile on saccadic testing (saccadic dysfunction); and his scores on visual information processing testing were below the 15th percentile on most of the tests.

Treatment

A vision therapy program was prescribed for convergence insufficiency, accommodative insufficiency, and saccadic dysfunction. A reevaluation after 12 visits of vision therapy revealed minimal progress. The near point of convergence was still receded with poor vergence ranges, slow and inaccurate saccades, and a reduced amplitude of accommodation. We arrived at the conclusion that the visual information processing problems might be interfering with his ability to perform the visual efficiency therapy techniques. We initiated therapy for visual analysis skills, using the sequence suggested by Rouse and Borsting (58). The next 12 therapy sessions were about equally divided between visual information processing techniques and techniques for saccades, convergence, and accommodation.

A reevaluation after 24 office visits again revealed minimal progress. We prescribed reading glasses with base-in prism (OD +2.75 with 1 base-in, and OS +2.75 with 1 base-in) and continued vision therapy for 12 more visits.

Outcome

Results after 36 office visits of vision therapy were also disappointing. Minimal improvement was found in all of the areas being treated. The patient was therefore dismissed after 36 office visits. At the last reevaluation, he reported that, even with the new glasses, he still experienced headaches and blur after short periods of reading. Determining when to discontinue vision therapy can be a difficult decision. We generally expect to see some significant improvement in symptoms and signs after 12 office visits. Even if no progress is evident, we still sometimes recommend continuation if there

are a number of complicating factors as we found in this case (memory and concentration problems, emotional lability, and visual information processing disorder). Vision therapy probably should have been discontinued after 24 visits. Because we had spent a considerable amount of time working with visual information processing skills during visits 13 to 24, we decided to continue with vision therapy in this case. The pre- and post-vision therapy results are summarized in Case Table 21.4.

CASE TABLE 21.4 EXAMINATION RESULTS BEFORE AND AFTER VISION THERAPY

Test	Before Vision Therapy	After Vision Therapy
Cover test (D)	Orthophoria	Orthophoria
Cover test (N)	6–8 exophoria	6–8 exophoria
Near point of convergence	20 cm break, 60 cm recovery	20 cm break, 30 cm recovery
Base-in (N)	X/10/6	X/12/6
Base-out (N)	X/8/6	X/10/8
Vergence facility (12 BO/3 BI)	0 cpm	0 cpm
Accommodative amplitude	<1 D OD and OS	2 D OD and OS

D, distance; N, near; BO, base-out; BI, base-in.

Factors Affecting the Outcome

The characteristics of D.B.'s binocular and accommodative problems were positive and suggested a relatively good outcome. However, the therapist working with D.B. noted frequent absences (52 scheduled visits were required to complete 36), poor carryover from one session to another because of memory problems, frequent loss of attention and concentration, and an overall inability to exert the effort needed to succeed in a vision therapy program.

He also presented with significant visual information processing problems that, along with his other cognitive difficulties, contributed to the poor outcome. It is interesting to note that even though the severity of the ABI in this case was less than that in the previous cases, the treatment outcome was poor. This is consistent with the findings of Krohel et al. (53), who reported that treatment success cannot be reliably predicted on an individual basis from the type or severity of trauma.

Case 21.5 Sensory Fusion Disruption Syndrome

History

R.F., a 61-year-old man, was shopping in a department store when an item from a shelf fell down and struck the left occipital area of his head. The item fell from a height of about 6 to 8 ft and weighed about 7 lb. There was no loss of consciousness, but immediately following the accident he reported a buzzing in his ears and difficulty with balance. He also reported double vision that was present most of the time. Neurologic testing revealed a mild concussion.

We examined him about 18 months after the injury. At that time his primary residual complaint was double vision. He had been to several eye doctors. The last eye doctor he had visited had prescribed prism glasses to be worn at all times. R.F. felt that the prism glasses did not help him.

Significant Clinical Findings

Current glasses:

OD: +1.00 with 1 base-down and 2 base-in;

OS: +1.00 with 1 base-up and 2 base-in; +2.50 add

VA (corrected):	OD: 20/20 OS: 20/20
VA (corrected):	OD: 20/20 OS: 20/20
Near point of convergence:	Diplopia at all distances
Cover test (distance, uncorrected):	2 to 4 Δ intermittent right hypertropia
Cover test (near, uncorrected):	6 Δ intermittent exotropia and 2 to 4 intermittent right hypertropia at near
Subjective:	OD: +1.00, 20/20 OS: +1.00, 20/20
Base-in vergence (near):	Diplopia; could not fuse with any combination of prism
Base-out vergence (near):	Diplopia; could not fuse with any combination of prism
Fixation disparity testing:	Diplopia; could not fuse with any combination of prism
Accommodative amplitude (push-up):	OD: 3 D; OS: 3 D
MAF:	OD: 3 cpm; OS: 3 cpm; difficulty with -2.00
BAF:	Diplopia
MEM retinoscopy:	+1.50 OD and OS
Worth four-dot test:	After neutralizing the vertical misalignment, we used horizontal prism to try to achieve fusion. R.F.'s responses were, at times, difficult to interpret. On occasion, it seemed as if he might be experiencing fusion for brief periods of time. For the majority of the time, however, R.F. reported that just as the images were about to come together, the images would move apart again.
Stereopsis:	None

Pupils were normal; all external and internal health tests were negative; the deviation was comitant; and color vision testing revealed normal function.

Diagnosis

We reached a diagnosis of intermittent right hypertropia, exotropia, and sensory fusion disruption syndrome. This diagnosis was based on the patient's inability to fuse with any combination of lenses and prisms or with any type of fusion target (first-, second-, or third-degree fusion targets).

Treatment

In spite of a guarded prognosis, we prescribed a trial period of vision therapy because R.F. displayed fleeting fusion at times during the examination. The primary approach was to use large peripheral first- and second-degree targets. The instrumentation included the major amblyoscope, Computer Orthoptics software, and vectogram targets projected using an overhead projector.

Outcome

No progress was noted at the reevaluation after 12 office visits. There had been no consistent progress in vision therapy. R.F. was unable to ever hold fusion for more than a moment. We discontinued the attempt to reestablish fusion and presented various occlusion options to eliminate the diplopia. The pre- and post-vision therapy results are summarized in Case Table 21.5.

CASE TABLE 21.5 EXAMINATION RESULTS BEFORE AND AFTER VISION THERAPY

Test	Before Vision Therapy	After Vision Therapy
Cover test (D)	2–4 Δ intermittent right hypertropia	2–4 Δ intermittent right hypertropia
Cover test (N)	6 Δ intermittent exotropia and 2–4 intermittent right hypertropia at near	6 Δ intermittent exotropia and 2–4 intermittent right hypertropia at near
Near point of convergence	Diplopia at all distances	Diplopia at all distances
Base-in (N)	Not measurable	Not measurable
Base-out (N)	Not measurable	Not measurable
Vergence facility (12 BO/3 BI)	Not measurable	Not measurable

D, distance; N, near; BO, base-out; BI, base-in.

Factors Affecting the Outcome

Although there was only a small intermittent exotropia and intermittent hypertropia, which suggested a positive outcome, the patient was unable to maintain fusion. Such a presentation is referred to as sensory fusion disruption syndrome (24,25). The term refers to a condition that results from severe closed-head trauma in which the patient is unable to fuse images even though they are aligned bifoveally under optimal conditions. This inability to fuse is similar to the clinical entity referred to as horror fusionis.

The prognosis in such cases is usually poor. Treatment with lenses, prism, vision therapy, or surgery is generally unsuccessful, although there have been some case reports (24,25) suggesting that some of these patients will regain fusion spontaneously or with treatment. Another possible treatment approach in cases like these is occlusion or monovision correction. This treatment approach was rejected by the patient because it made him feel even more uncomfortable. Nevertheless, it should be a consideration when intractable diplopia is present.

Because it is impossible to predict which cases will resolve with treatment, it is appropriate to attempt a trial period of treatment. This is another example of treatment of a relatively mild head trauma yielding a poor final outcome.

Summary

These cases illustrate some of the challenges associated with treating binocular vision, accommodative, and eye movement disorders associated with ABI. Factors likely to interfere with prognosis include cognitive and psychological disorders, poor motivation, visual field anomalies, and complicated motor and sensory disorders. Nevertheless, these case studies also demonstrate that in many cases optometric treatment can result in significant gains and improvement in quality of life.

Based on these case reports, our advice concerning the treatment of binocular vision problems associated with ABI is to adopt a sequential treatment approach. Vision therapy is an excellent option when the patient has adequate cognitive, memory, and attention skills; is able to demonstrate the presence of random dot stereopsis; and does not have an excyclotorsion component or a hemianopia. If any of these conditions is not met, vision therapy may still be appropriate, but the prognosis may not be so good. We recommend a short trial period of vision therapy, with follow-up to determine whether additional therapy is warranted.

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Binocular and Accommodative Problems Associated with Learning Problems

This chapter is not designed to provide new diagnostic tests or treatment procedures for vision disorders associated with reading problems. The accommodative, binocular vision, and eye movement disorders associated with reading are identical to those described earlier in this book. Rather, the area of emphasis of this chapter is the unique role of the optometrist in the comanagement of reading-related vision problems.

Comanagement is the key word, and it refers to the fact that, in most cases, to be maximally effective, the optometrist must interact with a number of other professionals when treating patients with reading-related vision problems. This need for comanagement makes this area one of the more challenging aspects of optometric care; to be successful in this role, an optometrist must have an understanding of the following:

- Reading dysfunction
- The relationship between vision problems and reading dysfunction
- Psychoeducational testing used in the diagnosis of reading dysfunction
- The objectives of optometric intervention

An understanding of these issues allows the optometrist to ask appropriate questions during the case history interview, relate test findings to the presenting complaints, and make appropriate management decisions.

Role of the Optometrist in the Management of Learning- and Reading-related Vision Disorders

Optometry has a long history of involvement in the area of vision, and learning and reading (1). Much of this interest has been generated by the concerns of parents and the referrals of teachers, psychologists, and other professionals who often turn to us for answers about whether a child has a vision problem that is contributing to (or responsible for) his/her poor school performance (1,2).

In 1997, the American Academy of Optometry and the American Optometric Association published a position statement on vision, learning, and dyslexia (3). This position statement was accepted and approved by all major organizations in the field of optometry. More recently, the American Optometric Association published its clinical practice guidelines on the care of the patient with learning-related vision problems (4). Both of these documents clearly delineate the role of optometry in the diagnosis and treatment of learning-related vision disorders. Both of these documents emphasize that optometrists do not treat learning or reading problems. The optometrist's primary role is the diagnosis and treatment of vision problems that may interfere with school performance. "The expectation for intervention should be the reduction or elimination of signs and symptoms associated with the particular visual deficits" (4). Optometrists do not directly treat the reading or learning problem. Therefore, the goals of optometric intervention must be specific and problem-oriented, rather than indefinite, such as "to improve school performance" (4). A key element in this philosophy is the recognition of the multifactorial nature of learning disorders. Children generally need a variety of services, such as educational remediation, psychological counseling, occupational therapy, and speech/language intervention, to deal with the actual learning disorder.

TABLE 22.1 THREE-COMPONENT MODEL OF VISION

Component	Included Visual Functions
Visual pathway integrity	Eye health Visual acuity Refractive status
Visual efficiency	Accommodation Binocular vision Eye movement skills
Visual information processing	Visual-spatial skills Visual analysis skills Visual-motor integration skills

Another important concept discussed in these documents, as well as in previous studies and reports (2,5), is that optometrists should conceptualize vision as comprising three interrelated areas, as listed in Table 22.1. To adequately identify learning- or reading-related vision problems, all three areas must be fully evaluated (3).

We strongly agree with these two essential concepts and believe that vision disorders can contribute to reading difficulties but they are generally not the primary etiologic factor. Rather, vision disorders represent one of the factors that may interfere with an individual's academic performance and make it difficult for him/her to perform up to his/her potential. To consider the relationship between vision and reading, we will use the model described in Table 22.1. This chapter is not intended to be a complete discussion of all vision problems associated with learning and reading disorders. For example, the topic of visual information processing disorders is not addressed. Readers interested in this topic should refer to other available textbooks (2,6–8).

Learning and Reading Disabilities: Definition and Epidemiology

In 1987, the Interagency Committee on Learning Disabilities at the National Institutes of Health (NIH) developed the following definition of learning disabilities (9):

Learning disabilities is a generic term that refers to a heterogeneous group of disorders manifested by significant difficulties in the acquisition and use of listening, speaking, reading, writing, reasoning, or mathematical abilities. These disorders are intrinsic to the individual and presumed to be due to central nervous dysfunction. Even though a learning disability may occur concomitantly with other handicapping conditions (e.g., sensory impairment, mental retardation, social and emotional disturbance) or environmental influences (e.g., cultural differences, insufficient or inappropriate instruction, psychogenic factors), it is not the direct result of those conditions or influences.

Solan (10) criticized this definition as being ambiguous and not testable, and noted that it is difficult to establish the specific criteria for diagnosing a learning disability from this definition. This is one of the main reasons why it has been nearly impossible to establish the number of people affected by learning disabilities in a particular population (10). Depending on the diagnostic process and the definition used, estimates of the prevalence of learning problems among school-aged children range from 2% to 10% (9,11). Nationally, about 5% of all schoolchildren are diagnosed with learning disabilities (and an equal or higher number have milder learning problems) (4). Of that population, as many as 75% have reading problems (12).

The objective of this chapter is to review the management of the most common visual efficiency problems that contribute to the most common learning disorder. Because the most common learning problem is reading dysfunction (4), it is the specific problem addressed in this chapter. We also use a series of cases to demonstrate some of the important concepts discussed in this chapter.

Reading Dysfunction

Failure to learn to read is the most predominant and important subtype of specific learning disability (10). Even after a century of concern, this enigmatic educational problem has eluded solution (10). Part of the difficulty has been confusion and disagreement over definitions and terminology. For the purposes of this

TABLE 22.2 TYPES OF DYSLEXIA

Type	Suspected Anatomic Location	Affected Coding Process
Dyseidnesia	Angular gyrus of left parietal lobe (for right-handers)	<ul style="list-style-type: none"> • Poor sight–word recognition • Relies on time-consuming word-attack skills to decode many words
Dysphonesia	The Wernicke area of left temporal and parietal lobes (for right-handers)	<ul style="list-style-type: none"> • Impaired phonetic ability • Relies on sight–word vocabulary
Dysnemkinesia	Motor cortex of frontal lobe (left hemisphere) for right-handers	<ul style="list-style-type: none"> • Abnormally high frequency of letter reversals

chapter, we define *reading dysfunction* as a failure to learn to read despite average or above average intelligence, adequate or even abundant educational opportunities, normal sensory development (auditory and visual), normal acculturation, no frank brain damage, and no primary emotional disturbance (13). Thus, conditions such as mental retardation, emotional disturbance, educational deprivation, hearing impairment, and visual handicaps are eliminated from being primary determinants (10).

Another term commonly used when discussing reading problems is *dyslexia*. The term is problematic because it can mean different things to different clinicians, leading to considerable confusion in research and clinical care (7). Some clinicians use the term *dyslexia* as a synonym for *reading dysfunction*. Most authors believe, however, that it is important to differentiate dyslexia from the more common nonspecific or general form of reading dysfunction described above. Griffin and Walton (14) suggested that dyslexia may be characterized as a specific type of reading dysfunction in which there is a deficit in an individual's ability to interpret the symbols of written language due to minimal brain dysfunction or differential brain function. Dyslexia tends to be a more severe form of reading problem, with a poorer prognosis, with the implication that it is due to some type of brain dysfunction.

A neuroanatomic model has been described that identifies three basic types of dyslexia, each with its specific anatomic location (15). The three types of dyslexia are listed in Table 22.2, along with the presumed anatomic location of the brain dysfunction.

The Dyslexia Determination Test (14) and the Boder Test of Reading–Spelling Patterns (16), which require about 30 minutes to administer, allow clinicians to determine the specific type of dyslexia. A screening test that requires only 5 minutes, the Dyslexia Screener, allows for rapid screening for the three types of dyslexia (17,18).

Dyslexia has received substantial publicity in the popular press, and parents may use this term when referring to their child's reading problem even if dyslexia is not actually present. The prognosis in cases of true dyslexia is guarded; in most cases, even with intervention, the individual never acquires normal reading ability. Fortunately, the majority of reading problems encountered in an optometric practice will be the less serious (more common) form of nonspecific reading dysfunction. With appropriate intervention, these cases have an excellent prognosis.

Relationship between Vision Problems and Reading Dysfunction

Flax (1,19) has emphasized the importance of using a task analysis approach when attempting to relate vision disorders to reading dysfunction. He believes that this approach is useful in both understanding patient complaints and, even more important, being able to explain patient behaviors and predict the outcome of optometric intervention (19).

Table 22.3 lists some of the common initial complaints that we hear as optometrists from parents of children who may have nonspecific reading dysfunction. The objective of the case history and task analysis approach is to gain a specific understanding of the nature of the reading disorder.

Flax (1) describes two excellent examples of children presenting with a chief complaint of “reading problems with poor comprehension.” We have summarized these two examples in Table 22.4.

To understand the nature of the reading problem faced by a child, Flax (1,19) and Borsting and Rouse (20) suggest a model that distinguishes between “learning to read” and “reading to learn.” These two phases of reading are summarized in Tables 22.5 and 22.6.

TABLE 22.3 COMMON PRESENTING COMPLAINTS

My child:
<ul style="list-style-type: none"> • is not doing well in school • is failing • is not working up to potential • is having trouble with reading • hates school • does not like to read

TABLE 22.4 DEFINING THE NATURE OF THE READING PROBLEM

Reading Comprehension with a Visual Basis	Reading Comprehension without a Visual Basis
<ul style="list-style-type: none"> • Can effectively identify single words in isolation • Can decode unfamiliar words • Shows a decline in efficiency on longer assignments • Reading comprehension becomes worse with smaller type • Frequently omits words, rereads the same line, and skips lines • Enjoys being read to and can discuss and recall effectively when material is read aloud • Can define words, give synonyms, and has good understanding of anything that is heard 	<ul style="list-style-type: none"> • Can pronounce words, but not define them • No indications of fatigue, asthenopia • Can work for hours, but does not understand what is being read • Performance does not improve when reading passage is read aloud • When attempting to explain what has just been read, patient repeats the same words that were in text but does not offer synonyms, alternative phrases, or anything suggesting insight • Mechanics of reading seem to be intact

TABLE 22.5 LEARNING TO READ**Task requirements**

Major emphasis on word recognition and recall
 Large type with few words on each page
 "Look and say" methods of teaching place premium on visual memory
 Phonic methods require careful scrutiny of internal details of individual words
 Activity usually does not extend over long time periods
 Writing may be utilized to reinforce reading

Important visual factors

Accurate ocular motor control
 Visual perception and memory
 Accommodation and binocular vision are usually not critical factors unless there is heavy utilization of ditto sheets or similar teaching aids
 Ability to integrate auditory and visual stimuli

As per this model, it is clear that visual efficiency disorders (accommodative, binocular vision, and eye movement disorders) are most likely to affect reading performance in grades 4 and above when a child is reading to learn (21). In the earlier grades, when children are learning to read, they are not expected to maintain prolonged attention and concentration on reading; the teacher changes activities frequently; and the print size is large. Of course, it is important to remember that school systems vary in the demands they place on children in different grades. It is critical, therefore, for an optometrist to become aware of the teaching philosophy of the children's respective school systems in order to understand the reading demands on children presenting in his/her practice with a reading dysfunction.

Table 22.7 lists the common signs and symptoms associated with visual efficiency problems and reading.

TABLE 22.6 READING TO LEARN

Task requirements
Longer reading assignments
Smaller type
Context cues become increasingly important to word recognition
Phonic and linguistic cues are more readily available
Word analysis becomes more automatic, with lesser need to depend primarily on form perception
Emphasis shifts to comprehension and speed
Important visual factors
Accommodation and binocular vision become more important
Oculomotor control is important to keep place and preserve continuity of input
Visual perception plays a decreasing role

TABLE 22.7 SIGNS AND SYMPTOMS ASSOCIATED WITH VISUAL EFFICIENCY PROBLEMS

Clinical signs (associated with reading)
Squinting
Frowning
Excessive blinking
Eye rubbing
Covering an eye
Tilting the head
Close working distance when reading
Avoidance of reading
Symptoms (associated with reading)
Blur
Diplopia
Eye discomfort
Headaches
Generalized fatigue
Sleepiness when reading
Omits small words, transposes word order or letter sequences
Frequent loss of place
Omits whole lines of text or rereads the same line
Uses finger to maintain place

Research Supporting the Relationship between Visual Efficiency Problems and Reading

Although there has been a considerable amount of literature devoted to determining whether there is a relationship between visual efficiency skills and reading, results have varied significantly from one researcher to another (21). Some investigators have reported a definitive relationship, others suggest that no relationship exists, and a third group believes that there is no definitive proof either way. Garzia (22) comments:

Unfortunately this confusion has been malinterpreted to mean that vision and more specifically visual function has a minor role or no role at all in reading achievement. This has been extended to the clinical domain by the general inattention directed to the visual efficiency of children experiencing difficulty learning to read.

Nevertheless, despite some difficulties in research efforts, a credible pattern of association between visual skills and reading ability emerges (22). In an extensive study-by-study narrative review of the literature, Grisham and Simons (23,24) concluded that there is a relationship between refractive status and binocular vision and reading. This was further supported by a meta-analysis of the same literature (21).

There also appears to be a relationship between eye movements and reading. When the reading eye movement patterns of disabled readers are evaluated, a characteristic pattern emerges. The eye movements of poor readers are characterized by an increased number of forward fixations per line of text, an increased number of regressions, longer fixation durations, and a higher prevalence of intraword scanning, when compared to normal readers (25). Studies by Pavlidis (26–28) indicate that disabled readers have poor eye movement control. He required his subjects to saccade between a series of sequentially illuminated equidistant targets. The reading-disabled subjects made a significantly higher number of inappropriate eye movements, especially regressions, and had longer and more variable fixations, and longer reaction times, than did matched normal control subjects.

Other visual functions have not been thoroughly investigated, but they also have the potential for adversely influencing reading proficiency. For an intuitive example, accommodative infacility would make it difficult for classroom reading-related activities that require rapid changes in fixation distance from the chalkboard or teacher to the desktop (22). Any vision assessment of a child having learning difficulty must include not only tests of visual acuity and refractive status but also tests of near point visual skills that are associated with reading. The visual efficiency skills of accommodation, vergence, and ocular motility should be investigated in detail for the presence of any dysfunction that can not only induce visual signs or symptoms but also has the potential for influencing reading achievement.

Colored Filters or Glasses and Reading

Optometrists working with reading-related vision problems invariably encounter questions about the use of colored glasses or filters to treat reading dysfunction. Information about this method of treating reading problems periodically appears in the popular media, and the approach has become accepted by many reading specialists and school systems around the country. It is therefore important for optometrists to be knowledgeable about this treatment approach.

Meares (29), Irlen (30,31), and Wilkins (32,33) have described a syndrome of visual symptoms and distortion that can be alleviated with colored filters. This syndrome is referred to as the *Meares-Irlen syndrome*. Individuals with this condition tend to be ineffective readers who must use more effort and energy when reading because they see the printed page differently from readers who do not suffer from the syndrome. The difficulties individuals suffering from the syndrome experience while reading may include sensitivity to light, eyestrain, difficulty focusing, unstable appearance of the print, distortion of the printed page, words appearing to be moving on the page, and words appearing washed out (31). These problems may lead to fatigue, visual discomfort, and inability to sustain attention as necessary for long periods of time.

Irlen (31) claimed that approximately 50% of the reading-disability and dyslexic populations have this syndrome and that it is a key factor that interferes with the reading process in these individuals. She suggested that close to 90% of individuals with this disorder can be successfully treated using appropriately tinted lenses called *Irlen filters*. The objective of her treatment procedure is to eliminate the discomfort associated with reading and to improve reading performance. Irlen (31) also suggested that scotopic sensitivity syndrome is a distinct entity that cannot be identified through standardized educational and psychological evaluations, vision examinations, medical checkups, or other standardized diagnostic tests.

Several optometrists (34–39) have raised concerns about Irlen's theories and methods. An important issue is the striking similarity between the symptoms that Irlen suggests to be associated with scotopic sensitivity syndrome and the symptoms associated with accommodative, binocular vision, and ocular motility disorders. Specifically, the following symptoms have been reported to be associated with both scotopic sensitivity syndrome or the Irlen syndrome (40) and visual efficiency problems (38,39,41): headaches, eyestrain, excessive blinking, excessive rubbing of the eyes, squinting, intermittent blur, occasional double vision, words appearing to be moving on the page, frequent loss of place, skipping lines, inability to sustain and concentrate, and rereading the same lines unintentionally. Could subjects diagnosed as having the "Meares-Irlen syndrome" simply have a refractive, accommodative, binocular vision, or eye movement disorder that has not been properly diagnosed?

Blaskey et al. (42) investigated this specific issue and found that 95% of subjects ($N = 39$) identified as good candidates for Irlen filters had significant (readily identifiable) vision anomalies. Lopez et al. (43) studied 39 children and found a significant tendency for subjects with more severe scotopic sensitivity syndrome to be candidates for vision therapy. It is important to stress that advocates of Irlen specifically claim that

scotopic sensitivity syndrome is an entity that is distinct from vision problems that could be identified in an optometric evaluation. The Irlen patient brochure implies that each client first receives a complete vision examination and that vision problems are treated prior to the Irlen diagnostic testing. A study by Blaskey et al. (42) addressed this issue. They found that 57% of their subjects had either periodic vision care or at least one eye examination within the previous year of the study. Of these subjects, 90% still had significant uncorrected vision problems. Another randomized trial did exclude all patients with significant vision disorders (including refractive, binocular, and accommodative disorders) and found a significant increase in reading rate with colored overlays (44). It is apparent that some people seeking treatment with colored lenses are likely to have uncorrected visual efficiency problems that require treatment.

Taub et al. (39) measured the reading eye movements of 60 adult subjects. Two test groups (symptomatic vs. asymptomatic) were identified via the use of a validated survey. Each subject was tested with each of 10 short reading passages and 10 colored overlays, in two separate visits. Color filters were not found to have an effect on any of the variables measured. An identifiable binocular disorder was present in 73% of symptomatic patients and 27% of asymptomatic patients. The data support the theory that many of those with Meares-Irlen syndrome symptoms actually have an underlying binocular/accommodative vision disorder.

In the last decade, researchers have investigated the use of colored filters as a treatment approach for reading dysfunction. In 1991, Evans and Drasdo (45) reviewed all available research on the use of tinted lenses to improve reading performance. They found 17 studies completed between 1983 and 1991. The authors concluded that because of the poor quality of much of the research (no controls, no statistical analysis, limited details, small numbers, no case reports, poor group matching), the claims of effectiveness of these procedures cannot be proved or disproved. A controlled study by Menacker et al. (46) was unable to substantiate the effectiveness of tinted lens therapy in a well-defined group of children with dyslexia. In 1992, Wilkins et al. (32) reported on the development of a new instrument designed to help determine the appropriate colored filter to be prescribed for individual patients. This instrument, called the intuitive colorimeter, allows a subject to view text that is illuminated by light whose hue, saturation, and luminance can be varied independently within a large range of colors. Using this instrument, Wilkins et al. (47) performed the first double-masked, placebo-controlled trial of the therapeutic use of tinted lenses for reading difficulty. Of the 55 subjects, 82% reported benefits from colored lenses and were still using the lenses 10 months later. In addition, the study showed that the benefit from colored filters was not solely attributable to a placebo effect. The authors also found, however, that binocular-vision problems and accommodative problems were common in the subjects studied and concluded that the first priority with regard to the treatment of a patient with the Irlen syndrome is treatment of any significant visual efficiency problem (48). Harris and MacRow-Hill (49) completed a double-masked, placebo-controlled study to investigate the effectiveness of ChromaGen lenses for improving reading rate in subjects with the Meares-Irlen syndrome and found a 17% increase in reading rate. The effect was only seen in subjects who had reading difficulties along with visual discomfort.

These results are evidence, therefore, suggesting that the use of colored filters may be of value in treating some patients with reading dysfunction and symptoms. However, all studies that have included a comprehensive evaluation of vision have concluded that most of the patients seeking treatment with colored lenses first require treatment for visual efficiency problems. The small percentage of patients still symptomatic after appropriate eye care may benefit from colored lenses.

Another important question that has been investigated is why some individuals experience relief of symptoms and improved reading performance with colored filters. Although a definitive answer to this question still eludes us, significant research has been conducted over the past decade to try to answer this question; several theories have been proposed. The most popular theory is that some reading-disabled individuals have a processing deficit in the transient visual system that can be improved using colored overlays or overlays that reduce the contrast of printed materials (50).

There are two parallel visual pathways: the transient (M or magnocellular pathway) and the sustained (P or parvocellular pathway) processing systems. The transient system is a fast-operating system that is most sensitive to low and middle spatial frequencies and high temporal resolution. It responds to quickly-moving targets for short periods of time. It has short response persistence and a short latency period. The transient system prepares the visual system for input to the slower, detail-oriented information processing of the sustained system. The sustained system responds more slowly and is most sensitive to high spatial frequencies. It has a primary role in identification of shape and resolution of fine detail. It is more sensitive to stationary targets. The sustained system responds subsequent to the transient output and is important in reading.

The transient visual system-processing deficit theory suggests that during reading the sustained system is used to obtain information about the group of letters being fixated, whereas the transient system is used to

organize the next saccade. The transient system is also believed to help erase the persistent image of the previous fixation from the sustained system during the saccade. The theory suggests that if the transient system fails to produce the correct saccade or to erase the image of the last fixation, significant reading problems can result which can cause the type of symptoms that Meares, Irlen, and Wilkins (29,31,33) have reported. Williams, Lecluyse, and Rock-Fauchoux (50) suggested that certain colors can alter the flow of information in the two systems and can rebalance the activity in the two pathways. Solan et al. (51) have demonstrated that there is a link between wavelength of light and reading comprehension and between luminance and reading ability. The authors also demonstrated that blue filters significantly improved eye movement efficiency in subjects with reading dysfunction. More recent studies by Solan and colleagues have demonstrated that vision therapy designed to improve temporal visual processing has a positive effect on magnocellular processing and reading comprehension in children with reading disorders and M-cell deficits (52–54). Although there are still some inconsistencies in the transient/sustained system research, there appears to be sufficient evidence to accept the premise that a defective transient system pathway may be one of the factors affecting reading skills in some patients.

Evans et al. (48) proposed a different mechanism, called *pattern glare*, for the Irlen syndrome. Pattern glare describes the symptoms that many people experience when viewing repetitive striped patterns, including text. Wilkins (33) proposed that a cortical hyperexcitability accounted for pattern glare and that colored filters of specific chromaticity could possibly reduce this hyperexcitability and alleviate the associated symptoms.

Although many questions remain, it does appear that some patients benefit from the use of colored lenses to improve reading comfort and performance. We believe that a vast majority of patients seeking treatment with colored lenses simply require good optometric care to solve their symptoms. Once treated with the appropriate lenses and vision therapy, they become comfortable and their attention, concentration, and sustaining ability when reading improve. However, there are cases in which the use of colored lenses seems to help patients even after they have been treated with lenses and vision therapy. Although it is still unclear why this occurs, the transient system deficit theory appears to be gaining momentum. As researchers continue to investigate this phenomenon, optometrists should educate their patients about the importance of a comprehensive vision examination before consideration of these lenses. If no vision problem is detected, the use of colored lenses should be explored. Although a widely accepted method for determining the appropriate color is not available, we are hopeful that this situation will change in the near future.

Psychoeducational Testing Used in the Diagnosis of Reading Dysfunction

Earlier in this chapter, we defined reading dysfunction as a discrepancy between intelligence and performance. Because optometrists must make decisions about treating visual efficiency problems that might be related to reading, it is important to have a basic understanding of how educators and psychologists determine a child's potential and performance levels. Psychoeducational evaluations are usually performed by a certified school psychologist (i.e., a psychologist who has specialized in school-related issues).

BASIC COMPONENTS OF PSYCHOEDUCATIONAL TESTING

A standard psychoeducational evaluation consists of four major components (55). Table 22.8 lists the different areas evaluated for each category. Each area is relevant to the overall functioning of a child. In most states, to be classified as learning or reading disabled and to receive special education services, a discrepancy must exist between a child's aptitude (or intellectual level) and his/her actual level of academic achievement (56). Hence, both intellectual level and academic achievement must be assessed thoroughly to make that determination. Furthermore, for the reading problem to be considered a reading disability, the academic problems must not be due primarily to emotional disturbance, vision or hearing problems, or environmental deprivation. Such difficulties, however, may exist along with the reading disability. As a result, from the perspective of qualification for services, these areas also must be understood thoroughly.

Another important reason for evaluating cognitive functioning, academic achievement, and emotional functioning is related to development of appropriate remediation strategies. As mentioned previously, inter-related areas of functioning must be considered for treatment strategies to be effective.

A comprehensive psychoeducational evaluation that includes the four areas described above generally takes approximately 5 to 8 hours to perform. Testing is often completed in two or three sessions, depending on the age and attention span of the child being tested.

TABLE 22.8 COMPONENTS OF A PSYCHOEDUCATIONAL EVALUATION

1. History
2. Cognitive functioning
IQ level
Language skills
Attention and concentration
Memory
Visual perceptual skills
Auditory perceptual skills
Cognitive style
Processing speed
3. Academic achievement
Reading—decoding and comprehension
Math
Spelling
Writing—handwriting, paragraph composition, thematic maturity, grammar, punctuation
4. Emotional functioning
Self concept
Frustration tolerance and coping mechanisms
Relationships with significant others
Reality testing
Diagnostic classifications for emotional disturbance

HISTORY

The process of gathering a comprehensive history is crucial to the understanding of the child's problem, for formulating a diagnosis, and for developing intervention strategies. It is also an opportunity to search for contributing factors and to decide what tests should be administered during the testing process. Information must be gathered about three general areas. These include information about the child, school history, and information about the family. The history obtained by the psychologist is generally summarized in the "background information" section of the written report that he/she provides. The optometrist can utilize this information as the basis for obtaining details that he/she thinks are relevant, probing those areas related to the referral question. It is particularly important for the optometrist searching for a connection between vision and reading to understand the age of onset of academic problems and how they became manifest.

COGNITIVE TESTING

Cognitive testing includes assessment of various abilities, including language, memory, auditory and visual perceptual skills, visual-motor abilities, attention and concentration, and cognitive style. This information is gathered by administering an intelligence test as well as supplemental tests. An intelligence test provides an Intelligence Quotient (IQ), as well as information about the various aspects of cognitive functioning mentioned above.

Intellectual functioning is generally classified in the following way: IQ scores have a mean of 100, with a standard deviation (SD) of 15. Thus, about two-thirds of all people obtain an IQ score between 85 and 115 (within 1 SD of the mean), and 95% obtain a score between 70 and 130 (a range of 2 SDs from the mean) (57).

The most commonly used IQ tests are the Wechsler Intelligence Scale for Children IV (WISC-IV), Wechsler Preschool and Primary Scale of Intelligence III (WPPSI-III), and the Wechsler Adult Intelligence Scale III (WAIS-III). These tests provide an overall IQ score, various index scores or standard age scores for different scales, and subtest scores for each individual subtest within the scales.

The Wechsler scales are three separate tests, distinguished by the age range they cover. The WISC-IV, which is administered to children aged 6 through 16 years, is the test that optometrists are most likely to encounter in a report. The test has ten core subtests and five supplemental subtests that may be administered. These subtests are divided into four scales, or indexes: (a) Verbal Comprehension Index, (b) Perceptual Reasoning Index, (c) Working Memory Index, and (d) Processing Speed Index. Four index scores and the Full Scale IQ are obtained from this test. The Full Scale IQ score is a combination of the four index scores, as elaborated upon in the following.

The child's functioning on verbally related subtests and on nonverbal, or more visual–spatial, tasks can be compared by comparing the Verbal Comprehension Index with the Perceptual Reasoning Index and the Processing Speed Index. Obviously, such a comparison would be quite relevant for an optometrist who may be exploring the role of vision in learning. The optometrist can determine whether verbal and nonverbal abilities are fairly consistent or whether one area is weaker than the other. This is one important issue to consider when determining whether vision therapy for visual processing skills is indicated. Intervention is indicated when the Perceptual Reasoning Index is significantly weaker than the Verbal Comprehension Index. An example of this would be a Verbal Comprehension Index of 110 and a Perceptual Reasoning Index of 90.

ACHIEVEMENT TESTING

Educational testing has an important place in a complete psychoeducational evaluation. Such testing is designed to determine achievement levels in all academic areas. In regard to reading ability, the first stage of the assessment involves evaluation of the child's ability to recognize words and apply word analysis strategies. If the child has significant difficulty in these areas, then there are many implications about how this could affect his/her overall functioning. After analysis of the word recognition and decoding strategies using isolated words and nonsense word patterns, it is beneficial to assess how the child handles word-reading demands while reading in context from representative text material. Finally, reading comprehension is evaluated.

Earlier, we discussed the importance of understanding the nature of the reading problem. The reading assessment provides the information necessary to determine whether the visual efficiency problem is related to the reading dysfunction.

EMOTIONAL OR PERSONALITY TESTING

Emotional issues can interfere and exacerbate reading problems. For example, reading is a developmental task that cannot be obtained until a youngster is ready. This includes an assumption that the central nervous system is mature enough to handle the complex demands of the act of reading. To some youngsters, taking that next developmental step is intimidating, and emotional issues surface. Reading may be perceived to be an act that only “the big people do,” and this little person may not feel equipped to tackle such an adult activity.

Typical psychoeducational assessments evaluate emotion and personality on a continuum from objective measures that ask the person directly how he/she feels about a certain issue to much more indirect or projective methods of gaining information. In the more direct method, the person is asked a range of questions in what is called a *clinical interview*. Insight can be gained about the person's feelings about himself/herself, key people in his/her life, school, and so forth from this interview.

Other ways of gaining insight into a person's emotional life include the more projective methods. Sentence completion tests ask the person to complete a sentence stem with the first thing that comes to mind, such as “All my life I . . .” Other methods include projective drawing, in which drawings are used to interpret major themes and issues that are relevant to the individual.

When optometrists consider the emotional/personality section of the report, the same basic concepts that were discussed in the achievement section apply. How severe are the emotional problems? What can an optometrist expect from the youngster? Will he/she be very difficult to manage in vision therapy? Is the child overly withdrawn? Is there too much anger and tension in the family system to expect consistent follow-up?

Diagnostic Testing and Case history

The diagnostic testing for reading-related vision disorders is identical to the testing presented in Chapter 1, with two important exceptions. First, if a child presents with reading problems, it is very useful to perform an infrared eye tracking evaluation while the patient is reading. The clinical instruments available today are the Visagraph II and the Readalyzer. Objective eye movement recording has several advantages over direct observation and timed or standardized tests. The Visagraph II and Readalyzer provide a permanent recording of the evaluation, and their use is an objective procedure that does not depend on the skill of the examiner. The information gained from objective recording is also more sophisticated. It provides information about number of fixations, regressions, duration of fixations, reading rate, relative efficiency, and grade equivalence. All of this information can be compared to established norms for different classes of population ranging from elementary schoolchildren to adults. We find it helpful to repeat this testing after intervention, in order to demonstrate the changes in reading eye movement patterns.

The other significant modification in the diagnostic routine, when the concern is whether a vision disorder could be interfering with reading performance, is the case history. Regarding the case history, Cotter (58) states, “As a diagnostic tool, its importance cannot be underestimated. An integral part of the evaluation, the case history offers a rich source of data for case formulation that is not available from other forms of assessment.” The case history information shapes the examination strategy, development of the management plan, and formulation of the prognosis.

DEFINING THE NATURE OF THE READING OR LEARNING PROBLEM

If the chief complaint is related to reading, it is important for the optometrist to gain as much information as possible about the specific nature of the reading problem. This information can be used to determine whether the reading problem can be related to a visual efficiency, visual information processing, or nonvisual (language) problem. This determination is a critical part of the evaluation and guides the management decisions that must be made. For example, if the history suggests a language problem, part of the treatment plan may include a referral to a psychologist, educator, or speech/language pathologist. If the history suggests that a visual information processing problem may be related to the child’s learning difficulty, further testing would be recommended to evaluate this possibility.

Table 22.9 lists suggested questions that can be asked to help determine whether the reading problem might be related to a visual efficiency, visual information processing, or language disorder. The most basic

TABLE 22.9 EDUCATIONAL HISTORY TO DETERMINE THE NATURE OF A READING OR LEARNING PROBLEM

Question	Response	Suggests Potential Problem with:
When did the problem start?	Present since grade 1	Visual processing or language
	Grade 4 and above	Visual efficiency
Does your child enjoy when you read to him/her?	Yes	Visual efficiency
	No	Language
Is your child able to verbally discuss reading passages and ask intelligent questions?	Yes	Visual efficiency
	No	Language
Trouble sounding out words?	Yes	Language
Trouble with sight vocabulary?	Yes	Visual information processing or language
Trouble with comprehension of long passages?	Yes	Visual efficiency
Trouble with reading speed?	Yes	Visual efficiency
Frequent loss of place, skipping words, lines?	Yes	Visual efficiency
Does your child read better when the print is larger?	Yes	Visual efficiency
Does your child’s reading performance deteriorate with time?	Yes	Visual efficiency
Reading level?	More than 2 y below the grade level	Language
	Less than 2 y below the grade level	Visual efficiency
Does your child tend to avoid reading tasks?	Yes	Visual efficiency
Does your child have difficulty copying from the board?	Yes	Visual information processing
Does your child have difficulty with written work?	Yes	Visual information processing
Does your child tend to reverse or transpose letters, numbers, and words more often than expected for his/her age?	Yes	Visual information processing
Does your child have difficulty with number or letter recognition?	Yes	Visual information processing

question is whether the problem started in grades 1 to 3 or in grades 4 and above. Binocular vision, accommodative, and eye movement problems tend to interfere with the reading process when a child reaches the level at which he/she is reading in order to learn, when speed is important, when reading longer passages, and when reading smaller print. As stated earlier, this tends to occur in about the fourth grade or above.

It is also important to ask the series of question suggested in Table 22.9 to try to determine whether the reading problem is language-based or visually based. For example, children who have problems with sounding out words and phonics tend to have auditory–language problems. Reading difficulty that involves poor comprehension, low speed, fatigue with long passages, loss of place, and deterioration with smaller print is more likely to be related to visual efficiency disorders.

Finally, the clinician should enquire about any additional learning issues, such as problems with written language or copying from the board, reversals, and difficulty with letter and number recognition. Positive responses to this series of questions tend to suggest visual information processing problems.

PREVIOUS TESTING

Children with a history of reading problems would often have undergone previous testing by psychologists, special educators, speech/language pathologists, occupational therapists, neurologists, developmental pediatricians, or other physicians. Table 22.10 lists suggested areas in which to probe for information about previous testing.

The objective is to determine the nature and severity of the reading or learning disorder. Optometric intervention tends to have the maximum impact when the history indicates that there is an isolated mild to moderate reading problem that appears to be related to speed, comprehension, fatigue, and loss of place when reading. Successful treatment of the visual efficiency problem, in such cases, may lead to better comfort and elimination of fatigue and loss of place. This improved comfort and visual efficiency, along with appropriate reading remediation, will generally have a positive impact on reading performance. Other positive indications would be a normal IQ, minimal difference between the verbal IQ and performance IQ, mild to moderate delays in reading (less than 2 years), and no significant problems in any other areas listed in Table 22.10.

TABLE 22.10 CASE HISTORY: PREVIOUS TESTING

Previous vision care
History of accommodative, binocular vision, or eye movement problems
History of visual information processing problems
Neurologic
Evidence of neurologic problems
Attention problems
Psychoeducational
Full Scale IQ
Verbal Comprehension Index
Perceptual Reasoning Index
Reading, math, and spelling grade levels
Attention and concentration problems
Emotional or behavior problems
Diagnosis
Recommendations
Audiological/speech and language
Language or speech problems
Previous speech or auditory processing therapy
Occupational therapy
Fine motor problems
Posture
Muscle tone
Sensory integration disorder
History of occupational therapy
Other treatment

MEDICAL OR DEVELOPMENTAL PROBLEMS AND FAMILY HISTORY

The final area that should be addressed in the case history is the determination of whether the child has any medical or developmental problems or a family history that may affect the prognosis for treatment or whether the child may be at risk for reading or learning problems. Cotter (58) defines a “child at risk” as one who has a greater than average chance of developing a sensory–motor deficit or a mental handicap in childhood. “Risk” is not a condition per se but a particular circumstance that increases the probability that a certain disorder will occur. These factors are listed in Tables 22.11 and 22.12.

The medical history allows the opportunity to identify particular circumstances that may have contributed to the child’s learning difficulties or that currently place him/her at risk for future academic problems (58). In addition, the optometrist can use this information to help make decisions about treatment and prognosis.

It is important to understand that visual efficiency problems can generally be successfully treated in most patients, using lenses, prism, and vision therapy. Although the prognosis for successful treatment of the underlying visual efficiency problem is good to excellent in most cases, the impact of this successful treatment on school or reading performance may depend on other factors (e.g., medical or developmental issues and family history). The prognosis for improved reading performance with appropriate intervention will certainly be the best for a child with normal medical, developmental, and family history, a normal IQ, and only mild to moderate reading problems. Conversely, a child with negative factors in these areas will probably not achieve as much benefit from appropriate intervention.

The use of a parent questionnaire (Fig. 22.1) is an efficient way to gather this information. This questionnaire is filled out before the examination; therefore, the optometrist can review the responses, searching for indications of medical or developmental problems that need to be considered when developing a treatment strategy.

We have also included a case history supplement that was suggested by Borsting and Rouse (20) (Fig. 22.2). This questionnaire includes 25 questions that require a “yes” or “no” response. The following

TABLE 22.11 IS THE CHILD AT RISK FOR READING PROBLEMS?

Medical history
Pre- and perinatal health events
Problems during pregnancy
Problems during labor and delivery
Environmental issues
Age of mother
Socioeconomic level
Use of drugs, smoking during pregnancy
Childhood medical history
Infections
Meningitis
Otitis media
Metabolic disturbances
Environmental contaminants
Lead
Carbon dioxide poisoning
Hazardous medical events
Head injury
Seizures
Abuse, neglect
Developmental history
See Table 22.12
Family history
Learning/reading problems

(From Cotter S. *Optometric assessment: case history*. In: Scheiman MM, Rouse MW, eds. *Optometric management of learning-related vision problems*. St. Louis: Mosby-Year Book, 1994, with permission.)

TABLE 22.12 A SAMPLING OF DEVELOPMENTAL MILESTONES

Skill	Approximate Age
Motor milestones	
Rollover	5–6 mo
Sit up independently	6 mo
Crawling	9–13 mo
Walking independently	12–14 mo
Pedals tricycle	3 y
Walks up and down stairs (alternate feet)	4 y
Rides two-wheel bike	7 y
Fine motor developmental milestones	
Transfers objects from hand to hand	3–5 mo
Holds bottle	6 mo
Pincer grasp	10 mo
Throws objects to floor	12–15 mo
Copies a circle	3 y
Buttons clothes	3.5 y
Catches a ball	4–5 y
Ties shoelaces	5–6 y
Language: expressive and receptive milestones	
Differential crying for discomfort, pain, and hunger	1 mo
Turns head toward interesting sound	3–6 mo
Pays attention to familiar voices	3–4 mo
Babbling	5–6 mo
“Ma-ma” and “da-da” used appropriately	12 mo
Obeys simple commands	18 mo
Recognizes names of common objects	13–15 mo
Combines words; two-word sentences	2 y
Simple “kernel sentences” with subjects, verb, and object	3 y
Names all primary colors accurately	4 y
Vocabulary of 2,000 to 2,500 words; asks “why?”; defines words, counts to 10	5 y

(From Cotter S. Optometric assessment: case history. In: Scheiman MM, Rouse MW, eds. *Optometric management of learning-related vision problems*. St. Louis: Mosby-Year Book, 1994:249, with permission.)

three areas are covered: school performance (questions 1 and 2), signs and symptoms associated with visual efficiency disorders (questions 3 to 19), and signs and symptoms associated with visual information processing disorders (questions 20 to 25). The use of such a questionnaire allows the optometrist to quickly scan the responses and determine whether a visual efficiency problem should be suspected.

Treatment

OBJECTIVES OF OPTOMETRIC INTERVENTION

If evaluation reveals a reading-related visual efficiency problem, the role of the optometrist is to treat the underlying vision problem. The expectation for the intervention should be the reduction or elimination of signs and symptoms associated with the particular visual deficits (4). It is important to reiterate that optometrists do not directly treat the reading or learning problem (5). Rather, remediating these vision problems allows children and adults to benefit more fully from educational intervention (5). The expectation is that with a reduction in asthenopia and other symptoms, the child will be able to read more comfortably, more quickly, and with better comprehension. The actual effect on reading level and performance, however, depends on the nature of the reading problem and many of the associated issues discussed above.

Name: _____ **Birthdate:** _____
School: _____ **Grade:** _____
Teacher(s): _____
Parent(s): _____
Occupations: Mother: _____ **Father:** _____
Medical insurance: _____

A. Entering complaint/major concern:

- 1) Please state briefly your main concern and the main problem your child is having:

- 2) Who first noted possible visual difficulties? _____
- 3) Who referred you to our office? _____

B. Visual history

- 1) Is this your child's first visual examination? _____
- 2) If not, when was your child's last examination? _____
- Please describe any previous visual treatment your child has received, including glasses, vision therapy, patch, surgery, or medications.

- 3) Please check any of the following that you or the teacher have noticed or that your child complains about:

- | | | |
|--|---|---|
| <input type="checkbox"/> Blurred distance vision | <input type="checkbox"/> Blurred vision during reading | <input type="checkbox"/> reverses letters and numbers |
| <input type="checkbox"/> Double vision | <input type="checkbox"/> Words moving or running together | <input type="checkbox"/> mistakes words with similar beginnings |
| <input type="checkbox"/> closes one eye when reading | <input type="checkbox"/> Tilts head | <input type="checkbox"/> trouble learning basic math concepts |
| <input type="checkbox"/> Eye turns in, out, up, down | <input type="checkbox"/> Frequent headaches | <input type="checkbox"/> poor reading comprehension |
| <input type="checkbox"/> Fatigue during near visual tasks | <input type="checkbox"/> Eye strain | <input type="checkbox"/> poor recall of visually presented material |
| <input type="checkbox"/> Squints or blinks excessively | <input type="checkbox"/> Red or teary eyes | <input type="checkbox"/> trouble with spelling and sight vocabulary |
| <input type="checkbox"/> Holds book or paper too close | <input type="checkbox"/> Avoids close work | <input type="checkbox"/> sloppy writing skills |
| <input type="checkbox"/> Loss of place when reading | <input type="checkbox"/> Skips or rereads lines | <input type="checkbox"/> trouble copying from board to book |
| <input type="checkbox"/> Uses finger or underliner to read | <input type="checkbox"/> Frequent reversals | <input type="checkbox"/> erases excessively |
| <input type="checkbox"/> Poor eye-hand coordination | <input type="checkbox"/> trouble learning left from right | <input type="checkbox"/> responds better orally than in writing |

C. Educational history

- 1) Has your child repeated any grades? _____
 If yes, which one? _____
- 2) Is your child receiving any extra help in school or in any special classes? Please describe.

- 3) Have there been any evaluations (psychological, educational, speech/language, occupational therapy, neurological, medical) done at school or by school recommendation?

If yes, please state when and describe the results.

- 4) Please check if there are difficulties in any of the following areas for your child:

- | | | |
|---|---|---|
| <input type="checkbox"/> reading | <input type="checkbox"/> handwriting | <input type="checkbox"/> math |
| <input type="checkbox"/> spelling | <input type="checkbox"/> copying from the board | <input type="checkbox"/> attention span |
| <input type="checkbox"/> behavior or motivation | | |

- 5) Please check if any of the following aspects of reading are difficult or are behaviors you have noted during reading:

- | | | |
|---|---|--|
| <input type="checkbox"/> comprehension | <input type="checkbox"/> word recognition | <input type="checkbox"/> phonics |
| <input type="checkbox"/> slow reading | <input type="checkbox"/> loss of place | <input type="checkbox"/> fatigue |
| <input type="checkbox"/> uses finger | <input type="checkbox"/> avoidance | <input type="checkbox"/> comprehension declines the longer he or she reads |
| <input type="checkbox"/> my child has good comprehension when I read to him or her but has difficulty with comprehension when reading on his or her own | | |

■ **Figure 22.1** Questionnaire for parents. (Continued)

6) Do you feel your child is performing up to his or her potential in school?

7) Does your child enjoy reading for pleasure?

D. Developmental history

1) Were there any complications with pregnancy or during birth? _____

2) Was the child born prematurely? _____ If yes, how soon? _____

3) Child's birth weight: _____

4) At what age did your child begin walking unassisted? _____

5) At what age did your child begin to say 2- to 3-word phrases? _____

6) Any speech problems now or in the past? _____

7) Any problems with fine motor coordination? _____

8) Is your child clumsy or does your child have difficulty with activities requiring good balance? _____

9) Does your child enjoy and participate in activities such as drawing, coloring, puzzles, block play, etc.?

E. Medical history

1) Have there been any severe childhood illnesses, injuries, or physical impairments?

If yes, please describe _____

2) Has your child had frequent ear infections? _____ If yes, what treatments has your child undergone?

3) Any current health problems?

4) Taking any medications? _____ If yes, list drugs and doctor who prescribed them:

5) Any significant allergies? Please describe:

F. Family history

1) Does anyone in the family have any of the following?

___strabismus (crossed eyes)

___amblyopia (lazy eye)

___high nearsightedness, farsightedness, or astigmatism

___learning or reading problems

___eye disease (please list)

WOULD YOU LIKE A WRITTEN REPORT?

If you would like us to send a report of the examination, please list the names and addresses of the individuals you would like to receive this report:

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■ Figure 22.1 (Continued)

In the ideal situation, the reading problem is mild to moderate and does not involve decoding, and the child has a normal IQ, good attention span, and no emotional problems. In such cases, the prognosis for improvement in reading after vision therapy is good (Case 22.1). Very few cases are ideal, however. Most children present with one or more complicating factors that make it very difficult to predict the effect of treatment on the visual efficiency disorder. Therefore, when presenting the treatment alternatives to patients, it is important to clearly define the objectives of treatment. The treatment goal is to eliminate the underlying visual efficiency problem. The rest of the treatment is left to other professionals who are involved with the child's care and educational instruction. This may involve reading instruction, psychological counseling, speech/language therapy, occupational therapy, additional optometric intervention for visual information processing disorders, medication for attention hyperactivity deficit disorder, or any combination of these interventions (Case 22.2).

Patient Name: _____

	Yes	No	
1	—	—	School performance not up to potential.
2	—	—	Attending grade level expected for age.
3	—	—	Skips and rereads words and/or letters.
4	—	—	Complains of blurred vision during reading and writing.
5	—	—	Complains of headaches associated with visual tasks.
6	—	—	Complains of print "running together" or "jumping around."
7	—	—	Reports sensation of eyes "not working together."
8	—	—	One eye turns in or out, up or down at any time.
9	—	—	Experiences unusual fatigue after visual concentration.
10	—	—	Reports pain around or in the eye at any time.
11	—	—	Reddened eyes or lids.
12	—	—	Excessive tearing of eyes or rubs eyes frequently.
13	—	—	Blinks excessively.
14	—	—	Frowns, scowls, or squints.
15	—	—	Tilts or turns head excessively.
16	—	—	Closes or covers one eye in bright light or during visual tasks.
17	—	—	Uses finger as a marker when reading.
18	—	—	Avoids close work.
19	—	—	Holds book too closely.
20	—	—	Reversals when reading (was for saw; on for no) or writing (b for d; p for q).
21	—	—	Poor recall of visually presented materials.
22	—	—	Transposition of letters or numbers (21 for 12).
23	—	—	Poor handwriting.
24	—	—	Clumsiness.
25	—	—	Makes errors in copying from the blackboard to paper.

From Borsting E, Rouse MW. Detecting learning-related visual problems in the primary care setting. *J Am Optom Assoc* 1994; 65: 642–650, with permission.

■ **Figure 22.2** Case history supplement to the questionnaire. (From Borsting E, Rouse MW. Detecting learning-related visual problems in the primary care setting. *J Am Optom Assoc* 1994;65:642–650, with permission.)

Case 22.1 Learning-Related Visual Efficiency Problem: Therapy May Directly Improve Reading Performance

History

Paul, a 9-year-old fifth grader, was brought in for an examination because his school performance had decreased significantly during the current school year. Until the current year, he had been an average student, achieving average grades in all subjects. The specific problem revolved around Paul's inability to read comfortably and difficulty with reading comprehension. He complained that after 10 to 15 minutes of reading, his eyes felt tired and ached. He also reported occasional burning feeling in the eye. If he continued to read, he eventually experienced headaches, and finally the words would blur and seem to move on the page. Because of his inability to read comfortably, he was falling behind in his assignments and felt he had to reread passages repeatedly to understand the material. He felt that the amount of required reading had increased significantly during the year. Because he had been doing well until the current year, there was no recent reading evaluation.

His medical history was negative, and he was not taking any medication. He had passed a visual screening by his pediatrician and in school earlier in the school year. He never had a full vision evaluation.

There was no significant family history of learning problems. Both parents were college graduates with high expectations for Paul's education.

Visual Efficiency Testing: Examination Results

VA (distance, uncorrected):	OD: 20/20 -2; OS: 20/20 -2
VA (near, uncorrected):	OD: 20/20; OS: 20/20
Near point of convergence:	Penlight: 20 cm break, 30 cm recovery
Cover test (distance):	Orthophoria
Cover test (near):	10 exophoria
Subjective	OD: -0.25 DS, 20/20; OS: plano -0.25 × 90, 20/20
Distance lateral phoria:	Orthophoria
Base-in vergence (distance):	X/18/10
Base-out vergence (distance):	10/18/10
Near lateral phoria:	9 exophoria
-1.00 gradient:	7 exophoria
Base-in vergence (near):	12/22/10
Base-out vergence (near):	4/6/1
Negative relative accommodation (NRA):	+1.50
Positive relative accommodation (PRA):	-2.50
Accommodative amplitude:	OD: 13D; OS: 13D
Monocular accommodative facility (MAF):	OD: 0 cpm, fails plus; OS: 0 cpm, fails plus
Binocular accommodative facility (BAF):	0 cpm, fails plus
Monocular estimation method (MEM) retinoscopy:	OD: -0.25; OS: -0.25

Assessment and Diagnosis

The history in this case was clearly characteristic of a reading problem secondary to a visual efficiency disorder. Analysis of the optometric findings revealed a receded near point of convergence, high exophoria, a low NRA, and difficulty with plus lenses on BAF. Based on these data, we reached a diagnosis of convergence insufficiency. In addition, the patient had a low MEM finding and difficulty with plus lenses on MAF, suggestive of accommodative excess. The patient's symptoms certainly were consistent with the diagnosis, and the recent onset of reading difficulty was not unexpected. It is likely that these visual efficiency problems were present before the current school year. However, with the increased reading demands in the fifth grade—smaller print and the need to read longer passages for comprehension—the child is now symptomatic.

Treatment

We recommended in-office vision therapy based on the approach suggested in Chapter 9. Eighteen 45-minute in-office visits were necessary. After 9 weeks, Paul reported elimination of all of his initial complaints and was able to read more comfortably, faster, and with better comprehension. He did not require any other intervention.

It is important to realize that this case is an exception to the rule. In most cases, the patient presenting with reading disorders has a more significant reading problem with multiple etiologic factors. After successful treatment of the visual efficiency problems, the patient may be more comfortable when reading, but the reading dysfunction remains and requires reading remediation.

Case 22.2 Learning-Related Visual Efficiency Problem: Therapy Unlikely to Directly Improve Reading Performance

History

A psychologist who had just completed a psychoeducational evaluation referred Jimmy, an 8-year-old third grader, for a vision evaluation. Jimmy learned to speak very early and was always a very verbal child. Although his parents' expectations had been very high for him, Jimmy has had a history of school-related problems since kindergarten. In kindergarten, he experienced difficulty with letter and number recognition and fine motor coordination. He had great difficulty in first grade with handwriting and copying from the board. He reversed letters and numbers excessively and had difficulty with his sight-word vocabulary. His parents noted that when they read to him, his comprehension was excellent. Because of these reported difficulties, he was detained in first grade. Even after detention, he continued to experience problems, and his parents finally took him to a psychologist for psychoeducational testing. Jimmy claimed to be asymptomatic when reading. However, he rarely read for more than 10 minutes at a time and never read for pleasure.

The parents brought a copy of the psychoeducational evaluation report. This report indicated that there were no significant emotional issues, and the WISC-IV results included a verbal IQ of 128 and a performance IQ of 104. Jimmy scored almost 2 years behind his chronological age on the Bender Gestalt Test, which is a test of visual-motor integration. Auditory processing and language skills were strengths for Jimmy.

Achievement testing was also done as part of the psychoeducational testing. This testing suggested a 1.5-year lag in reading, with weaknesses in sight-word vocabulary, comprehension, and age- or grade-appropriate math skills. In her summary, the psychologist reached a diagnosis of a learning disability with primary weaknesses in visual processing and strengths in language function. She recommended part-time placement in a resource room and tutoring in reading. In addition, she suggested a comprehensive optometric evaluation.

Jimmy's medical history revealed a normal pregnancy, but a very long and difficult labor and delivery by cesarean section. Otherwise, there was no significant medical history. Developmental milestones showed a variable pattern. Language skills developed faster than average. For instance, Jimmy used two-word sentences by 18 months of age and was always a very verbal child. Fine motor skills, however, developed more slowly than expected. He always had difficulty holding a crayon and did not enjoy coloring or playing with puzzles. He could not copy a circle until about 4 years of age.

There did not seem to be any family history of learning problems, and there had been no other testing.

Visual Efficiency Testing: Examination Results

VA (distance, uncorrected):	OD: 20/20 -2; OS: 20/20 -2
VA (near, uncorrected):	OD: 20/20; OS: 20/20
Near point of convergence:	Penlight: 2.5 cm break, 5 cm recovery
Cover test (distance):	4 esophoria
Cover test (near):	8 esophoria
Subjective:	OD: +1.25, 20/20; OS: +1.25, 20/20
Distance lateral phoria:	Orthophoria

Base-in vergence (distance):	X/7/4
Base-out vergence (distance):	10/16/10
Near lateral phoria:	2 esophoria
–1.00 gradient:	14 esophoria
Base-in vergence (near):	8/12/8
Base-out vergence (near):	14/25/14
NRA:	+2.50
PRA:	–2.00
Accommodative amplitude:	OD: 12D; OS: 12D
MAF:	OD: 10 cpm; OS: 10 cpm
BAF:	0 cpm, diplopia with –2.00
MEM retinoscopy:	OD: +0.75; OS: +0.75
Developmental eye movement (DEM) test:	Fifteenth percentile (errors)
	Fifteenth percentile (ratio)

Assessment and Diagnosis

The optometric evaluation revealed hyperopia and greater esophoria at near, with low direct and indirect negative fusional vergence findings, supporting a diagnosis of hyperopia and convergence excess. Based on the findings from the DEM test, we also reached a diagnosis of ocular motor dysfunction. In contrast to Case 22.1, these findings, although clinically significant, did not adequately explain many of the signs and symptoms experienced by this child. Many of these signs and symptoms were more likely to be related to a visual information processing disorder.

Treatment Plan

We recommended eyeglasses for school and all reading and homework (OD +1.25 and OS +1.25). In addition, we recommended a visual information processing evaluation. This testing revealed significant problems in visual–spatial tasks, visual analysis, and visual–motor integration skills. We recommended in-office vision therapy to treat the eye movement disorder and visual information processing problems.

Jimmy required forty-two 45-minute in-office visits. In addition, a considerable amount of therapy was done at home. He was seen twice a week for about 6 months. A reevaluation at that point revealed significant improvements in both the error and ratio scores on the DEM test and in visual information processing skills. Jimmy also received help at school and had private tutoring in reading. During the active vision therapy, we asked the teachers to temporarily de-emphasize written work, particularly copying from the board.

During 6 months of combined educational and optometric intervention, Jimmy made outstanding progress. At completion of therapy, he found it easier to express his thoughts in writing, copying from the board was considerably better, and he was no longer reversing excessively. His reading level increased by about 18 months, and he was no longer as frustrated in school as he was before the treatment. We dismissed him from vision therapy, and he continued to receive help at school and from his private reading tutor.

This case illustrates a more common presentation in which the learning problems are more complicated and in which both visual efficiency and visual information processing problems are present. In such cases, although it is important to treat the visual efficiency problems, it is also important to make sure that a visual information processing examination is performed and that appropriate educational remediation takes place.

SEQUENTIAL TREATMENT APPROACH FOR READING-RELATED VISUAL EFFICIENCY PROBLEMS

The sequential treatment approach adopted will depend on the specific diagnosis. We recommend the specific sequences described earlier in the book for the various binocular vision, accommodative, and eye movement disorders. The one additional issue that must be considered when dealing with reading-related visual efficiency disorders is comanagement with other professionals.

ROLE WITH EDUCATORS

Hoffman (5) discusses two important responsibilities of the optometrist when working with educators. The first is to provide general information related to the effect of vision disorders on learning; the second is to provide specific information about the vision disorders of the educator's student. This might include the suspected relationship of vision disorders with the child's symptoms and signs, the recommended treatment, and the estimated length of treatment. Optometrists should also make recommendations for classroom accommodations that the educator can make in the short term until the vision problem is resolved. Typical classroom accommodations would include large-print materials, line markers, shortened time on tasks, and extended time for written tests.

ROLE WITH OTHER PROFESSIONALS

In many cases, the patient will have been referred by another professional to rule out a vision problem that could be interfering with learning. In such cases, it is important for the optometrist to provide a written report that summarizes the evaluation results and recommendations, and offers suggestions for classroom management. If vision therapy is recommended, it is also important for the optometrist to coordinate the treatment with any other treatment that the patient is receiving.

In some cases, the optometrist may see children who are struggling with reading before any other professional is consulted about their reading problems. In such cases, it is particularly important to determine the nature of the reading dysfunction. If the reading problem appears to be moderate to severe, or language based, or if the child is difficult to examine because of attention and concentration issues, a referral for psychoeducational testing would be warranted. It is the role of the optometrist to counsel the child and his/her parents about the objectives and importance of such testing and to encourage the family to request the testing from the child's school or through a private psychologist.

Summary

Management of reading-related visual efficiency problems is one of the more challenging aspects of optometric care. In addition to being able to diagnose and treat visual efficiency problems, the optometrist must be knowledgeable about reading dysfunction, the relationship between vision problems and reading dysfunction, and psychoeducational testing. An understanding of these issues allows the optometrist to ask appropriate questions during the case history interview, relate test findings to presenting complaints, and make appropriate management decisions.

The other important issue emphasized in this chapter is that optometrists do not treat learning or reading problems. Rather, their primary role is the diagnosis and treatment of vision problems that may interfere with school performance. The expectation is that with a reduction in asthenopia and other symptoms, the patient will be able to read more comfortably, more quickly, and with better comprehension. Thus, remediating these vision problems allows children and adults to benefit more fully from psychoeducational intervention.

Study Questions

1. An optometrist is treating a child with reading-related visual efficiency problems and tells the parents and teacher that he expects the child's reading skills to improve significantly after vision therapy and that no additional intervention should be necessary. State whether you agree or disagree with this statement and explain your reasoning.

2. What aspects of vision should be evaluated when a child presents with a reading-related vision problem?
3. Describe two differences between nonspecific reading dysfunction and dyslexia.
4. Describe three different forms of dyslexia.
5. List five questions that you could ask during the case history interview that would help determine whether the reading problem is related to visual efficiency problems.
6. Explain the concepts “learning to read” versus “reading to learn” and describe how an optometrist would use these concepts in practice.
7. A parent asks you about the effectiveness of colored filters for reading dysfunction. What would your response be?
8. Describe what you would expect to find when reading the results of the IQ test from a psychoeducational report for a child with a significant language problem. What would you expect if there was a problem with visual processing?
9. List the components of the psychoeducational evaluation and describe the significance of each component for an optometrist.
10. List five factors that may place a child at risk for reading or learning problems.

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Development and Management of Refractive Error: Binocular Vision-based Treatment

There is substantial variation in the refractive state (RS) at birth (1); yet, most people become nearly emmetropic, essentially needing no correction, by age 5 (2). In the ensuing years more than 30% become myopic at some point, and the majority of those who do not become myopic develop hyperopia during their presbyopic years. In addition to increased knowledge of the genetic profiles underlying RS development, knowledge of anomalous RS development and its subsequent treatment will likely be improved through understanding of:

- The relationships between the ocular components that make up the RS and how changes in these components influence the ability to maintain a stable RS
- The effects of unilateral and bilateral blur on the RS
- How the interactions between vergence (both eyes) and accommodation (in each eye) influence changes in the RS

This chapter discusses development and maintenance of a stable RS using a conceptual model of emmetropization. It also presents a sequential management approach to RS treatments that incorporates a binocular vision-based approach.*

Binocular Vision-based Refractive Development

Early visually driven models of emmetropization considered accommodation to be an important aspect of emmetropization. However, these models failed to account for the fact that most objects are closer than infinity and therefore provide an effective stimulus for accommodation. If accommodation is so influential in development of the final RS, why doesn't everyone become or remain myopic? It has become increasingly evident that significant factors in emmetropization include the influence of genetically programmed ocular growth on the refractive state, the role of peripheral retinal defocus on ocular growth, and the fact that neither the fovea nor the ability to accommodate accurately is well developed at birth.

ACCOMMODATION AND THE SOURCE OF BLURRED IMAGES

Carroll (3) and Schor (4) described the dual interactive model of accommodation and vergence portrayed in Figure 23.1. There are mutual interactions and feed-forward crosslinks between the accommodative and vergence motor control systems. The feed-forward crosslinks are accommodative convergence (AC/A) and convergence accommodation (CA/C). Tonic vergence (vergence adaptation) occurs after the CA/C crosslink and feeds forward into the convergence system, because vergence adaptation does not affect dark focus (5). Vergence adaptation relieves the fusional vergence controller effort and reduces convergence accommodation, decreasing the exaggerated effects of sustained vergence on the AC/A ratio (6). These effects cause excessive accommodation convergence interaction to be transient because they are relieved by vergence adaptation within 15 seconds (7). The knowledge of stimulus location (proximal input) increases vergence and

* (Much of this chapter is based on papers originally published in the *Journal of Optometric Visual Development* in Spring, Summer, and Fall 2000. Portions of the text and most of the figures are reprinted with the kind permission of the College of Optometrists in Vision Development.)

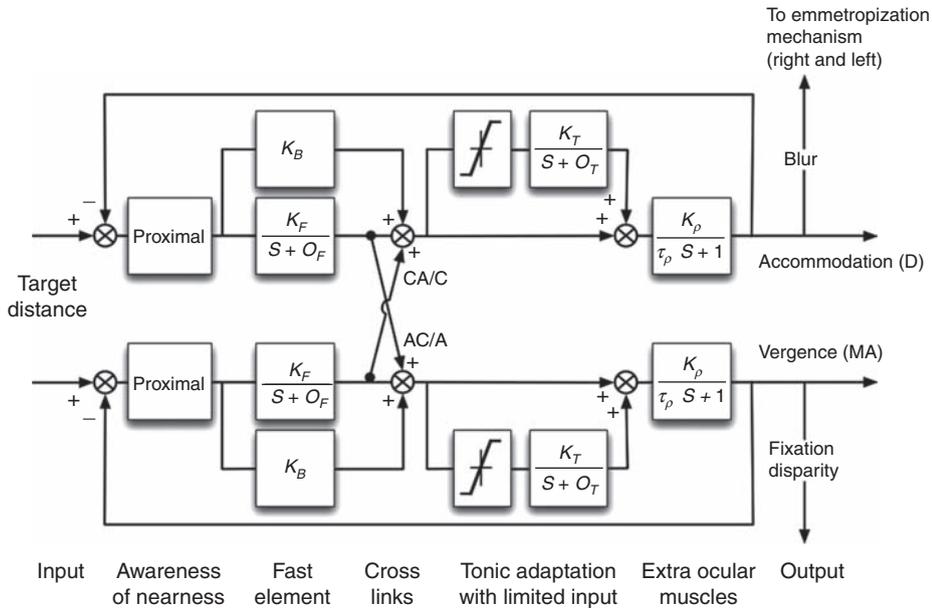


Figure 23.1 In the dual interactive model of accommodation and vergence, there are mutual interactions and feed-forward crosslinks between the accommodative (AC/A) and vergence (CA/C) motor control systems. Vergence adaptation occurs after the CA/C crosslink and feeds forward into the convergence system. Vergence adaptation relieves the fusional vergence controller effort and reduces convergence accommodation, decreasing the exaggerated effects of sustained vergence on the AC/A ratio within 15 seconds. Knowledge of stimulus location (proximal input) increases vergence and accommodative response as well as the CA/C and AC/A ratios.

accommodative response. These effects occur prior to the feed-forward crosslinks as proximal effects increase both the CA/C and the AC/A ratios (8).

The relation between the accommodative stimulus and accommodative response is represented by the accommodation stimulus–response curve (Fig. 23.2). This relation may be modified by factors such as target color (9), luminance (10), spatial frequency content (11), and the age of the person (12). However, in general

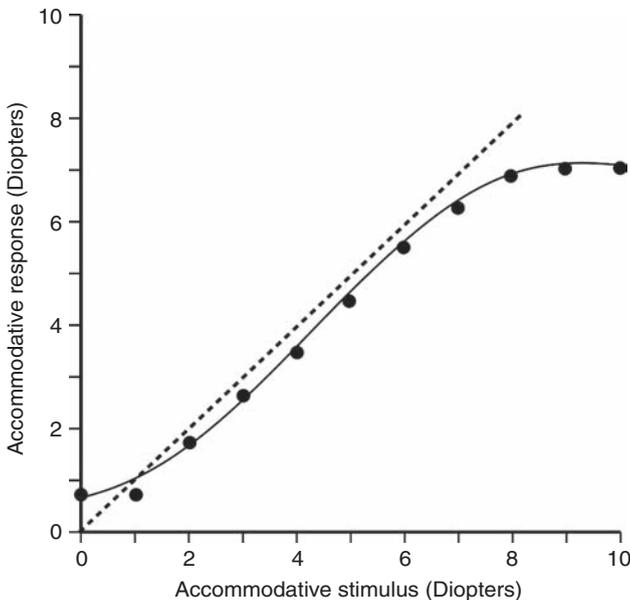


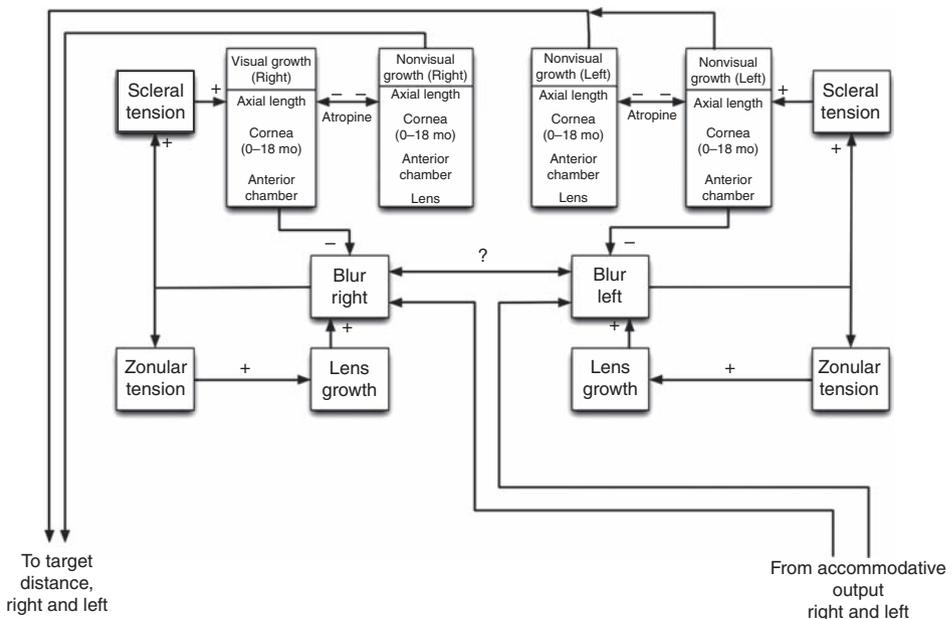
Figure 23.2 The relation between the accommodative stimulus and accommodative response is represented by the accommodation stimulus–response curve, which exhibits a “lead” of accommodation (relative myopia) for distance targets and an increasing “lag” (relative hyperopia) for near targets. This relation may be modified by factors such as target color, luminance, spatial frequency content, and age of the viewer.

there is a “lead” of accommodation (relative myopia) for distance targets and an increasing “lag” (relative hyperopia) for near targets. Thus, near objects make the eye effectively hyperopic, which stimulates an accommodative response that tends to refocus the image. However, proportional controller–based negative feedback systems do not completely nullify the error signal. For example, an object at 40 cm (a 2.5 D stimulus) typically results in approximately 2.0 D of accommodation, and a lag of accommodation of 0.5 D ensues (an error signal of 0.5 D, which is a steady-state effective hyperopia). This error is typically not perceived as blur because it is within the depth of focus of the eye.

A Conceptual Model

A conceptual model can be designed that takes the form of dual intersecting feedback loops in which genetically programmed ocular growth of each eye is altered by blur derived from peripheral retina defocus and interactions between accommodation and vergence (Fig. 23.3). The blur magnitude output of the accommodative system is input into the visual growth mechanism as precise focus of the central and, especially, the peripheral, retinal images, rather than as accommodation, and is hypothesized to alter the genetically programmed ocular growth. In the visual growth mechanism, continued relative hyperopic blur (e.g., from the lag of accommodation at near and the relative peripheral retinal defocus) increases scleral elasticity and promotes axial elongation; lens growth is retarded by concurrent reduction in zonular tension. The resulting reduction in lens thickness (with an increase in power) and the increased axial length decrease the accommodative demand associated with near visual tasks. The visual growth then feeds into and combines with the genetically programmed ocular growth to result in the final RS.

Two crosslinks are present. The potential influence of suppression on the response of the RS to blur is indicated by the crosslink between the blur mechanisms. Pharmacologic (e.g., atropine) effects are shown by the crosslink between visual and genetically programmed growth. Atropinization blocks development of



■ **Figure 23.3** A conceptual model takes the form of dual intersecting feedback loops in which genetically programmed ocular growth of each eye is altered by blur derived from interactions between accommodation and vergence. The potential influence of suppression on the response of the refractive state (RS) to blur is indicated by the crosslink between the blur mechanisms. In the visual growth mechanism, continued relative hyperopic blur (e.g., lag of accommodation at near) increases scleral tension and promotes axial elongation; lens growth is retarded by concurrent reduction in zonular tension. The resulting reduction in lens thickness (with an increase in power) and the increased axial length decrease the accommodative demand associated with near visual tasks. Visual growth feeds into and combines with genetically programmed ocular growth to result in the final RS.

axial growth in the presence of lid-suture myopia (13). This result seems contradictory, since atropine clearly paralyzes accommodation. However, it is also known that chronic use of atropine produces alterations in the retinal vasculature of developing kittens (14). Atropine also causes an increase in the number of ciliary zonules, along with a concurrent increase in the number of elastic-fiber myofibrils (13). Thus, it is likely that it is not blockage of accommodation per se but rather the other pharmacologic consequences of atropine use that result in decreases in the axial growth rate.

The following sections present and describe the implications of three propositions regarding how the genetically programmed ocular growth of each eye might be altered by blur derived from peripheral retinal defocus along with that resulting from interactions between accommodation and vergence.

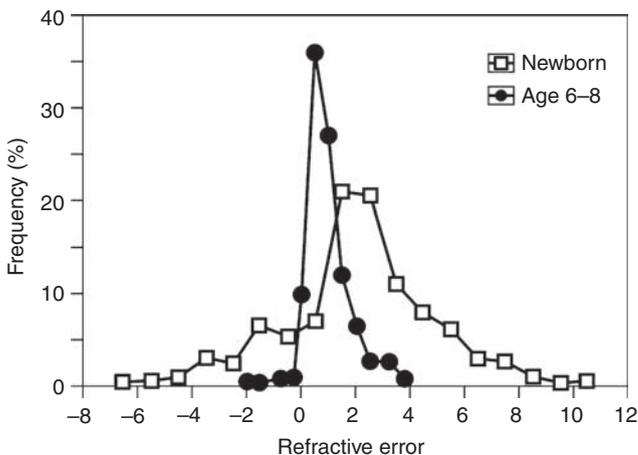
- *Proposition I:* The RS that ultimately develops is a result of genetically programmed ocular growth modified by visually driven ocular growth. (Implied in this proposition is that, rather than occurring separately, the two kinds of growth occur in tandem.)
- *Proposition II:* Genetically programmed (nonvisual) ocular growth, which is typically the same in both eyes, decreases in rate with age and ceases at about age 14 to 16 (although there is individual variation in both the overall pace of growth and the age of termination).
- *Proposition III:* Visually driven ocular growth, which results from the time-average retinal blur derived through interactions between accommodation and convergence and the stimuli to ocular growth from relative peripheral retinal image defocus, decreases to its minimum magnitude by about age 21 and may not be bilaterally symmetrical.
- *Corollary:* Visually driven ocular growth is altered by changes in refractive correction because the input from the blur-driven feedback system is modified by the intervention, essentially reinitiating the blur-driven visual growth process with each new correction.

THE REFRACTIVE STATE: DISTRIBUTION OF REFRACTIVE ERROR AND ITS COMPONENTS

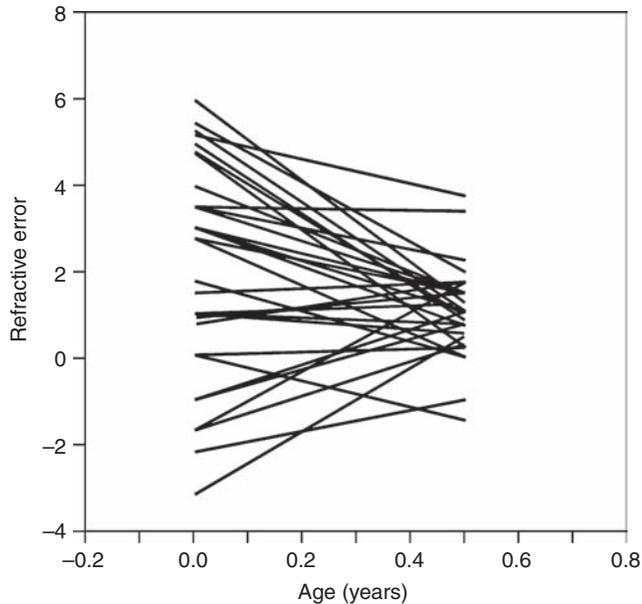
The RS at birth averages to about 2 D of hyperopia and has a roughly normal distribution (1) (Fig. 23.4). As the eye rapidly grows over the next few months, there is a substantial and rapid change in the RS toward emmetropia (15) (Fig. 23.5). The decrease in both myopic and hyperopic RS results in a more peaked (leptokurtotic) distribution, with a corresponding decrease in the standard deviation of the RS in the population by age 6 (2) (Fig. 23.4).

GROWTH OF OCULAR COMPONENTS

The shift from the large variation in RS seen in infancy to the nearly emmetropic state normally found in adults has been attributed to coordinated growth of the ocular components. For example, Sorsby et al. (16) developed the concept that decrease in the magnitude and standard deviation of the RS in the population involves the correlated growth of four ocular components: axial length, corneal power, crystalline lens power,



■ **Figure 23.4** Distribution of refractive error. The refractive state at birth averages to about 2 D of hyperopia and has a roughly normal distribution, but by age 5 most people have become nearly emmetropic.



■ **Figure 23.5** As the eye rapidly grows over the first 6 months of life, there is a substantial and rapid modification of the refractive state (RS). The decrease in both myopic and hyperopic RS results in a more peaked (leptokurtotic) distribution, with a corresponding decrease in the standard deviation of the RS in the population.

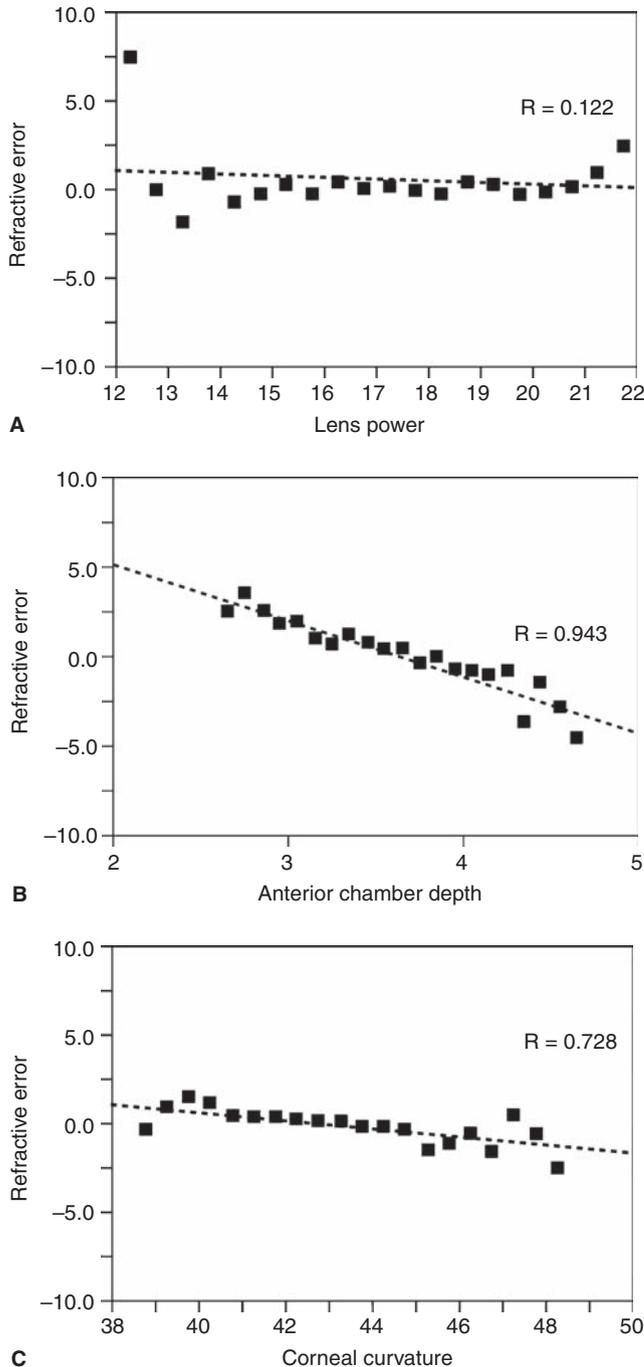
and anterior chamber depth. A high correlation produces emmetropia, whereas failure of correlated growth produces ametropia. During the first year of life, there is lesser variability in the axial length as infant eyes undergo rapid growth from an average of about 17 mm to slightly more than 19 mm (17) while the corneal power decreases from 50 D to 43 D (18). Hofstetter (19) suggested that development of a leptokurtotic distribution of the RS, often described as emmetropization (20), was a mathematical artifact because a given eye can be emmetropic regardless of its size, provided that growth occurs in a manner that allows proportionate increases of the radii of the cornea and axial dimensions. Unfortunately, the human eye does not grow in such a manner (see below), calling this suggestion into question.

From ages 1 to 8 years, axial length continues to increase to the adult value of about 24 mm with little change in the RS (21). This increased axial length, which could result in up to 15 D of myopia, must be largely negated by flattening of the lens (and deepening of the anterior chamber), since corneal power reaches approximately the adult values prior to the age of 2 years. Thus, it is difficult to totally attribute maintained emmetropia to correlated growth because only the axial dimensions of the eye and the power of the crystalline lens seem to be correlated in their changes during early childhood. Indeed, a substantial amount of basic (animal) research suggests that visual feedback contributes to the RS developed from infancy (see, for example, Ni and Smith (22)).

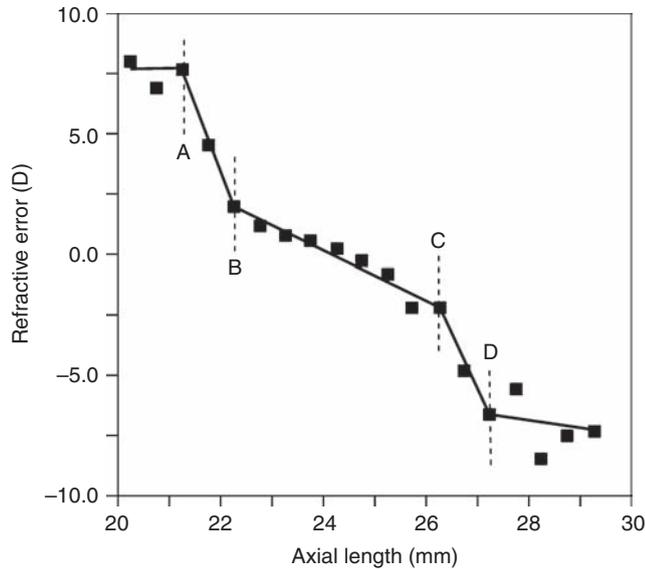
Variations in ocular development can be inferred from the clinical differences seen in the RS. For example, 2% to 5% of infants begin life with, and maintain, significant myopia or hyperopia (16). These children suffer from substantially different ocular development from the up to 50% of children who become emmetropic only to subsequently become myopic during grade or middle school years. The infant with a high myopia or hyperopia typically has a very long or very short vitreous chamber, respectively—what Sorsby et al. (16) considered an uncorrelated eye. Children who become myopic in grade school seldom acquire more than 6 to 8 D of myopia; these children also seem to differ substantially in ocular development from young adults who develop myopia after 16 to 20 years of emmetropia (so-called *late-onset myopia*).

Van Alphen (23) suggests that grade school children may develop myopia when the cortico-subcortical control of tonus to the ciliary muscle is disrupted, either by ocular (cornea, optic nerve, or brain) or by non-ocular factors (extreme autonomic endowment, psychological factors, and stress). Adult-onset myopia seems to develop in association with substantial amounts of near work (24) and changes in certain underlying physiologic factors (25). In any event, all classes of myopia typically share a common structural correlate, namely, increased axial length when compared to emmetropic eyes (26).

By the time we reach age 20, variations in lens power are unrelated to the RS (Fig. 23.6A) (27–32). Anterior chamber depth and corneal curvature are linearly related to the RS (Fig. 23.6B,C), and variations in axial length have a complex relation to the RS (33). Figure 23.7 relates axial length to RS for adults aged 20 to 35 years, and indicates that for subjects who are nearly emmetropic (RS between +0.75 and -0.25) there can be substantial variation in axial length. The slopes of the relation between the RS



■ **Figure 23.6** By the time we reach age 20, variations in lens power (**A**) are unrelated to the refractive state. Anterior chamber depth (**B**) and corneal curvature (**C**) are linearly related to the refractive state. Data from Stenstrom ($N = 1,000$) (27–32).



■ **Figure 23.7** Variations in axial length have a complex relation to the refractive state. Three of the four visible breaks in the data (labeled A through D) are statistically significant by one-way ANOVA polynomial regression testing (B, C, and D; $df = 1$, $F = 12.61$, $P = 0.0004$). The available data are insufficient to adequately test for the significance of visible break A. The slopes of the relation between the refractive state and axial length are statistically different for nearly emmetropic patients (slope B–C) and those having 2 to 7 D of hyperopia (slope A–B) or 1 to 6 D of myopia (slope C–D) ($F = 10.91$; $P = 0.0052$). Data from Stenstrom ($N = 1,000$) (27–32).

and axial length are statistically different for subjects with RS between +1.75 and –1.75 (slope B–C) and those having 2 to 6 D hyperopia (slope A–B) or 2 to 7 D of myopia (slope C–D) ($F = 10.91$; $P = 0.0052$). For patients with very high hyperopia (>6 D) or myopia (>7 D), it again appears that substantial variation in axial length coexists with a similarly large RS, although there are not enough data for accurate statistical analysis.

Accepting the implications of Proposition I (i.e., the RS that ultimately develops is a result of genetically programmed ocular growth modified by visually driven ocular growth), the large variation in axial length with a near emmetropic RS would be due to a physiologic balance between visually directed and genetically programmed ocular growth. In this view, patients with a very high RS are probably born with an RS so large that the visually directed mechanism is unable to sufficiently influence genetically programmed growth, and they remain with the abnormal RS throughout life. Further, the similarity in the slope of the relation between axial length and the RS for moderate hyperopia (2–6 D) and myopia (2–7 D) (Fig. 23.7, slope A–B and slope C–D) suggests that these forms of RS result from comparable breakdowns in the ocular growth mechanisms. For example, a moderate strength genetically programmed ocular growth might be overwhelmed by visually directed growth and lead to moderate myopia. Conversely, if very weak genetically programmed ocular growth is present, correspondingly weak visually directed growth might be insufficient to achieve more than moderate hyperopia.* The slopes of the relation between axial length and the RS in moderate hyperopia and myopia (Fig. 23.7, slope C–D and slope A–B) are not statistically different ($F = 0.62$; $P = 0.44$), lending additional support to the idea of a mismatch in visually directed growth and genetically programmed ocular growth contributing to these refractive states. Two other possibilities may contribute to moderate myopia (34):

1. Some eyes may inexorably continue to grow once started.
2. Initial growth may sufficiently stretch the choroidal/scleral collagen to facilitate subsequent growth.

* The reference here is not to recessive and dominant genes, because RS is likely to be polygressive in genetic nature, but rather to the relative strength of the genetically programmed ocular growth. Thus, all other factors being equal, strong genetically programmed growth and/or strong visually directed growth would likely lead to myopia, whereas weak genetically programmed and/or visually directed growth would lead to maintenance or development of hyperopia.

GENETICALLY PROGRAMMED OCULAR GROWTH

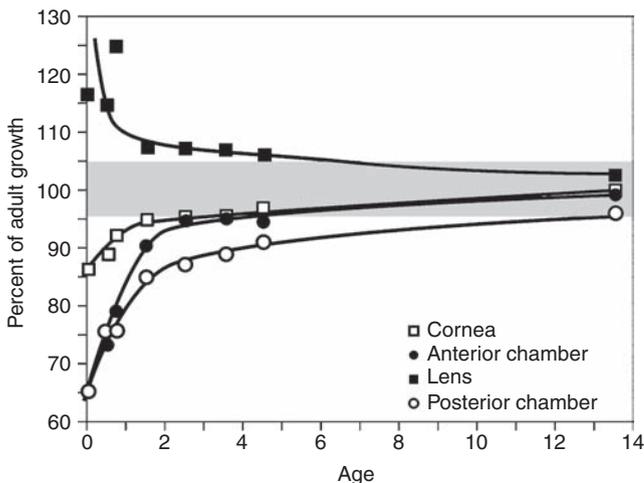
Genetically programmed (nonvisual) ocular growth accounts for the clinical finding that 2% to 5% of infants begin life with, and maintain, significant refractive error; their eyes obviously grow in size during life but fail to emmetropize. In addition, substantial genetically programmed ocular growth occurs for human eyes at two different times of life—infancy, where there is rapid growth that brings the anterior segment of the eye up to almost adult size and functional power by age 3 years (35), and childhood, where there is slower definitive growth between ages 3 to 14 years during which time the RS for the most part remains stable and change in power derived through axial elongation is mainly negated by flattening of the crystalline lens and deepening of the anterior chamber (36). This latter growth may also have hereditary influences, explaining why myopia tends to “run in families” (37) and often manifests at similar ages from generation to generation (37–39).

Relative Strength of Genetically Programmed Ocular Growth: Axial Length to Corneal Radius Ratio

The concept of genetically programmed ocular growth might allow prediction of who will become myopic, at what age myopia might occur, and how much myopia might result, if an estimation of the relative strength of genetically programmed ocular growth could be developed. The axial length to corneal radius (AL/CR) ratio is usually very close to 3.0:1. There have been clinical suggestions that when the ratio is higher than 3.0:1 emmetropic subjects are at risk for development of myopia (40–42). The usefulness of the AL/CR ratio owes to the fact that relative timing of the growth of the components of the eye varies substantially. For example, based on data from York and Mandell (18), the cornea reaches 95% of its adult curvature before age 2, and Larsen (35) found a similar result for the depth of the anterior chamber (Fig. 23.8). However, lens thickness and axial length continue their growth for a substantially longer time and are not within 5% of adult growth until ages 6 and 11 years, respectively (Fig. 23.8) (35,43,44).

Proposition I implies that the final RS is achieved through a balance between genetically programmed and visually driven ocular growth. In the case of a person who might develop myopia, for example, corneal growth and changes in anterior chamber depth typically cease at about age 2. If emmetropia is to be maintained, a continued increase in axial length must be compensated for by a corresponding decrease in lens power (Fig. 23.9A). If axial growth continues, it will eventually reach a point at which the other ocular components can no longer compensate for the continued growth. Thus, the AL/CR ratio is of clinical predictive value because it provides an estimation of when the point has been reached beyond which further axial growth cannot be compensated by other ocular components (e.g., relative lenticular thinning; Fig. 23.9A, arrow).

Considering the AL/CR ratio, Proposition II (i.e., genetically programmed [nonvisual] ocular growth, which is typically the same in both eyes, decreases in rate with age and ceases at about age 14) suggests that the strength of genetically programmed growth is indicated by values significantly higher or lower than 3.0 (45). Clinical



■ **Figure 23.8** Growth of ocular components. The cornea and anterior chamber reach 95% of their adult curvature before age 2. Lens thickness and axial length continue their growth for a substantially longer time and do not reach 95% of adult growth until ages 6 and 11, respectively.

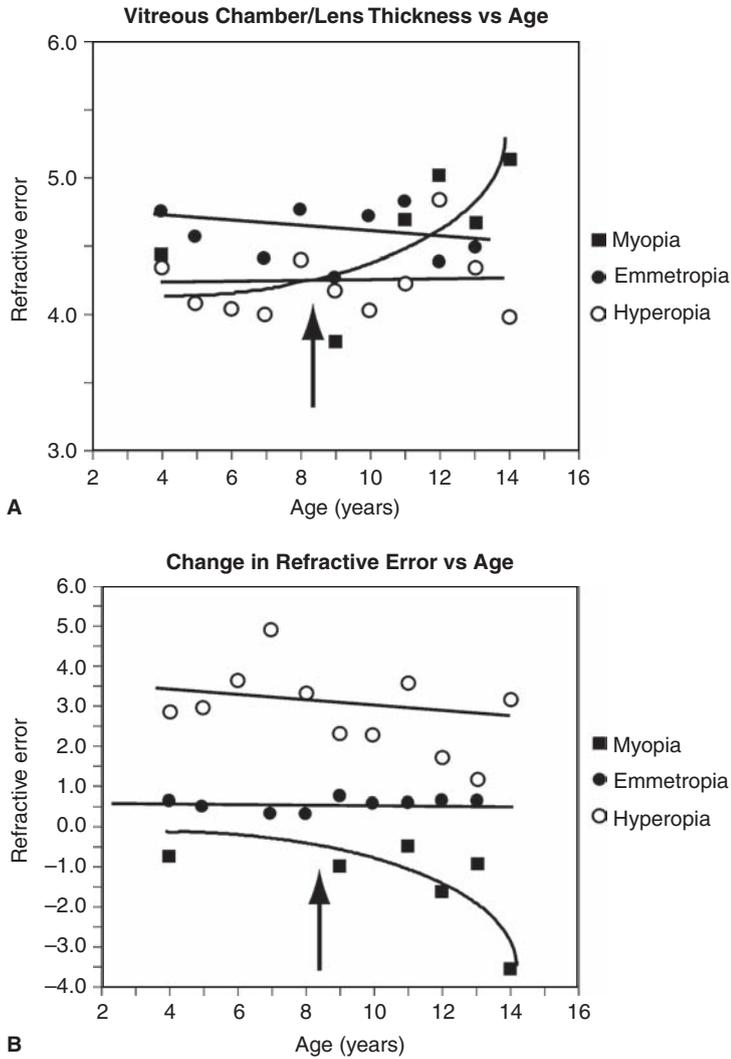


Figure 23.9 A: The ratio of vitreous chamber depth to lens thickness is higher in patients with moderate myopia than in those with emmetropia or hyperopia. Further, the axial length to corneal radius (AL/CR) ratio is higher than 3.0 for these patients (arrow), suggesting that high values of AL/CR ratio signal development of myopia. **B:** The age at which the AL/CR ratio becomes higher than 3.0 and the age at which development of myopia occurs are about the same, again suggesting a strong relation between these two occurrences.

measurement of the axial length and corneal radius could allow clinical RS predictions. For emmetropic children, a high AL/CR value indicates that visually driven growth may be about to overwhelm genetically programmed growth and that myopia development is impending (Fig. 23.9B, arrow). For emmetropic adults, a high value indicates that the maximum axial length that can sustain emmetropia has been achieved and that further visually directed axial growth will lead to (late-onset) myopia. Thus, clinical measurement of the axial length and corneal radius might allow determination of whether and when to consider intervention to maintain a desired RS.

Heredity

An additional clue to a strong genetically programmed growth is the relation seen between parental myopia and the development of myopia in children (46–48). Table 23.1 presents the incidence of childhood myopia based on the presence of myopia in the parents (49). This apparent hereditary influence would suggest that the parents pass along a strong genetically programmed ocular growth tendency (although it could also be that they foster a “reading environment”), which in some cases may be overcome by visually driven growth, explaining why not all children of myopic parents develop myopia.

TABLE 23.1 INCIDENCE OF CHILDHOOD MYOPIA BASED ON PARENTAL MYOPIA

Number of Myopic Parents	Incidence (%)	Odds Increase
2	12	4×
1	8	2.67×
0	3	—

In infants, growth toward an emmetropic RS occurs rapidly, whereas changes away from this normal condition occur much more slowly during childhood or adulthood. Evidence from basic research suggests that a genetically programmed growth mechanism assists in maintaining the ocular shape (50). According to Proposition I, the visual mechanism adds to the genetically programmed mechanism, resulting in rapid attainment of normal eye proportions in infants who emmetropize. If this is correct, in adults only the blur-driven (i.e., visual) mechanism would remain (because genetically programmed growth would be complete at about age 14), resulting in a more stable and less malleable RS. In this manner, visually directed growth modifies genetically programmed ocular growth (as described below); it is this visually driven emmetropization that forms the basis for subsequent sections of this chapter.

VISUALLY DRIVEN GROWTH

Accepting Proposition III (i.e., visually driven ocular growth, which results from the time-average retinal blur derived through interactions between accommodation and convergence and the stimuli to ocular growth from relative peripheral retinal image defocus, decreases to its minimum magnitude by about age 21), growth of each eye is stimulated by blur that is derived from visual stimuli (especially relative peripheral hyperopic retinal defocus). Small amounts of sustained peripheral retinal blur promote axial elongation, presumably by increasing scleral tension, and retard lens growth by reducing zonular tension (51). Both the resulting axial elongation and reduction in lens thickness, with correspondingly increasing lens power through increased refractive index (52), decrease the blur associated with a given visual task. Based on the growth rate observed for ocular components (Fig. 23.8), most of the changes induced by visual growth affect the axial length and lens power. To a lesser extent anterior chamber depth and corneal shape may also be influenced, especially in infants and younger children.

Blur versus Accommodation

Proposition III suggests that sustained peripheral and, to a lesser extent, central retinal blur, and not accommodation, is the stimulus to ocular axial growth. This conclusion is supported by the results of research on infant monkeys in which blurred peripheral images cause the infant eye to become either hyperopic or myopic, depending on the type of blur induced (53,54). Accommodation might be hypothesized to be the stimulus for development of myopia when a minus lens is placed before an infant eye and there is a resulting increase in axial length (a relative decrease in hyperopia or increase in myopia) concurrent with the stimulus to accommodation caused by the lens. However, accommodative change is less likely to be helpful in clearing a blurred image caused by a plus lens that artificially induces myopia and a hyperopic growth shift. In addition, eyes that have been rendered surgically aphakic ultimately develop shorter axial lengths and relative hyperopia (55) as compared with fellow untreated (noncataract) eyes, hardly an accommodation-related change given the induced aphakic state. Further, stimulation of accommodation by parasympathomimetic agents (e.g., pilocarpine) during development does not facilitate development of lid-suture myopia (56). Also, overcorrection of myopia in childhood does not appear to increase the rate of progression (57). Finally, Zadnik (58) demonstrated that diopter-hours of near work do not significantly influence developing myopic RS. Taken together, these studies lend strong support to the hypothesis that sustained blur of the retinal images is the primary stimulus to visually driven emmetropization, rather than accommodation (or diopter-hours of near work) per se.

According to Proposition III, the lead of accommodation from distance fixation results in an effective myopia at distance and a stimulus for the eye to slow or cease growth, whereas the lag of accommodation for near and relative hyperopic peripheral retinal defocus result in an effective hyperopia at near and a stimulus for the eye to increase growth. As a result of these two conflicting growth signals, genetically programmed ocular growth is altered by visual growth as the eye fine-tunes its focus for the visual environment.

THE RELATIVE STRENGTHS OF THE GENETICALLY PROGRAMMED GROWTH AND OCULAR GROWTH MECHANISMS

The data portrayed in Figure 23.8 for the growth of ocular parameters (Larson's data (35,43,44)) and Sorsby's data for myopic patients (16,59,60) are essentially exponential decay curves. Thus, genetically programmed growth and visual growth have a combined growth curve that takes the mathematical form of an exponential decay curve, consistent with Goss's (61) observation that myopic refractive changes of children are essentially linear during times of rapid RS change.

RATE OF REFRACTIVE CHANGE

Myopia

Data from Kent (62) indicate that the average change in RS for adults who develop myopia is about 0.112 D per year. Based on Propositions I and II, change in the RS of adults must be due solely to influences of visually driven ocular growth, because genetically programmed ocular growth ceases at about age 14 years (35). According to Proposition I, both the genetically programmed and the visually driven ocular growth contribute to the changes in RS seen up to age 14. Typical RS changes average from 0.4 D (63) to 0.5 D (64) per year for children developing myopia, with standard deviations of about 0.3 D. (Larson's data (44) for changes in axial length yield similar numbers of 0.53 D per year.) Smith (65) described infant monkey experiments that suggest that the growth rate of infant eyes stimulated by progressive changes in lens correction is around 3 D per year (based in terms of human years). These values are useful in that changes substantially outside of these amounts (e.g., a 1.0 D per year increase in myopia for children between ages 6 and 14 years) might signal a need for more aggressive treatment.

Hyperopia

For hyperopic patients, a similar relation can be developed. The infant hyperopic RS decreases at a rate similar to that of the infant myopic RS (2) (Fig. 23.5). However, hyperopia present after age 3 seldom decreases substantially, which may be attributed to a reduced combined rate of visual and genetic growth (and perhaps the influence of refractive correction—see below).

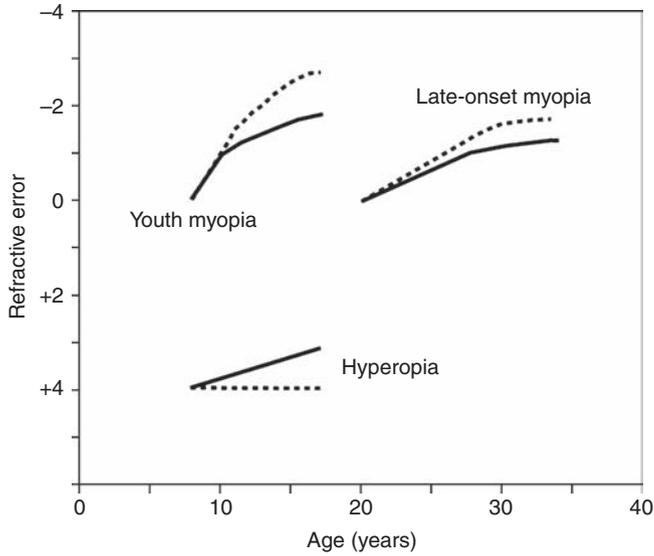
The Effect of Lenses

According to the corollary to Proposition III, wearing a lens correction changes the RS development because the blur signal utilized by the visual feedback system is altered by the visual correction, resulting in a new stimulus to RS development. The effect of corrective lenses on the RS state was described by Medina (66,67), who demonstrated statistically ($P < 0.001$) that the ultimate RS can be better predicted if lens correction has a significant effect on the developing RS. This was confirmed by Ong et al. (68), who reported that non-wearers of myopic correction exhibit an age-adjusted 3-year progression approximately one-half that of full-time wearers (although statistical analysis of their results shows no significant difference, presumably due to the small sample size).

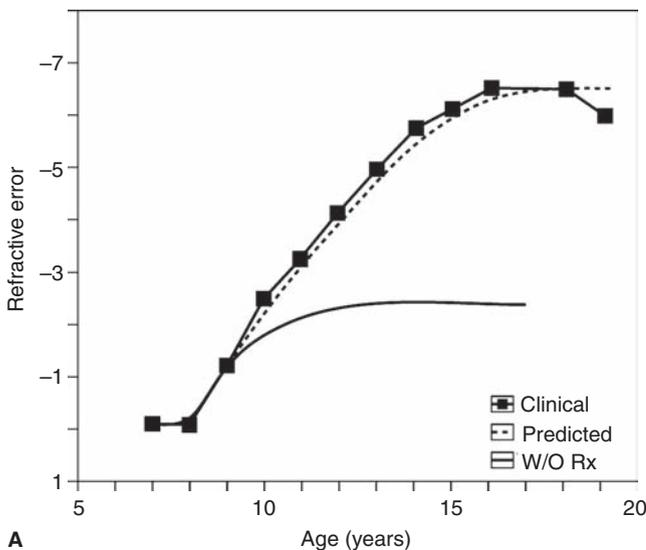
Generally, the model suggests that the overall effect of corrective lenses in persons developing myopia is to increase the refractive state in amounts depending on the relative strength of the growth rate caused by peripheral retinal image defocus and the magnitude of the RS that might develop for a patient who remains uncorrected. For hyperopic patients, corrective lenses minimize visually driven emmetropization. As a result, once visual correction is prescribed, further reduction in hyperopia is not expected unless near tasks are performed that maximize persistent near blur to stimulate an increase in axial length to decrease the hyperopic RS (blur-driven emmetropization).

Rates of Ametropia Progression

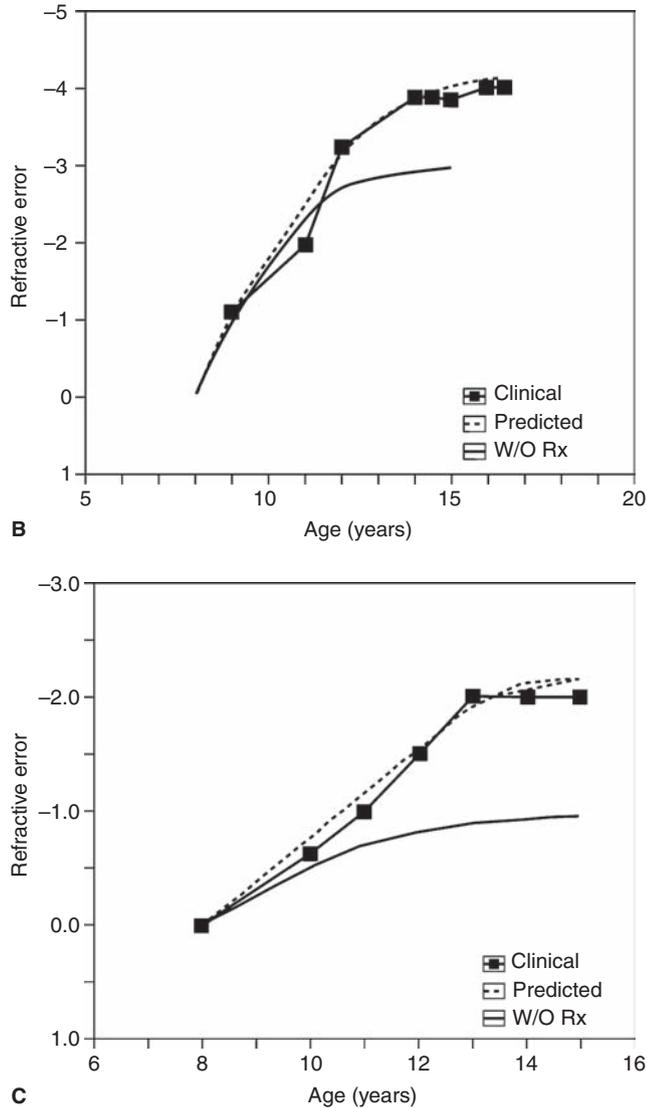
The general cases of RS progression are shown in Figure 23.10 for youth-onset myopia, late-onset myopia, and hyperopia. In each case, the dashed line represents the predicted value with changes in correction determined in a "standard" clinical manner (yearly changes in correction or at least 0.50 D change in RS required if longer than 1 year was necessary to attain such a change), and the solid line represents the amount of change predicted to occur if lens corrections were not prescribed. Three clinical examples (Fig. 23.11) are



■ **Figure 23.10** The general cases of refractive state (RS) progression are shown for youth-onset myopia, late-onset myopia, and hyperopia. The dashed lines represent the predicted value with changes in correction prescribed at the ages a patient would probably receive new lenses, and the solid lines represent the predicted change if lens corrections were not prescribed. The curves are constructed using average growth (k) and RS (c) constants, which predict RS progression similar to that observed clinically. If the effects of corrective lenses are not included (*solid lines*), a significantly smaller myopic RS results.



■ **Figure 23.11 A–C:** Three examples are overlaid on the clinical changes in the refractive state (RS) for female children with typical rates of myopia progression. The curves are constructed by varying the growth (k) and RS constant (c). For **A**, 1 SD of growth rate was added to both the growth and the RS constant; for **B**, 1 SD was added to the growth and 0.5 SD to the RS constant; and for **C**, 1.5 SD was added to the growth and 0.5 SD was subtracted from the RS constant. Predicted changes (*dashed lines*) correspond well to clinical findings (*solid lines connecting black squares*), assuming that effects of corrective lenses are included and that exponential growth ceases at approximately age 14. Increases in the myopic RS are essentially linear during the growth period as long as refractive correction is prescribed at regular intervals. The single solid line represents the change predicted if lens correction is not prescribed. (*Continued*)



■ **Figure 23.11** (Continued)

overlaid on the clinical changes in the RS reported by Goss and Winkler (69) for three female children with typical rates of myopia progression. In each figure, the solid line connecting open black squares represents the clinical data (69), the dashed line represents the predicted value with changes in correction prescribed at the ages the patient received new lenses (yearly or at least 0.5 D change), and the single solid line represents the amount of change predicted if no lens correction were prescribed.

As can be seen in Figure 23.11, predicted changes in the RS (dashed lines) correspond well to those observed clinically (solid lines connecting black squares), assuming that effects of corrective lenses are included and exponential growth ceases at approximately age 14. If the effects of corrective lenses are not included (solid lines), a significantly smaller myopic RS is predicted than what actually develops. It should be noticed that for each patient increases in the myopic RS are essentially linear during the growth period, as described by Goss (61), as long as refractive correction is prescribed at regular intervals. After growth ceases, the exponential decay function results in a smooth decrease in the change, and future myopic changes are no longer linear.

CLINICAL ASPECTS OF THE MODEL

Influence of Genetically Programmed Ocular Growth

The basic components of the visual connections between the eye and the brain are present at birth. However, the substance of these components can be dramatically modified based on environmental influences. For example, it is well known that decreased visual experience in one eye of an infant animal (e.g., monocular lid suture) results in diminished input to the cells in the visual cortex driven by that eye (70). It is probable that a similar mechanism exists for the RS; that is, the basic components of the refractive system are largely in place at birth, and genetically programmed ocular growth continues after birth but is altered by visually directed ocular growth. During the first 12 months of life, the eye elongates and the cornea flattens—largely a mechanistic change. By about age 18 months, further changes in corneal curvature are virtually nonexistent (18), and changes in lenticular structure must primarily compensate for subsequent increases in axial length.

Treatment Strategies Based on Altering Visually Directed Growth

The basic goals of strategies aimed at altering the influence of visually directed growth are:

1. To minimize the near lag of accommodation by controlling interactions between vergence and accommodation
2. To minimize or provide peripheral retinal defocus that slows (in the case of myopic patients) or enhances (in the case of hyperopic patients) visually directed ocular growth.

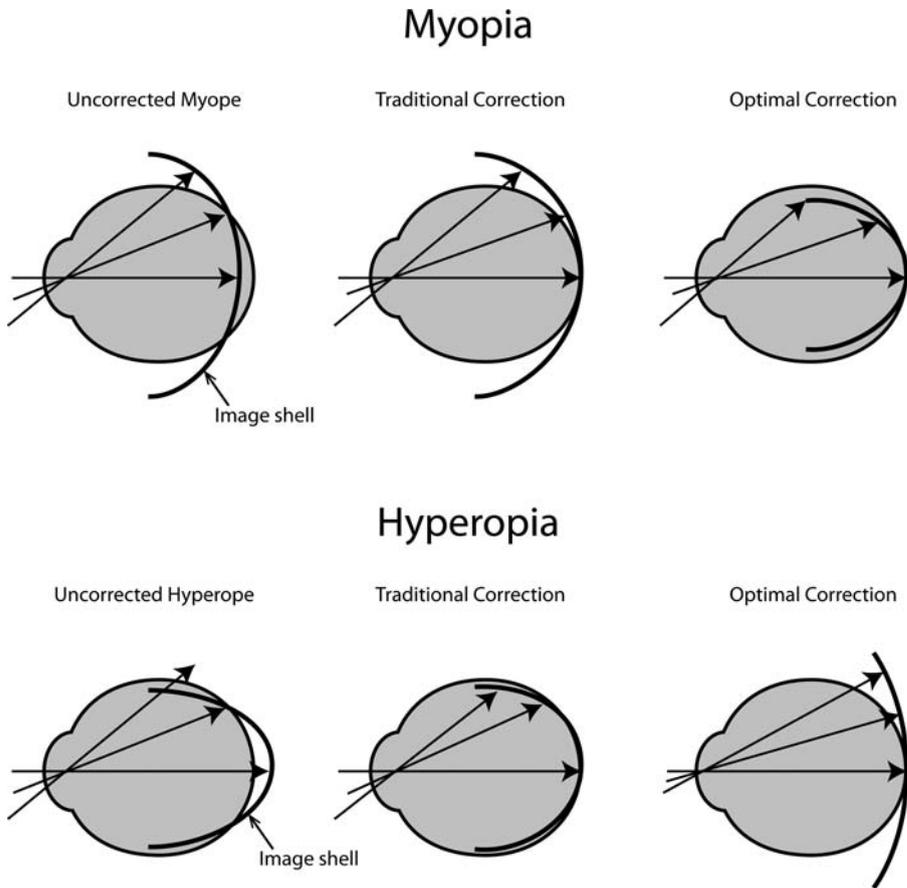
Figure 23.12 depicts the ocular conditions of myopia (top) and hyperopia (bottom). In the top left-side panel (Fig. 23.12A) it can be seen that, for myopic eyes, the image shell for distance objects tends to be flatter (relative hyperopic defocus) than the surface of the retina (71,72). When traditional visual correction is prescribed, there is clear central vision but an increase in the relative peripheral defocus which further increases in magnitude with increasing eccentricity (Fig. 23.12B) (73,74). This situation provides a strong stimulus for myopic growth (75,76). This relation is reversed for hyperopic patients (Fig. 23.12 bottom panel). As shown in the top right panel (Fig. 23.12C), the goal of an optimal peripheral treatment strategy is to provide clear distance vision with a concurrent increase in the curvature of the image shell to provide stimuli that reduce visually driven axial growth (i.e., myopic rather than the traditional hyperopic retinal defocus). For the hyperopic patient correction that increases the stimuli to visually driven ocular growth by creating a relative hyperopic peripheral image defocus would tend to help the patient “outgrow” his/her hyperopia (Fig. 23.12F). These corrections are a significant departure from the traditional negative (for myopia) or positive (for hyperopia) powered lenses which typically increase the inappropriate signal to visually directed ocular growth (77,78).

Sequential Management Protocol

The crucial clinical concept of the model is that visual experience alters the basic components of the refractive system to influence the RS that ultimately results. The following sections describe and give the rationale for a sequential RS treatment program consisting of the following:

1. Refractive correction (with emphasis on maximum plus for myopia and minimum plus for hyperopia) designed in such a way that peripheral retinal image defocus reduces (myopic patients) or stimulates (hyperopic patients) visually driven ocular growth (79).
2. Pharmacologic (e.g., atropine) treatment (for rapidly advancing myopia)
3. Added lenses when needed (to maintain a lead of accommodation at near for myopia and a lag of accommodation at near for hyperopia)
4. Active ongoing therapy to ensure that the patient maintains the ideal focus at near and improves binocularity when needed
5. Diet modification to enhance and maintain proper ocular growth

Most of these treatments, which primarily involve altering the visual experience to influence RS development, are only now beginning to be extensively investigated in clinical research, and prospective studies will



■ **Figure 23.12** Schematic of how optical treatment using a peripheral treatment strategy could be used to slow the progression of myopia (*Top*) and decrease the ultimate hyperopic RS (*Bottom*). The top left panel illustrates the typical position of the image shell for a distance object in an uncorrected myopic eye. The middle panel shows that traditional minus correcting lenses provide an in-focus foveal image but do not correct the relative hyperopia that usually occurs in the periphery. The right panel emphasizes the goal of the peripheral treatment strategy: to provide optimal central vision while eliminating peripheral visual signals that may stimulate growth and increase myopia progression. The bottom left panel illustrates the position of the image shell for a distance object in a typical uncorrected hyperopic eye. The middle panel shows that traditional plus correcting lenses provide an in-focus foveal image but do not correct the relative myopia that often occurs in the periphery. The lower right panel demonstrates the goal of the peripheral treatment strategy for patients with hyperopia: to provide optimal central vision while increasing the peripheral visual signals that may stimulate growth and decrease hyperopia.

be required to validate their use. In the meantime, the model presented in this chapter provides a rationale for cautious use of sequential RS treatments and suggests randomized clinical trials that might be designed to investigate such treatments and their possible effectiveness.

Myopia

Most eyes should become less hyperopic or even myopic over time, because both the relative hyperopia caused by the lag of accommodation at near and the typical relative hyperopic peripheral retinal image defocus are primary stimuli to visually driven myopic changes in the RS. Such a result has been observed clinically; the hyperopia present at birth typically decreases and the RS distribution ultimately develops a skewed myopic tail (2). However, in reference to the development of myopia, there are several interesting factors that should be considered.

One important clinical question relates to the stability of both childhood and adult refractive error. Specifically, why do some persons have a myopic change in the RS when others who seem to be performing the same or similar tasks do not? The answer will probably be determined through investigation of the following:

- Range of sensitivity of the emmetropizing mechanism to blur
- Amount of relative blur at near (lag of accommodation) and how this blur is influenced by interactions between accommodation and vergence
- Amount and direction of relative peripheral defocus in each eye
- Correction worn and how it influences the amount and type of blur experienced
- Amount of near work performed and the resulting time-average blur experienced

NORMAL VISUAL ACUITY AND THE RANGE OF SENSITIVITY TO BLUR

The range of normal visual acuity falls within a bell-shaped curve, with acuity ranging from slightly better than 20/10 to about 20/30 (80). This acuity range may have a parallel in the ability to respond to and interpret blur. It has been speculated that persons who ultimately become myopic have decreased blur sensitivity (81); as a result, they would tend to tolerate a more blurred retinal image. If this is true, such persons might also have a higher near lag of accommodation as a result of an inability to readily recognize near blur (82). This near-blur-induced high lag would in turn provide more input into the visually driven emmetropization controller and more stimuli for an increase in myopia.

AMOUNT OF LAG AND INFLUENCE OF INTERACTIONS BETWEEN ACCOMMODATION AND VERGENCE

Any time an abnormally high near lag of accommodation is present, an increased stimulus to myopic change results. An increased near lag of accommodation is a frequently seen clinical sequelae to abnormal motor alignment at near (83). For example, an esophoria at near is often easier to fuse if accommodation is inhibited; this inhibition results in a larger lag of accommodation at near. Clinical findings corroborate that near esophoria (a motor misalignment) is often associated with development of myopia (84) both during childhood (85) and in adulthood (85). Jiang (85) tested this when he investigated the hypothesis that specific parameters of the motor system differ between young adult emmetropes who develop late-onset myopia and those who do not. Jiang (85) found that dark focus shows a transient inward shift and that the accommodative convergence to accommodation (AC/A) ratio increases and remains high in patients who later develop myopia. He speculated that the increased AC/A results in an increase in the lag of accommodation, which in turn creates equally blurred images on each retina (thereby activating visually directed ocular growth and increasing myopia).

In the same manner that a high lag of accommodation provides sufficient near blur to stimulate myopic changes in the RS, emmetropic children with intermittent exotropia (IXT) should have increased stimulus to become myopic when they converge to maintain single binocular vision at distance and near. When the IXT patient fuses the two retinal images, there is a substantial amount of convergence needed; this excess convergence drives accommodation through the CA/C ratio. For example, if there is an 18 prism diopter distance IXT and a normal CA/C (0.5 D/MA) (86), about 1.5 D of accommodation is stimulated when the patient fuses at distance ($3 \text{ MA} \times 0.5 \text{ D} = 1.5 \text{ D}$). This accommodation must be inhibited if the IXT patient is to maintain clear vision. Given the normal distance depth of focus, the stimulated accommodation leaves the IXT patient with a lag of accommodation at both distance and near, resulting in a strong visual stimulus to develop myopia. Clinically, more than 50% of IXT patients ultimately become myopic (87).

AMOUNT AND DIRECTION OF PERIPHERAL RETINAL BLUR

There is an increasing amount of basic research that implicates peripheral retinal signals as a significant driver for visually directed refractive changes. Observations that emmetropization does not occur in animals reared in total darkness (88), that form deprivation results in open loop axial growth (89), that animals can recover from induced growth (90,91), and that powered lenses can be used to alter the eye's refractive state by a known amount (92) provide powerful evidence that ocular growth and refractive development are regulated by visual feedback. Further, vision-dependent mechanisms that regulate refractive development operate in a regionally

selective manner as evidenced by experiments where the optic nerve is compromised and refractive changes still occur when the retinal image is degraded (i.e., alteration of the retinal image is sufficient, by itself, to change the refractive state) (93). In addition, these vision-dependent retinal mechanisms can be stimulated in a regionally selective manner with changes in ocular length and refractive state seen in only a portion of the retina (94). These results suggest that peripheral retinal changes alone can alter the refractive state—it is difficult to imagine how accommodation could produce regional changes in eye shape or refractive error.

Visual signals from the fovea are not essential for many aspects of vision-dependent growth. Foveal signals can be eliminated in one eye, for example by laser photocoagulation, and still the development of the refractive state is similar for both the eyes (95). Thus, peripheral vision plays a significant role in regulating ocular growth to optimize the refractive error.

In the presence of conflicting signals to the central and peripheral retina, peripheral visual signals can dominate central refractive development. Monkeys reared with clear central vision and peripheral form deprivation were more myopic than normal monkeys (96). This demonstrates that visual signals from the periphery can override visual signals from the central retina and alter refractive development. Finally, refractive errors can vary with eccentricity and peripheral optical errors can alter central refractive development. It is common for the eye's spherical-equivalent error to vary substantially with eccentricity (97). This variation could influence development of the myopic refractive state, if there is a relative hyperopic demand. However, the relation is complex and, until more is known about the relation between the peripheral refractive state and refractive development, it may be difficult to confidently attribute a causal relationship between change in refractive state and existence of a peripheral refractive error.

AMOUNT OF NEAR WORK PERFORMED

Even in the presence of a normal distance heterophoria, a normal lag of accommodation at near, and a small stimulus to visually driven growth from the retinal periphery there can be sufficient visually driven stimulus to myopic change to cause an increase in myopia if substantial amounts of near work are performed (98,99). (However, Zadnik (58) suggests otherwise based on correlation of myopia development and diopter-hours of near work.)

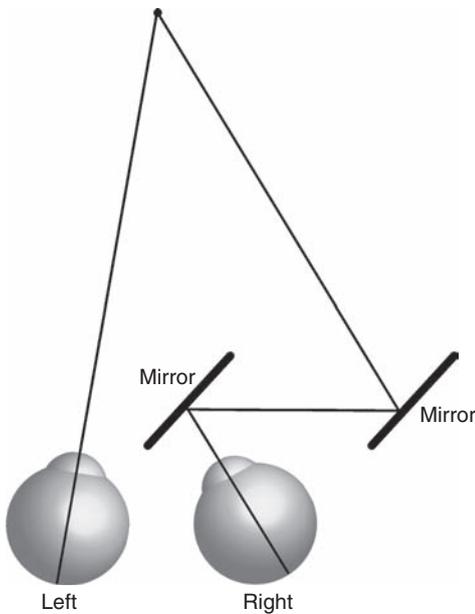
TREATMENT OF MYOPIA OR OF PATIENTS WITH RISK FACTORS INDICATING THE POSSIBILITY OF DEVELOPING MYOPIA

Risk factors for development of myopia include both parents with myopia (42,46,47,100) and an AL/CR ratio higher than 3.0 (85). In addition, there is a high stimulus for visually driven myopia in a child with a normal AL/CR ratio if there is a near esophoria (42,47,100,101), a high distance exodeviation (87), a high lag of accommodation at near (24,42,47,100), or substantial near demands (46). Further, pre-presbyopic adults who work with infinity-based instruments or who perform near tasks many hours per day may also be at risk (102). The initial change in refraction that may signal impending myopia development is a small increase in against-the-rule astigmatism (7), especially in early grade school (103).

Treatment of patients who are at risk of developing myopia can only be directed at the visually driven emmetropization mechanism because current knowledge does not provide treatment that would affect genetically programmed growth. The results of sustained treatment that minimizes the lag of accommodation, enhances blur detection ability, minimizes the relative hyperopic peripheral retinal signal, and reduces the amount of near work (or equalizes it with “far” work) should be a reduction in the visually driven signal to myopia development (through a decrease in the sustained near relative hyperopic blur that drives visually driven emmetropization) and an RS that remains closer to emmetropia. Ideally, treatment should be initiated before myopia development commences, certainly before there is a substantial myopic change.

Minimizing the Accommodative Lag

Minimizing the lag of accommodation can be initiated through the CA/C ratio. For example, therapy that increases convergence at near (e.g., base-out prism or mirrors that widen the pupillary distance; Fig. 23.13) would stimulate accommodation through the CA/C ratio, causing a reduced lag or even a lead of accommodation at near. If this lead of accommodation can be maintained while the patient reads, the stimulus to myopia development would be reduced. Further reduction in myopia stimulus might be achieved by having the patient perform excessive convergence while reading through added plus lenses. These tasks may need



■ **Figure 23.13** Increasing convergence at near can be accomplished using mirrors that widen the pupillary distance. This resulting disproportionate near convergence would stimulate accommodation through the CA/C ratio, causing a reduced lag or even a lead of accommodation at near. Prolonged maintenance of this convergence while the patient reads reduces the stimulus to myopia development.

to be varied every 15 to 30 seconds to reduce the effects of vergence and accommodative adaptation, which reduce the demands over time (85). This requirement could be facilitated with an instrument-based approach (i.e., instruments that incorporate the concepts in Fig. 23.13).

Refractive Correction

New spectacle and contact lenses are being developed that decrease the relative hyperopic peripheral blur. Most of these are not yet available clinically. However, there are commercially available multifocal contact lenses that change the relative peripheral defocus in a manner that could be used to appropriately minimize the relative peripheral refractive error. For example, a multifocal contact lens that causes a relative peripheral hyperopic defocus can be designed to provide the “correct” peripheral retinal defocus to minimize myopia progression (see Fig. 23.12).

Near Additions

Although near additions might be useful for patients who have a high lag of accommodation at near or a near esophoria (103–106), such prescriptions may not be useful for all patients with developing myopia (107,108). For example, it is unlikely that prescribing a near addition will be helpful unless it actually reduces the near lag of accommodation. Raphaelson (108) reported that 57% of elementary school children (287 of 503) started near work at farther than 10 inches but after only a few minutes more than 80% (425 of 503) held their near work at 6 inches or less. Thus, many people probably adjust their near working distance to maintain a habitual near lag of accommodation through the new bifocal correction, defeating the purpose of the correction entirely. Even prescribing a progressive addition lens will not solve this problem; careful instruction and ongoing therapy will be needed to ensure that the child holds the near work at an appropriate distance to minimize the lag (and, if possible, maintain a lead) of accommodation at near.

If near plus correction is to be successful, each patient should be individually assessed to determine the lag, and then the near addition that reduces the near lag of accommodation as close to zero as possible should be prescribed (Case 23.1). This prescription must then be used for all near tasks *without* allowing the patient to adjust his or her working distance to resume a near lag of accommodation *and* for sufficient time to allow the visually directed stimulus to emmetropization to decrease the progression rate of myopia. Frequent follow-up will be required to ensure that the patient maintains the appropriate working conditions and to change the correction as the visual response changes. Failure to achieve and maintain these conditions may explain why studies investigating the use of bifocals to slow progression of myopia have achieved equivocal results (104,107,109).

Case 23.1 Successful Myopia Treatment

A 9-year-old girl was brought for an examination because she failed her school screening. Her unaided visual acuity (VA) was 20/30–, with the following noncycloplegic refraction:

OD: –0.50
OS: –0.50 VA 20/20 +1

The cover test at distance was 2 exophoria and at near was 5 esophoria. The calculated AC/A ratio was 7.2:1 (PD = 60). In both eyes, axial length was 23.0 mm with a flat corneal radius of 7.65 (K = 44.12); the AL/CR ratio was 3.01.

The small myopia is becoming significant in this case, and correction will be needed to allow clear distance vision in school. The use of added lenses can be helpful in the treatment of this patient. Because of the high AC/A ratio, glasses can be prescribed to help control the deviation. The use of +1.25 OU would significantly reduce the esophoria at near. However, in treatment of myopia, we want her to have a lead of accommodation when she reads. Clinical testing with monocular estimation method (MEM) retinoscopy indicated a lead of accommodation at her normal 37-cm working distance with a +2.25 near addition. This was prescribed in bifocal form:

OD: –0.50
OS: –0.50
+2.25 add

In this case, the use of –0.50 with a +2.25 add OU is a valuable optical management technique to achieve a near lead of accommodation, while the maximum plus distance refraction provides a distance lead as well. Thus, provided the child can be induced to read at the correct distance, she will have continued stimulus to change her refractive error toward less myopia. Over time her myopia decreased slightly, and she went to college with glasses only for reading.

Age	Correction Prescribed	Other Treatment
9	OD: –0.50 OS: –0.50 Near add +2.25	Therapy to maintain working distance at 37 cm.
10	No change	Working distance counseling and encouragement to continue full-time glasses when reading.
12	OD: –0.25 OS: Pl c –0.25 × 180 Near add +2.25	Therapy to maintain 40-cm working distance.
14	Near add +1.75 Distance refractive findings below were not prescribed: OD: Pl OS: Pl c –0.25 × 180	Therapy to maintain 40-cm working distance with proper lighting while studying. Encouragement to continue full-time glasses when reading.
18	Near add +1.50 Distance refractive findings below were not prescribed: OD: Pl OS: Pl c –0.25 × 10	Encouragement to continue full-time glasses when reading. Therapy to maintain 40-cm working distance.

Unfortunately, not all patients can become or remain emmetropic despite the potential of the treatments described here. For example, many patients who have the risk factors indicating the possibility of developing myopia will have sufficient genetically programmed ocular growth to overwhelm all interventions; others will not have the ability or desire to maintain the proper working distance or will not wear glasses or perform therapy as directed (Case 23.2).

Case 23.2 Unsuccessful Myopia Treatment

A 10-year-old girl was brought for an examination because she had blurred distance vision. Her unaided VA was 20/30–, with the following refraction:

OD: –0.75
OS: –0.75 VA 20/15

The cover test at distance was orthophoria and at near was 6 esophoria. The calculated AC/A ratio was 8.4:1 (PD = 60). In both eyes axial length was 22.5 mm with a flat corneal radius of 7.46 (K = 45.25); the AL/CR ratio was 3.02.

The small myopia is significant in this case, and correction will be needed to allow clear distance vision in school. The use of added lenses can be helpful in the treatment of this patient. Because of the high AC/A ratio and the desire to attempt to treat her myopia, glasses were prescribed. Clinical testing with MEM retinoscopy indicated a lead of accommodation at her normal 35-cm working distance with a +3.00 near addition. This was prescribed in bifocal form:

OD: –0.50
OS: –0.50
+3.00 add

In this case the use of –0.50 with a +3.00 add OU is a valuable optical management technique to achieve a near lead of accommodation, while slightly less than the maximum plus distance refractive correction provides a distance lead as well. Thus, provided the child can be induced to read at the correct distance, she will have continued stimulus to change her refractive error toward less myopia.

The patient was variably compliant with using the near add and frequently did not maintain the correct working distance. Over time her myopia increased and she was fit with contact lenses.

Age	Correction Prescribed	Other Treatment
9	OD: –0.50 OS: –0.50 Near add +3.0	Therapy to maintain working distance at 37 cm.
10	No change	Working distance counseling and encouragement to continue full-time glasses when reading.
11	OD: –1.00 OS: –1.00 c –0.25 × 10 Near add +2.75	Therapy to maintain 40-cm working distance.
14	OD: –1.75 c –0.25 × 180 OS: –1.75 c –0.25 × 10 Near add +2.25	Therapy to maintain 40-cm working distance with proper lighting while studying.
16	OD: –2.00 c –0.25 × 175 OS: –2.00 c –0.25 × 15	Encouragement to continue full-time glasses when reading. Fit with spherical high Dk soft lenses per patient's choice. Encouragement to continue +1.75 glasses and proper working distance when reading.
18	OD: –2.25 c –0.25 × 175 OS: –2.00 c –0.25 × 10	Continue spherical high Dk soft lenses and discontinue +1.75 glasses per patient's choice

Pharmacologic Treatments

Many clinical studies suggest that daily cycloplegic treatment decreases the rate of myopia progression (110–112). In general, clinical studies demonstrate reduced progression of myopia with any cycloplegic, although atropine probably holds the maximum promise as a treatment. In two fairly large-scale clinical studies, Bedrossian (113,114) found that progression of myopia essentially ceased with regularly scheduled atropine use; these findings have been duplicated in subsequent studies (115–120). The decrease in myopia progression with atropine probably results from two factors:

- The unspecified effect of atropine on the retina, choroid, and zonules
- The use of bifocals to restore clear near focus when prolonged cycloplegia is utilized

Atropine might pharmacologically inhibit ocular growth. This inhibitory effect would add to the effect of bifocal correction, which would influence visual emmetropization of children treated with atropine. The children would have an increased stimulus to become hyperopic because the bifocals effectively eliminate the usual lag of accommodation at near and provide no stimulus to increase myopia over prolonged work periods, assuming an appropriate working distance to achieve a lead (rather than a lag) of accommodation is actually used. The normal lead of focus at distance then gets added to by the lead at near, reversing the typically myopia-developing visually driven stimulus for refractive change and minimizing further myopic shift in the RS.

Systemic toxicity (increased pulse rate, dryness of mouth and throat, loss of neuromuscular coordination, raised blood pressure, and mental confusion) is a possible side effect of atropine treatment. However, such sequelae are uncommonly seen with the standard clinical doses; atropine treatment is typically safe and seldom causes significant systemic distress. Typically, the most noteworthy clinical side effect of atropine treatment is extreme light sensitivity due to pupillary dilation (which generally can be compensated with spectacles or sunglasses with ultraviolet protection for outdoor wear). There are also new drugs, such as pirenzepine, that seem to mimic atropine's myopia-decreasing effects (121,122) without causing pupil dilation and light sensitivity. However, there are some initial indications that pirenzepine may not be as effective as atropine (122), and other possible candidates, including retinoic acid analogs, may ultimately be developed.

Generally, pharmacologic treatment with atropine has been reserved for patients at risk of developing significant myopia (more than 6 D) in which the risk of clinical sequelae such as retinal detachment is high. Such children can be identified because they develop myopia at a young age, typically have two myopic parents, and have an AL/CR ratio higher than 3.0. Because these children are at very high risk of development of substantial myopia, maximal treatment will be needed (Case 23.3). A rapid increase in myopia (more than -1.25 D) in a 6- to 12-month period for such children might signal enough concern to recommend long-term atropine therapy (123).

Case 23.3 Myopia Treatment Incorporating Atropine

An 8-year-old boy was brought for an examination because he had decreasing distance vision. At his previous examination 1 year ago, he had a refraction of -0.25 with an unaided VA of 20/20. The current unaided VA was 20/70 with the following refraction:

OD: -1.50
OS: -1.50 VA 20/20 +1

The cover test at distance and near was a 2 exophoria. The calculated AC/A ratio was 6.0:1 (PD = 60). In both eyes axial length was 23.5 mm with a flat corneal radius of 7.80 (K = 43.25); the AL/CR ratio was 3.02. Both parents were significantly (>4.00 D) myopic. Cycloplegic refraction with atropine was as follows:

OD: -1.00
OS: -1.00 VA 20/20 -1

The myopia is significant in this case, and correction will be needed to allow clear distance vision in school. In view of the rapid change in refraction and VA, and the father's concern about his son ultimately developing myopia, discussion of treatment options included use of atropine. Added lenses can also be helpful in the treatment of this patient. Because of the atropine, if a distance correction is provided, correction must also be given to provide clear near vision. The use of +2.25 OU would focus the schoolwork at near. In this case we want him to have a lead of accommodation when he reads. Clinical testing with MEM retinoscopy while the patient was cyclopleged with atropine indicated a lead of accommodation at his normal 36-cm working distance with a +2.75 near addition. This was prescribed in bifocal form:

OD: -1.00 20/20-
 OS: -1.00 20/20-
 +2.75 add

In this case the use of -1.00 with a +2.75 add OU during atropine cycloplegia is a valuable optical management technique to achieve a near lead of accommodation, while the distance refraction gives a distance lead as well. Thus, provided the child can be induced to read at the correct distance, he will have continued stimulus to change his refractive error toward less myopia.

Over time the patient's myopia decreased. He is currently in high school with an RS of -0.25 and continues to use atropine every summer.

Age	Correction Prescribed	Other Treatment
8	OD: -1.00 OS: -1.00 Near add +2.75	Atropine Q7d. Therapy to maintain working distance at 37 cm.
9	OD: -0.50 OS: -0.50 Near add +2.75	Atropine Q7d. Therapy to maintain working distance at 37 cm.
10-13	No change	No change
14	OD: -0.25 OS: -0.25 Near add +2.75	Atropine Q7d in summer and school vacations. Therapy to maintain 40-cm working distance with proper lighting while studying. Encouragement to continue full-time glasses when reading.
15-18	No change	Atropine Q7d in summer only. Therapy to maintain 40-cm working distance with proper lighting while studying. Encouragement to continue full-time glasses when reading.

Contact Lenses

The Chromatic Aberration Error Signal: Difference between Rigid Gas Permeable and Soft Contact Lenses

One example of how corneal factors might be implicated in maintenance of a stable refractive state comes from the results of studies of rigid gas permeable (RGP) contact lens fitting in children, where the typical clinical observation is a slowing of myopia development even when there is little change in corneal curvature (124). It is possible that the spherical surface of the RGP contact lens, which becomes the front surface of the ocular optical system, provides different peripheral retinal image defocus information to the emmetropization controller than that provided by the aspheric corneal surface. If this is the case, this "spherical" feedback results in decreased myopia progression, even in the absence of substantial changes in corneal curvature. This has been noted in clinical reports of fitting schoolchildren with RGP contact lenses, where the finding was

that the RGP-wearing children apparently had a relatively stable RS (125,126). The expectation is that RGP-wearing patients should have a more stable RS than that observed in soft lens wearers, even in the presence of little corneal change. However, although traditionally fitting (on-K) RGP lenses slightly slow down myopia progression in children, there is no effect on axial length; the refractive effect is due to corneal flattening that is probably transient (125).

Thus, traditionally fitting (on-K) RGP contact lenses are likely to be a marginally effective treatment for young patients at risk of myopia development (125,126). Probably the treatment should be initiated prior to development of significant myopia unless a small amount of myopic RS is desired (e.g., to ease the near demands of presbyopia). For optimum results, RGP treatment should be combined with other interventions (properly prescribed bifocals, blur interpretation therapy, lifestyle changes, pharmacologic treatment, etc.) and not prescribed solely to minimize myopia progression (125,126). Further, the treatment will need to be carried out until age 14 to 18 years, at which point genetically programmed growth decreases and the patient's risk of developing myopia is minimized.

Orthokeratology: Myopia Reduction with Reverse Geometry Contact Lenses

Reverse geometry lenses are RGP contact lens designed to temporarily correct myopia (nearsightedness) by reversibly reshaping the cornea, typically while the patient sleeps. This process has been variously called *orthokeratology* (ortho-K), *corneal refractive therapy* (CRT), *vision shaping treatment* (VST), and *refractive modification* (127). Most patients have rapid improvement in the first few days of treatment and achieve nearly their optimum vision in 7 to 14 days. In June 2002, the FDA granted overnight wear approval to a type of corneal reshaping therapy (CRT); other overnight wear approvals followed. In the FDA clinical study for approval of CRT, 93% of patients achieved 20/32 vision or better, and 67% achieved 20/20 or better. In the clinical study for FDA approval of one VST design, about 95% achieved 20/40 vision or better, and 73% achieved 20/20 or better. Both studies followed patients over at least a 9-month period (127).

Generally, reverse geometry (ortho-K) RGP lenses have been found to slow down myopia progression (127) and axial length growth (127,128), with a wide range of outcomes; it is difficult to predict which children will get significant effect and which will get no effect (129). The treatment has generally been safe, without significant corneal distress (130), although there have been reports of infectious keratitis (131) and corneal ulcers (132) in children who presumably did not adequately care for their lenses.

Thus, reverse geometry (ortho-K) RGP contact lenses are likely to be a potentially useful treatment for young patients at risk of myopia development (127,128). When the patient is relatively more myopic the reverse geometry (ortho-K) RGP seems to be more successful than it is on patients with lower amounts of myopia. However, given the potential reversibility (109), for maximum long-term results, treatment should be initiated prior to development of significant myopia and combined with other interventions (properly prescribed bifocals, blur interpretation therapy, lifestyle changes, pharmacologic treatment, etc.) (Case 23.4).

Case 23.4 Myopia Treatment with Atropine and Reverse Aspheric Rgp Contact Lenses

An 11-year-old boy was brought for an examination because he had decreasing distance vision. At his previous examination 1 year ago he had a refraction of -1.25 with an unaided VA of 20/50. The current unaided VA was 20/100–, and the refraction was as follows:

OD: -2.25

OS: -2.25 VA 20/20 +1

The cover test at distance and near was a 1 exophoria. The calculated AC/A ratio was 6.0:1 (PD = 60). In both eyes axial length was 23.25 mm with a flat corneal radius of 7.63 (K = 44.25);

the AL/CR ratio was 3.05. Both parents were myopic, with the father being very myopic (> -6.00 D). Cycloplegic refraction with atropine was as follows:

OD: -1.75

OS: -1.75 VA 20/20 -2

The myopia is significant in this case, and correction will be needed to allow clear distance vision in school. In view of the rapid change in refraction and VA and the parents' concern about their son ultimately developing myopia, discussion of treatment options included the use of atropine. The use of added lenses can be helpful in the treatment of this patient. Because of the atropine, glasses must be prescribed to provide clear near vision. The use of $+2.25$ OU would focus the schoolwork at near. In this case we want him to have a lead of accommodation when he reads. Clinical testing with MEM retinoscopy while the patient was cyclopleged with atropine indicated a lead of accommodation at his normal 40-cm working distance with a $+2.50$ near addition. This was prescribed in the form of contact lenses (reverse aspheric RGP lens) to reduce the RS, along with reading lenses to be worn when he studies.

OD: Reverse aspheric CL; over refraction PL VA 20/20–

OS: Reverse aspheric CL; over refraction PL VA 20/20–

Reading glasses $+2.50$ add

In this case the use of reverse aspheric contact lenses along with atropine cycloplegia is a valuable optical management technique. The over-glasses allow a near lead of accommodation, while the reverse aspheric contact lenses give a distance lead as well. The end result of this is a smaller refractive error and the ability to maintain it. Thus, provided the child can be induced to read at the correct distance, he will have continued stimulus to change his refractive error toward less myopia.

Over time, the patient's RS remained stable, and he is currently in high school with an RS of $+0.25$. He continues to use atropine every summer and wears his contact lenses 2 nights per week to maintain the distance refractive error.

Age	Correction Prescribed	Other Treatment
11	OD: Reverse aspheric CL OS: Reverse aspheric CL Reading glasses $+2.50$ add	Atropine Q7d. Therapy to maintain working distance at 37 cm. CL follow-ups on days 1, 3, 7, and 14. He achieved 20/20 unaided VA for a full day in 14 days and continued nightly wear.
12	OD: Reverse aspheric CL OS: Reverse aspheric CL Reading glasses $+2.25$ add	Atropine Q7d. Therapy to maintain working distance at 37 cm. Encouragement to continue full-time glasses when reading. CL wear nightly.
13	No change (new CL)	No change
14	No change (new CL)	No change
15	No change (new CL)	No change
16	No change (new CL)	Atropine Q7d in summer and during school vacations. Therapy to maintain 40-cm working distance with proper lighting while studying. Encouragement to continue full-time glasses when reading. CL wear every other night—unaided VA remains 20/20.
17	No change (new CL)	No change
18	No change (new CL)	Atropine discontinued. Therapy to maintain 40-cm working distance with proper lighting while studying. CL wear every Sunday night—unaided VA remains 20/20 throughout the week.

Soft Multifocal Contact Lenses

For myopia treatment the goal of soft multifocal fitting is to provide a continuous relative hyperopic stimulus to the peripheral retina (see Fig. 23.12). This can be accomplished with any of the currently commercially available soft multifocal lenses that have a center distance lens design (79). The center distance design would provide relatively clear distance vision while the added power in the periphery would provide a relative peripheral hyperopic defocus and a reduced stimulus to visually directed ocular growth (see Fig. 23.12). Typically the contact lens should be fitted using the least minus for distance with the highest add that does not reduce the corrected distance by a clinically significant amount (generally the distance acuity corrected with the center distance multifocal design contact lens should be within one line of the best spectacle correction).

Enhancing Blur Detection Ability

Blur detection can be enhanced through training (133). Such training might be effective for persons who develop myopia due to a high lag secondary to reduced blur recognition. If training is effective, the lag of accommodation should lessen and the stimulus to myopia development should be reduced. It is likely that this treatment would need to be combined with other treatments such as bifocals for maximum effectiveness.

Reducing the Amount of Near Work and Undercorrecting Myopia

Reducing the amount of near work is not likely to be an effective treatment for most patients in our society. Such a lifestyle change might be effective for some persons who develop myopia, but it probably would be difficult to achieve enough reduction to be effective in most instances. In the same manner, undercorrection of myopia would be only of limited usefulness because the primary stimulus to increase in the myopic RS is the relative amount of hyperopic blur at near (e.g., lag of accommodation). Further, significant undercorrection (0.75 D or more) has actually been shown to cause more myopic change rather than prevent a change (134)—this may be because significant undercorrection moves the distance focus outside of the range over which the visual system can respond. (Maximum plus refraction allows a lead of focus at distance that the visual system can respond to, whereas too much distance blur is outside the range of response and, then, only the near lag is effective in altering the rate of myopia progression.) In any event, unless the patient can be induced to hold the near work at the appropriate distance to reduce the stimulus to become more myopic, the reduced stimulus at distance will continue to be overcome by the anomalous near position.

Diet

Considering the implication of Proposition I (i.e., the RS that ultimately develops is a result of genetically programmed ocular growth modified by visually driven ocular growth), there must be (at least) a functional as well as a hereditary facet of myopia. The tenet of this chapter is that the functional facet can be modified by visual experience to influence ocular growth; it is also likely that the hereditary facet can be modified by diet to alter ocular growth. (For those who do not think that environment can influence health, here is an analogy: consider that many people smoke all their lives but most long-term smokers do not develop lung cancer; should we therefore conclude that lung cancer must be hereditary and not caused by smoking? It is also a mistake to apply such a reasoning to development of myopia as well; factors relating to development of myopia may be inherited but are also influenced by environment [diet].)

The structural defect that occurs in myopia development is an increase in axial length, and better nutrition may increase the stability of scleral connective tissue. Gardiner (135) and Lane (136) suggested that high-protein (low-carbohydrate) diets decrease myopia progression. This may be due to the increase in chronic hyperinsulinemia (137) caused by diets rich in carbohydrates, although other components of the diet, including zinc and vitamin intake, also seem to contribute to myopia development (138). For example, deficiency in vitamin D has been demonstrated in Caucasian adults with myopia progression (139). In any event, it is likely that the rate of myopia progression can be reduced by a diet that contains fewer carbohydrates and increased amounts of protein, along with effective supplements. In light of the evidence (and even in the absence of clinical trials), it is probably prudent to recommend diet modifications (increased protein and fewer carbohydrates) and effective supplements (especially vitamin D) for children who are having significant changes in myopia.

Hyperopia

Hyperopia is typically present from early childhood. Significant hyperopia (>2 D) present at age 5 years seldom decreases during future ocular growth (140). Analysis of the data from Sorsby, Benjamin, and Sheridan (59) and Sorsby, Sheridan, and Leary (60) indicates that children aged 4 to 8 years who maintained moderate hyperopia had a much lower AL/CR ratio than subjects the same age who achieved an emmetropic RS (1) (Fig. 23.9A,B). Subsequent prescription of corrective lenses may also have altered the emmetropization process by minimizing visually programmed growth to the point at which it was unable to overcome the low genetically programmed growth rate.

TREATMENT OF HYPEROPIA

The challenge in treatment of hyperopia will be to work with the very young children who typically are not emmetropizing correctly. If such children can be induced to spend substantial amounts of time using toys designed incorporating infinity-based optics, there should be increased stimulus to reduce hyperopia if the instrument is focused at zero accommodative demand or closer. This effectively eliminates the usual lead of accommodation at distance and provides a constant stimulus to decrease in hyperopia over time. The clinical result should be a reduction in hyperopia and an RS closer to emmetropia. In addition, prescribed lens corrections need to minimize plus because a full-plus correction may reset and minimize visually directed emmetropization (66,67).

Soft Multifocal Contact Lenses

For hyperopia treatment the goal of soft multifocal fitting is to stimulate ocular growth by providing a continuous relative myopic stimulus to the peripheral retina. This can be done with a soft multifocal lens with a center near design. The center near design would provide relatively clear distance vision while the added power in the periphery would provide a relative peripheral myopic defocus and an increased stimulus to visually directed ocular growth (see Fig. 23.12). Typically the contact lens should be fitted using the minimum plus for distance with the highest add that does not reduce the corrected distance by a clinically significant amount (generally the distance acuity corrected with the center near multifocal design contact lens should be within one line of the best spectacle correction).

Since we do not advocate “pushing plus” in this treatment design, this may clinically mean choosing between a hyperopic RS and an unacceptably large esodeviation if substantial hyperopia is left uncorrected. Further, uncorrected hyperopia influences development of skills needed to perform well in school (141). These issues must also be considered in the decision about how much hyperopia should be left uncorrected and what the appropriate intervention should include (Case 23.5).

Case 23.5 Hyperopia Treatment

A 4-year-old girl was brought for a routine preschool examination. Uncorrected cover test at distance was an 8 esophoria at distance and 10 esophoria at near. The refraction was as follows:

OD: +3.25

OS: +3.25

With correction, the cover test at distance was a 1 exophoria at distance and 1 esophoria at near. The calculated AC/A ratio was 6.2:1 (PD = 54).

The hyperopia and uncorrected esophoria are significant in this case, but the concern is that refractive correction may not allow the patient to continue to emmetropize. Use of added lenses would not be helpful in the treatment of this patient. In view of the slightly high AC/A ratio, glasses can be prescribed to help control the deviation. The use of +2.75 OU would allow good fusion at near while

also giving her a chance to emmetropize because she would have a lag of accommodation at distance and near. These were prescribed in single vision distance form:

OD: +2.75

OS: +2.75

The patient used +2.75 OU for 1 year. At the next examination she had a refraction of +2.75. Her glasses were changed to +2.25; she continued with this correction for 2 more years, at which time she needed a +2.00 distance correction. She is now in third grade and continues to use +1.25 for schoolwork and studying.

Age	Correction Prescribed	Other Treatment
4	Distance refractive findings: OD: +3.25 OS: +3.25 Prescription (Rx) given: OD: +2.75 OS: +2.75 Phoria with Rx: 1 e at 6 m, 2 e at 40 cm	Antisuppression therapy to enhance fusion. Encouraged to spend significant time coloring at 30 cm.
5	Distance refractive findings: OD: +2.75 OS: +2.75 Rx given: OD: +2.25 OS: +2.25 Phoria with Rx: 1 e at 6 m, 2 e at 40 cm	Antisuppression therapy to enhance fusion. Significant time coloring at 30 cm.
6–7	No change	Therapy to maintain 30-cm working distance with proper lighting while studying.
8	Distance refractive findings: OD: +1.50 OS: +1.50 Rx given: OD: +1.25 OS: +1.25 Phoria with Rx: 0 at 6 m, 1 e at 40 cm	Therapy to maintain 40-cm working distance with proper lighting while studying. Wear glasses only for prolonged near work (test days and studying)

Anisometropia

The difference between the RS of the two eyes, known as *anisometropia*, is typically less than 1.0 D (142). For example, in the general clinical population only about 10% of adults have more than 1 D of anisometropia, although the prevalence is higher in myopic persons (143), and anisometropia is somewhat more common in older age groups (142). Anisometropia prevalence by type is approximately 55% myopic anisometropia, 35% hyperopic anisometropia, and 10% antimetropia (144).

MYOPIC ANISOMETROPIA

Development of myopic anisometropia typically confounds models that attempt to account for anisometropia that develops during adolescence (142). Laird (143) demonstrated that significant myopic anisometropia (>2.00 D) is the result of an unequal growth rate of the two eyes. In his retrospective study of 60 patients

with more than 2.00 D of anisometropia, he found that RS progression rates (i.e., comparison of the growth rate of the eye showing the smaller change with that of the eye showing the larger change) correlate highly ($r = 0.856$, $P < 0.025$). This implies that either the genetically programmed or the visually directed growth rates of each eye, although similar, are unequal and that the visual system is unable to maintain isometropia. In the case of anisometropic myopia, the mechanism fails in both eyes, emmetropia is not maintained in either, and one eye progresses more rapidly into myopia than the other. Unequal genetically programmed growth rates may describe the 2.5% of patients with anisometropia higher than 2 D (143), but not the substantial numbers of patients who have lesser differences between the eyes.

Head Position

Unequal changes in monocular refraction might occur in response to unilateral blur of one eye that results from prolonged blur of one image as might occur when the head is habitually turned toward a near target or when near work is consistently placed to one side (e.g., some computer users and some children who habitually turn their head). This result has been reported as a clinical observation in adults who were continually exposed to near work on one side of their desk (145) (e.g., accountants who always keep their near work on the right side). Continued optical correction of this anisometropia would then lead to more amounts of anisometropia.

Suppression of One Eye

Clinically, patients with intermittent exotropia (IXT) frequently have suppression of one eye associated with the IXT. It is possible that suppression of an eye results in partial or complete deactivation of the blur-driven emmetropization mechanism. If unilateral deactivation occurs in IXT, the strabismic eye will undergo only genetically programmed ocular growth, whereas the other will have both genetically and visually driven ocular growth. In the case of myopic anisometropia, the eye that is habitually used will continue to emmetropize via the visually driven emmetropization mechanism while the blurred eye might surge ahead in growth because the blur-driven mechanism is not available to counteract genetically programmed ocular growth. Ultimately, significant myopic anisometropia may develop. Clinically, this has been observed; more than 50% of IXT patients ultimately develop anisometropic myopia, with the exotropic eye typically being more myopic (87). Treatment of such a patient is detailed in Case 23.6.

Case 23.6 Myopia Treatment for a Patient with Intermittent Exotropia

A 12-year-old girl was referred to our office for a vision therapy examination because her doctor had noticed that her right eye was drifting out during the visual examination. The parents had noticed the eye turn for the last few years and felt that the proportion of time that the eye turned was increasing. They felt that the eye turn was more frequent toward the end of the day and when the child was tired. The refraction was as follows:

OD: -1.25

OS: -0.50 VA 20/20+

The cover test at distance was an intermittent 25 right exotropia (deviates 10% of the time). At near, the cover test was 5 exophoria. The calculated AC/A ratio was 14:1 ($PD = 60$).

The ametropia is significant in this case and needs to be corrected. Use of added lenses can also be helpful in the treatment of this patient. In view of the high AC/A ratio, glasses can be prescribed to help control the deviation. The use of full refractive correction would significantly improve fusion at distance. Because it could also lead to a high degree of esophoria at near, investigation of the use of a bifocal is also appropriate. In this case, the use of -1.00 OD and -0.50 OS with a $+1.75$ add OD and $+1.50$ OS, along with working distance training, was prescribed. This gives a lead of focus at distance (more in the right eye) and a lag at near (more in the right eye)—both giving the right eye a stimulus to change toward less anisometropia. The feature of this case is that the patient needs a very

slight difference in each eye to keep her within the emmetropizing range, combined with substantial fusion and antisuppression therapy to help assist fusion and to enhance the effect of the refractive change therapy.

The patient used OD -1.00 , OS -0.50 with unequal add along with fusion and antisuppression therapy for 1 year. At the next examination she had a refraction of OD -0.5 , OS Pl. Her glasses were changed to this, with the same unequal near addition; she continued with this correction and fusion and antisuppression therapy twice a week at home for 1 more year, at which time she needed OD -0.25 , OS Pl. Glasses were then discontinued, but fusion and antisuppression therapy continued twice a week at home. When she was 17 she continued with no refractive correction and maintained straight eyes without suppression during all waking hours.

Age	Correction Prescribed	Other Treatment
12	Distance refractive findings: OD: -1.25 OS: -0.50 Rx given: OD: -1.00 OS: -0.50 Near add: OD $+1.75$, OS $+1.50$	Antisuppression therapy and convergence therapy to enhance fusion for 12 weeks; maintenance therapy twice a week. Therapy to maintain 45-cm working distance with proper lighting while studying.
13	Distance refractive findings: OD: -0.50 OS: Pl Rx given: OD: -0.50 OS: Pl Near add: OD $+1.75$, OS $+1.50$	Twice weekly maintenance antisuppression therapy and convergence therapy to enhance fusion. Therapy to maintain 45-cm working distance with proper lighting while studying.
14–16	No change	Twice weekly maintenance antisuppression therapy and convergence therapy to enhance fusion.
17	Distance refractive findings: OD: -0.25 OS: Pl No Rx given	Twice weekly maintenance antisuppression therapy and convergence therapy to enhance fusion.

Facial Symmetry

Martinez (146) reported the clinical observation that anisometropic patients tend to have asymmetric monocular nasopupillary distances (although the asymmetries are not consistently lateralized relative to the degree of anisometropia). Anisometropia might occur in response to asymmetric location of the orbits. For example, if one eye is laterally displaced, that eye will have to converge more than the other for near tasks. Over time, this asymmetric convergence would result in an unequal blur stimulus to one eye (assuming near work is held symmetrically despite the facial asymmetry) that might drive anisometropic changes in the RS.

HYPEROPIC ANISOMETROPIA

Development of hyperopic anisometropia higher than 1.25 D may represent a threshold that results in development of increasing anisometropia (143). Humphriss (147) and Simpson (148) demonstrated that as little as 0.75 D of unilateral blur results in central suppression of the blurred eye. In a manner similar to development of myopic anisometropia in IXT, suppression might also allow ever-increasing hyperopic anisometropia if the suppression caused by the anisometropia resulted in deactivation of the blur-driven emmetropization mechanism. In the case of hyperopic anisometropia, the eye that is habitually used will continue to emmetropize, whereas the blurred eye would lag behind in growth (presumably because of deficient genetically programmed ocular

growth), ultimately developing significant hyperopic anisometropia. Of course, the ultimate RS in these instances is a result of the interaction between visually directed ocular growth and the genetically programmed growth rate and either myopia or hyperopia might develop, depending on the relative strength of the interactions.

ANISOMETROPIC AMBLYOPIA

Clinically, a person with one emmetropic and one hyperopic eye frequently develops amblyopia in the more hyperopic eye (149). One suggested treatment of childhood amblyopia involves full correction of the RS of each eye combined with additional treatment such as occlusion and vision therapy (150) (Chapter 17). This treatment typically restores substantial vision to the amblyopic eye (150,151). However, although full correction of the RS of each eye will provide clear retinal images, emmetropization will continue from the point of correction; that is, if the right eye correction is +1.00 and the left eye correction is +4.00 (an anisometropia of 3 D), subsequent visually driven emmetropization after full correction of the RS and treatment of anisometropic amblyopia after full correction of the RS of each eye allow changes in the RS from the 3 D anisometropia difference.

Sherman (152) has criticized the technique of providing full correction to each eye in anisometropic amblyopia, suggesting instead that partial correction be provided to the amblyopic eye along with prescription of substantial amounts of time spent performing vision therapy designed to reduce suppression and increase resolution of the amblyopic eye. Provided sufficient time is spent in vision therapy, Sherman's therapy protocol should allow the amblyopic eye to somewhat normalize in RS, becoming more equal to the other eye (153).

TREATMENT OF ANISOMETROPIA

Children who develop anisometropia might be treated by reducing the power of the lens before the more anisometropic eye. Provided sufficient time is spent in vision therapy to reduce suppression (153), this technique may allow the more anisometropic eye to develop an RS more equal to the other eye, regardless of whether the anisometropia is myopic or hyperopic. To be successful, the patient should be treated before the anisometropia becomes too significant (Case 23.7). The problem with this treatment is that substantial amounts of vision therapy will be needed. Many children or parents may be unwilling to devote the time and effort required to achieve the desired results.

Case 23.7 Refractive Treatment of Hyperopia Concurrent with Treatment of Anisometropic Amblyopia

A 4-year-old boy presented for a routine preschool examination. He had no symptoms. External and internal ocular health was within normal limits. Visual acuity and refraction with cycloplegia was as follows:

OD: +3.00 -1.00 ×103	20/60
OS: +0.25	20/20
OU: 20/20	

There was a comitant 3 esophoria at 6 m and 40 cm. Fixation was central with both eyes. There was intermittent suppression of the right eye on Worth dot testing, and stereopsis was 140 seconds at 40 cm with Randot circles.

The cycloplegic refractive finding was prescribed with less power before the right eye:

OD: +2.50 -0.75 ×103	20/60
OS: +0.25	20/20
OU: 20/20	

The patient returned for reevaluation in 2 weeks with acuities unchanged from above. Two hours per day of direct occlusion and 2 hours per day of binocular antisuppression therapy were prescribed. Binocular therapy consisted of dot-to-dot books with a red pencil while wearing red/green glasses (red lens over the left eye) to enhance the acuity of the right eye and reading using a red/green bar

reader to reduce suppression. Accommodative therapy using lens flippers (starting with ± 1.25) was included at week 4. Over the next 8 weeks the print was made progressively smaller and the accommodative flippers made progressively stronger as the patient's acuity and binocular status improved as summarized in the following table.

Week	Management	Acuity of Amblyopic Eye	Stereopsis (s)
1	Exam Rx (spectacles with slightly less plus on the amblyopic eye)	Aided: 20/60	140
2	Progress visit 2 h/day direct occlusion Binocular vision therapy (VT)	Aided: 20/60 + 1	140
4	Binocular and accommodative VT	Aided: 20/40	100
6	Continue VT	Aided: 20/30	60
8	Continue VT	Aided: 20/25	40
10	Continue VT	Aided: 20/20	20

The prescription gives a lead of focus at distance (more in the right eye), giving the right eye a stimulus to change toward less anisometropia. The feature of this case is that the patient needs a very slight difference in each eye to keep him within the emmetropizing range, combined with substantial fusion and antisuppression therapy to help assist the refractive change therapy.

The patient used OD +2.50 c -0.75 \times 103, OS +0.25 along with fusion and antisuppression therapy for 1 year. At the next yearly examination he had a refraction of OD +2.00 c -0.50 \times 93, OS Pl. His glasses were changed to OD +1.50 c -0.25 \times 93, OS Pl; he continued with this correction and fusion and antisuppression therapy twice a week at home for 1 more year, at which time he needed OD +1.00 c -0.50 \times 95, OS Pl. Further reduction in the power of the right eye was unsuccessful, and glasses with a small anisometric correction (OD +1.00 c -0.50 \times 95, OS Pl) were continued along with fusion and antisuppression therapy performed twice a wk at home. Until he was 9 years old he continued with a small anisometric refractive correction (OD +1.00 c -0.50 \times 95, OS +0.25) and weekly maintenance therapy. His acuity remained 20/20 in each eye.

Age	Correction Prescribed	Other Treatment
4	Distance refractive findings: OD: +3.00 c -1.00 \times 103 OS: +0.25 Rx given: OD: +2.50 c -0.75 \times 103 OS: +0.25	Antisuppression therapy and convergence therapy to enhance fusion for 10 wk; maintenance therapy 5 days a week thereafter
6	Distance refractive findings: OD: +2.00 c -0.50 \times 93 OS: Pl Rx given: OD: +1.50 c -0.50 \times 93 OS: Pl	Antisuppression therapy and convergence maintenance therapy 5 days per week
7-9	Rx: OD: +1.00 c -0.50 \times 95 OS: +0.25	Antisuppression therapy and convergence maintenance therapy 5 days per week for 2 years and currently weekly maintenance therapy
17	Distance refractive findings: OD: -0.25 OS: Pl No Rx given	Twice weekly maintenance antisuppression therapy and convergence therapy to enhance fusion

Soft Multifocal Contact Lenses

For anisometropia treatment the goal of soft multifocal fitting is to provide a continuous relative stimulus to the peripheral retina that is different for each eye. This can be done with a soft multifocal with a different center design for each eye. For example, a myopic patient could be fitted with different center distance designs for each eye or with a standard lens for the less myopic and a high add center distance lens for the more myopic eye. This would provide relatively clear distance vision for each eye while the added power in the periphery would provide a different relative peripheral hyperopic defocus for each eye and a different stimulus to visually directed ocular growth for each eye (see Fig. 23.12).

Astigmatism

Up to 80% of infants have astigmatism (154), a much higher incidence than in children or adults. In most infants the horizontal meridian typically has the highest refractive power (155), resulting in a condition defined as against-the-rule (A-T-R) astigmatism (156). Infantile astigmatism decreases rapidly over the first 18 months of life, and by age 6 years 81% of children have less than 0.25 D astigmatism (157). Although the prevalence of astigmatism then increases slowly over the next decades of life, only about 3% of adults have over 1.00 D of astigmatism, typically with-the-rule (W-T-R) astigmatism. In a study of over 1,200 eyes, Lyle (158) found no discernible hereditary pattern for astigmatism less than 2.00 D. Indeed, Hofstetter and Rife (159) concluded that astigmatism was mostly environmentally determined. For example, Childress, Childress, and Conklin (145) described a relationship between astigmatism and occupation and suggested that eye movements inherent in some occupations or visual conditions (e.g., people with nystagmus typically have high incidence of W-T-R astigmatism (160)) influence the amount and direction of astigmatism that adults develop.

AGAINST-THE-RULE ASTIGMATISM IN INFANCY, IN SCHOOLCHILDREN, AND IN PRESBYOPIA

The high incidence of A-T-R astigmatism in infancy probably results from a number of factors related to genetically programmed ocular growth. The small infant eye typically has a relatively large angle lambda (161) (the angle between the pupillary axis and the line of sight subtended at the entrance pupil of the eye (162)). This large angle lambda, which results from the eccentric placement of the fovea in the small infant eye, ranges from 2 to 7 degrees in infants but is less than 2 degrees in the longer eyes of myopic adults. The large infantile angle lambda is a source of measures of off-axis astigmatism and probably results in overestimation of the incidence of apparent A-T-R astigmatism (163,164).

A significant factor leading to the high incidence of A-T-R astigmatism relates to the ocular structure. Because the vertical diameter of the globe is slightly less than the horizontal diameter (165), the plane of the crystalline lens is slightly tilted in such a way that the top is 2 to 3 degrees forward (165,166). Tilt of the lens results in A-T-R astigmatism. Visual growth is promoted by small amounts of sustained "hyperopic" blur that increase scleral tension (leading to axial elongation) and reduce zonular tension (retarding lens growth). Axial elongation and lens diameter changes might initially lead to increased crystalline lens tilt (and increased astigmatism) until overall ocular growth allows the lens to better fit within the anterior portion of the globe. This growth process could be the source of the high incidence of A-T-R astigmatism observed in infants, the A-T-R astigmatism frequently observed in grade school children before the initial measurement of myopia (101,167), and the increase in A-T-R astigmatism in presbyopia when the eye changes in hyperopia (168). In these cases observation of A-T-R astigmatism may be a clinical sign that a change in ocular dimensions is occurring. In line with this growth hypothesis, Lyle (169) found no evidence that the astigmatic axis rotates with time from with-the-rule through oblique to against-the-rule. Instead, he found that the incidence of W-T-R astigmatism decreases with age, and A-T-R astigmatism gradually increases in rate of occurrence.

TREATMENT OF ASTIGMATISM

Development of small amounts of A-T-R astigmatism in childhood is probably a clinical sign that anterior segment ocular growth is occurring (170) and may also indicate that axial length change is imminent. Treatment of these children should be designed to minimize myopia development, as described in Cases 23.1 to 23.3.

Larger amounts of astigmatism (>1.00 D W-T-R) may influence emmetropization (15); the child will either emmetropize as well as possible (a “plano” equivalent sphere) or develop substantial myopia by adulthood. In general, treatment should be designed to clear the retinal images, followed by treatment to minimize development of myopia (Case 23.8).

Case 23.8 Treatment of Myopia and Astigmatism Incorporating Reverse Geometry Rgp Lenses

A 9-year-old girl was brought for an examination because she failed a school screening. The refraction was as follows:

OD: -1.25 c -2.25×180 VA 20/20
 OS: -1.50 c -2.25×180 VA 20/20

The cover test at distance was a 5 exophoria at distance and near. The calculated AC/A ratio was 6:1 (PD = 60).

The myopia and astigmatism are significant in this case, and correction will be needed to allow clear distance vision in school. The use of added lenses can be helpful in the treatment of this patient. In this case we want her to have a lead of accommodation when she reads. Clinical testing with MEM retinoscopy indicated a lead of accommodation at her normal 37-cm working distance with a $+2.25$ near addition. This was prescribed in bifocal form:

OD: -1.25 c -2.25×180
 OS: -1.50 c -2.25×180
 Near add $+2.25$

In this case the use of a $+2.25$ add OU is a valuable optical management technique to achieve a near lead of accommodation, while the distance refraction gives a distance lead as well. Thus, provided the child can be induced to read at the correct distance, she will have continued stimulus to change her refractive error toward less myopia. Training was provided to help her learn to maintain the correct reading distance. Over time her myopia remained stable at the following:

OD: -1.00 c -1.75×180
 OS: -1.25 c -1.75×180
 Near add $+2.25$

She was successfully fitted with reverse aspheric RGP lenses when she was 14. Her unaided refractive error during the day remains at 0.50 c -0.50×180 in each eye. This is maintained with 2 nights per week of contact lens wear and continued use of $+1.50$ reading glasses at a working distance that maintains a lead of accommodation at near.

Age	Correction Prescribed	Other Treatment
9	OD: -1.25 c -2.25×180 OS: -1.50 c -2.25×180 Near add $+2.25$	Therapy to maintain working distance at 37 cm.
9–13	OD: -1.00 c -1.75×180 OS: -1.25 c -1.75×180 Near add $+2.25$	Working distance counseling and encouragement to continue full-time glasses when reading.

14	OD: Reverse aspheric CL OS: Reverse aspheric CL Reading glasses +1.50 add Wears lenses every night; unaided VA 20/20–1 OD, OS	Therapy to maintain working distance at 37 cm. CL follow-ups at days 1, 3, 7, and 14. She achieved 20/20 unaided VA for a full day in 14 days and continued nightly wear. Therapy to maintain 40-cm working distance with proper lighting while studying. Encouragement to continue full-time glasses when reading.
15	No change (new CL) Wears lenses every other night; unaided VA 20/20– 1 OD, OS	No change

Summary and Conclusions

The shift from the large variation in RS seen in infancy to the nearly emmetropic state found in most adults is accompanied by development of a leptokurtotic distribution of the RS. This process, often described as emmetropization, has been characterized here using a conceptual model that takes the form of dual intersecting feedback loops in which the genetically programmed ocular growth of each eye is altered by blur derived from interactions between accommodation and vergence (Fig. 23.3) and relative peripheral defocus. In the model, myopic visual growth results from prolonged relative hyperopic blur via lag of accommodation at near and relative peripheral hyperopic defocus. Visual growth feeds into and modifies genetically programmed ocular growth to result in the final RS.

The conceptual model in Figure 23.3 allows specific predictions about the changes that influence development and maintenance of a stable RS as well as about possible treatments of refractive error. Table 23.2 summarizes the predicted changes in refractive state from a visually driven emmetropization mechanism, which could form a basis for modifications of clinical care that might normalize an anomalous RS or maintain an existing emmetropic RS. Unfortunately, it is unlikely that all patients can become emmetropic despite the potential of treatments based on the model. For example, it is possible that many patients who have the risk factors indicating the possibility of developing myopia will have a combination of genetically programmed and visually driven ocular growth to overwhelm all interventions. The clinical challenge is to determine, through clinical research and prospective randomized trials, which treatment or treatments effectively influence the RS to change in the desired manner. For our patients the ultimate goal is a more normal RS achieved via utilization of visually directed emmetropization to counteract the influence of excessive or deficient genetically programmed ocular growth.

TABLE 23.2 CHANGES IN REFRACTIVE STATE FROM VISUALLY DRIVEN EMMETROPIZATION MECHANISM

Age	Description	Probable Maximum Amount of Change	Time of Change	Basis for Prediction (Selected Examples)
0–1	Infancy	11 D	Mo	Basic research (53,54) Clinical measurement (42)
1–5	Preschool	9 D	Mo to y	Basic research (53,54) Clinical measurement (60)
6–12	Grade school	7 D	Y	Clinical observation (32,34)
12–19	Puberty	5 D	Y	Clinical observation (46,58)
20–44	Adult	3 D	Y	Clinical observation (62)
44+	Mature adult	1.5 D	Y	Clinical observation (151)

Study Questions

1. What is the distribution of refractive state at birth? How does this distribution change over the first few years of life?
2. If the axial length increases approximately 6 mm between ages 1 and 8 years, how can the eye maintain emmetropia?
3. How can there be a similar refractive error over a large range of axial lengths?
4. What is the relation between the amount of myopia your parents have and the amount of myopia you may have?
5. Some studies have shown that bifocals help reduce the rate of myopia progression while others have not shown the same results. What factors might lead to these different results? How would you control them?
6. How does the peripheral retina influence ocular growth?
7. What happens to the refractive error when glasses are prescribed—do glasses make your patient's eyes worse?
8. What type of soft lens might help decrease the rate of myopia progression? Describe the lens design and the fitting?
9. What type of therapies/treatments could help decrease the rate of myopia progression?
10. Is there any possible therapy for anisometropia?

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Binocular Vision Problems Associated with Refractive Surgery

The popularity of refractive surgery has grown over the years, and an estimated 1.3 million Americans had laser-assisted in situ keratomileusis (LASIK) surgery in 2005 (1). Optometrists play a significant advisory role with patients before surgery, comanage patients undergoing refractive surgery, and care for the patient after surgery. A 2004 survey on refractive surgery revealed that 55.5% of surgeons comanaged patients, with another ophthalmologist or optometrist performing the preoperative and postoperative care (2).

Despite improvement in technologies and the increased experience of surgeons, complications do occur. In the 2004 refractive error survey, the most commonly reported complications were dry eye, glare, diffuse lamellar keratitis, and epithelial ingrowth (2). Other authors have reported infection, scarring, cataract formation, and corneal decompensation (3). In a survey of complications in 101 dissatisfied patients seeking consultation after refractive surgery, Jabbur, Sakatani, and O'Brien (4) reported that the most common subjective complaints were blurred distance vision (59%), glare and night-vision disturbances (43.5%), and dry eyes (29.8%). Although strabismus, binocular vision problems, and diplopia do not appear among the most common complications of refractive surgery, a review of the literature indicates that these problems do occur after refractive surgery (4–23). Based on our experience with the underdetection of binocular vision disorders in the general population by ophthalmic clinicians, we suspect that the true prevalence of these problems is higher than indicated in the literature. Thus, in addition to advising and comanaging refractive surgery patients, optometrists must be prepared to deal with the binocular vision complications that occur as a result of refractive surgery.

This chapter reviews the literature on binocular vision–related complications of refractive surgery, recommends strategies for minimizing such complications preoperatively, and recommends treatment strategies to deal with such complications when they do occur.

Review of Refractive Surgery

LASER IN SITU KERATOMILEUSIS

LASIK is a lamellar laser refractive surgery in which the excimer laser ablation is done under a partial-thickness lamellar corneal flap. The procedure permanently changes the shape of the cornea with an excimer laser and a microkeratome or femtosecond laser. The microkeratome or femtosecond laser produces a hinged lamellar flap in the cornea. The microkeratome uses an oscillating blade to cut the flap after immobilization of the cornea. Microkeratome cuts can vary widely in depth, even with the same preset thickness. The femtosecond laser provides more accuracy in flap thickness than was available in previous methods and is less dependent on corneal curvature. As compared with surface ablation, LASIK results in earlier and faster improvement of uncorrected visual acuity, causes less postoperative discomfort, and offers improved stability and predictability. With LASIK, however, there are risks of flap-related complications such as wrinkles, folds, and diffuse lamellar keratitis (24,25).

SURFACE ABLATION TECHNIQUES

This type of laser refractive surgical procedure uses the excimer laser to ablate the most anterior portion of the corneal stroma. These procedures do not require a partial-thickness cut into the stroma, and thus leave a larger residual bed to retain the cornea's biomechanical strength (25). However, ablation of the anterior stroma leads to a wound-healing response that might result in more stromal haze and more serious scarring than those resulting

from LASIK. Recovery after surface ablation is slower and more painful than after LASIK. Methods of surface ablation being used include photorefractive keratectomy, laser-assisted subepithelial keratectomy (LASEK), and epi-LASIK. These methods differ in the manner in which the epithelial layer is handled in the surgery.

Photorefractive Keratectomy

Photorefractive keratectomy (PRK) is the second most popular laser vision correction procedure. Like LASIK, PRK uses an excimer laser to reshape the cornea. But in PRK, instead of creating a corneal flap, the surgeon removes the corneal epithelium and then applies the excimer laser treatment to the surface of the eye. The epithelium might be removed in several ways, including excimer laser destruction, mechanical debridement with a surgical blade, abrasion with a brush, or the use of alcohol to loosen the epithelium. Because epithelium is removed, a large epithelial defect is present, and healing occurs by migration and division of surrounding epithelium. Although healing time is longer after PRK, it produces visual results that are comparable to LASIK. PRK is often the treatment of choice for patients whose corneas are too thin for LASIK.

Laser-assisted Subepithelial Keratectomy

LASEK is another surface ablation procedure designed for patients whose corneas are too thin for LASIK. LASEK resembles PRK in that the surgeon does not create a LASIK-style flap in the first step of the procedure. Instead of removing the outer corneal epithelium completely, the LASEK surgeon replaces the epithelial sheet after the excimer laser treatment is completed. LASEK offers results that are similar to those achieved by LASIK, but (like PRK) it involves more postoperative discomfort and longer healing times. The epithelium is protected from blinks and eye movements by the use of a bandage contact lens.

Epi-LASIK

Epi-LASIK is yet another surface ablation procedure for patients whose corneas are too thin for LASIK. Epi-LASIK is very similar to LASEK, but instead of subjecting the eye to a dilute alcohol solution to loosen an epithelial flap, epi-LASIK uses a hand-held device to create a hinged sheet of corneal epithelium. After the eye is reshaped with an excimer laser, this epithelial flap is returned to its original position and held in place with a bandage contact lens for several days. Epi-LASIK patients usually experience some postoperative discomfort, but reportedly less than that experienced by patients who have undergone PRK or LASEK.

PHAKIC INTRAOCULAR LENSES

The phakic intraocular lens (IOL) procedure is usually reserved for patients whose refractive error is too severe to be corrected by LASIK surgery or for patients whose corneas are too thin for LASIK, PRK, or epi-LASIK. In the phakic IOL procedure, a thin plastic lens is implanted inside the eye either in front of the iris or behind the pupil. Some refractive surgeons today believe that phakic IOLs are the procedure of choice for high myopia and high hyperopia. Advantages of phakic IOLs include the possibility to remove the implanted lens if problems arise or a change in the power of the lens is required, and the fact that no thinning of the cornea is required. Because the phakic IOL procedure is relatively new, no long-term studies are available to assess the procedure's potential for complications such as cataract formation and the loss of endothelium cells. Still, phakic IOL implantation currently appears to be safe and effective for many patients who are not good candidates for LASIK.

The 2004 Refractive Surgery Survey revealed that LASIK was the current refractive surgery procedure of choice, although wavefront-guided ablation was gaining in popularity (2). Surface ablation techniques such as PRK, LASEK, and epi-LASIK were also popular, as was implantation of phakic intraocular lenses. In 2004, 71% of the refractive surgeons surveyed reported using PRK, 40.8% LASEK, and 17.4% phakic IOLs (2).

Binocular Vision Complications of Refractive Surgery for Myopia, Hyperopia, and Astigmatism

A variety of binocular vision problems have been reported after refractive surgery, including aniseikonia related to induced anisometropia (5,10,11), decompensated esodeviation (5,12,13,26,27), decompensated exodeviation (5,9,16,17,20,23,27), and decompensated fourth nerve weakness (5,19,27). Kushner and

TABLE 24.1 POTENTIAL CAUSES OF BINOCULAR VISION AND ACCOMMODATIVE PROBLEMS AFTER REFRACTIVE SURGERY

Complications associated with refractive surgery
<ul style="list-style-type: none"> • Scarring • Ablation zone too small • Decentered treatment zone • Astigmatic axis or power change • Residual hyperopia in presence of accommodative esotropia • Residual hyperopia in presence of anisometropic exotropia • Overcorrection
Previous use of prism
<ul style="list-style-type: none"> • Lack of attention to previous history of prism correction
Aniseikonia
<ul style="list-style-type: none"> • Lack of attention to previous history of aniseikonia • Induced aniseikonia
Mono vision
<ul style="list-style-type: none"> • Poor adaptation to creation of monovision • Diplopia due to fixation switch
Accommodative/convergence issues
<ul style="list-style-type: none"> • Elimination of accommodative convergence to supplement inadequate fusional vergence

Based on Kushner BJ, Kowal L. Diplopia after refractive surgery: occurrence and prevention. *Arch Ophthalmol* 2003; 121:315–321.

Kowal (5) completed a retrospective review of patients seen in two private strabismus practices and found 28 patients who experienced chronic monocular or binocular diplopia after refractive surgery. Their objective was to determine the causative mechanism for the diplopia of these patients, and they established five different causes (Table 24.1).

COMPLICATIONS ASSOCIATED WITH THE REFRACTIVE SURGERY

Creation of an intralamellar flap during LASIK procedures increases the risk of intraoperative complications such as an irregular flap and a dislodged flap. Other complications can also occur, such as scarring, an ablation zone that is too small, and a decentered treatment zone. These problems were all implicated as causes of diplopia in Kushner and Kowal's (5) case series. In two cases, patients reported monocular diplopia caused by scarring and a small ablation zone. Other surgical complications are related to an undesirable refractive endpoint. For example, surgically induced anisometropia can cause induced aniseikonia, or a unilaterally blurred retinal image can cause diplopia (Case 24.1), and leaving an accommodative esotrope with residual hyperopia can lead to a decompensated esotropia (Case 24.2).

Case 24.1 Surgically Induced Anisometropia Causing Aniseikonia

History

Chris, a 26-year-old accountant, presented with complaints of eyestrain, blurry vision, and diplopia after about 20 minutes of reading. He had had these problems for several months since having LASIK for myopia and had been referred for evaluation. He had been told in the past that one eye occasionally turned out, but, in his previous visits to eye doctors, no treatment other than glasses had been recommended. His medical history was negative, and he was not taking any medication.

Examination Results

Previous prescription (pre-LASIK)	−3.50 −4.50
Interpupillary distance (IPD):	65 mm
VA (distance, uncorrected):	OD: 20/20 OS: 20/25
VA (near, uncorrected):	OD: 20/20 OS: 20/25
Near point of convergence	
Accommodative target:	8 cm
Penlight:	8 cm
Cover test (distance):	15 exophoria
Cover test (near):	12 exophoria
Subjective:	OD: PL −0.25 × 180, 20/20 OS: +1.00 −0.75 × 50, 20/20
Cycloplegic:	OD: +0.25 −0.25 × 180, 20/20 OS: +1.00 −1.00 × 47, 20/20
Distance lateral phoria:	15 intermittent exotropia, POTA 70%
Base-in vergence (distance):	X/12/−2
Base-out vergence (distance):	6/10/6
Near lateral phoria:	13 exophoria
−1.00 gradient:	9 exophoria
Gradient AC/A ratio:	4:1
Calculated AC/A ratio:	4.8:1
Base-in vergence (near):	4/8/−3
Base-out vergence (near):	6/9/2
Vergence facility:	3 cpm; difficulty with base-out and base-in
Negative relative accommodation (NRA):	+1.50
Positive relative accommodation (PRA):	−1.25
Accommodative amplitude (push-up):	OD: 11 D; OS: 11 D
Monocular accommodative facility (MAF):	OD: 11 cpm; OS: 11 cpm
Binocular accommodative facility (BAF):	2 cpm
Monocular estimation method (MEM) retinoscopy:	+0.25

Pupils were normal; all external and internal health tests were negative; the deviation was comitant; and color vision testing revealed normal function.

Diagnosis

Analysis of the results of accommodative testing revealed a normal amplitude, facility, and accommodative response. The NRA and PRA were both low; given the normal accommodative function, these findings reflect a problem with fusional vergence. The findings for both positive fusional vergence (PFV) and negative fusional vergence (NFV) were reduced on direct measures and indirect tests of fusional vergence. The low NRA, PRA, and reduced BAF results suggested problems with fusional vergence. These findings, and the significant exophoria at both distance and near, led to the conclusion that the most likely cause of Chris's symptoms was a previously existing vergence disorder that was aggravated by the blur of the left eye after LASIK.

Treatment

Chris was prescribed a toric contact lens for the left eye and given home vision therapy procedures to practice. We followed the sequence outlined in Chapter 10 (Table 10.7); 8 weeks of home vision therapy with two visits of in-office vision therapy were necessary to achieve a successful result.

Outcome

At the end of therapy, Chris reported that he was once again able to read for as long as he wanted without any discomfort, provided that he wore his contact lens. He is currently considering whether to seek enhancement for the left eye.

Case 24.2 Residual Hyperopia Causing Decompensated Esotropia

History and Significant Clinical Findings

A 28-year-old woman presented with a complaint of eyestrain, blurred vision, and inability to concentrate after 10 minutes of reading. These problems had been bothering her since she had had LASIK for hyperopia 4 months prior. The pre-LASIK refraction was +3.75D in each eye; she reported that she had worn these lenses since childhood, when her eyes “crossed at times.” The current (post-LASIK) refraction was +1.00 D OD and OS; the unaided distance phoria was 6 esophoria; and the unaided near phoria was 10 esophoria (IPD = 58 mm). The calculated AC/A ratio in this case is 7.4:1. Near point testing through subjective refraction revealed the following:

NRA:	+2.50
PRA:	−1.00
Near lateral phoria:	4 esophoria
Base-in (near):	4/10/4
Base-out (near):	16/26/16
Vergence facility:	0 cpm; diplopia with base-in
MEM retinoscopy:	+1.25 OD and OS
BAF:	Diplopia with −2.00, 0 cpm
MAF:	12 cpm

Diagnosis

Analysis of the near point data indicates that all of the direct and indirect measures of negative fusional vergence are low. Because the AC/A ratio was high, these findings, and the significant esophoria at both distance and near, led to the conclusion that the most likely cause for the symptoms was a previously existing vergence disorder (esophoria or accommodative esotropia) that was aggravated by the residual accommodation needed in response to uncorrected hyperopia after LASIK surgery.

Treatment

The use of added plus lenses is indicated in this case and will eliminate the remaining esophoria, balance the NRA/PRA relationship, and normalize the MEM and base-in findings. Because the AC/A

ratio is high, it is important to prescribe for the ametropia in this case. Prescribing +1.00 will reduce the near phoria to about 2 esophoria. The near point analysis in this case suggests that a +0.75 to a +1.00 add is appropriate.

Outcome

With full plus lenses and a +0.75 near addition, the patient is able to read and work with comfort all of her waking hours. She is currently considering whether to seek additional LASIK correction for hyperopia. So far she is happy simply having to wear glasses for work and not full time.

PREVIOUS PRISM WEAR

Refractive surgery can allow a preexisting binocular vision problem that has been controlled with prism to become manifest. Examples of binocular vision problems that respond to prism are vertical deviations, divergence insufficiency, and convergence insufficiency. Three patients in the Kushner and Kowal (5) sample experienced diplopia after refractive surgery because the patients no longer used prism after surgery. One might ask how the surgeon could allow this happen. In some cases, the patient or the doctor may be unaware that prism is incorporated into the eyeglasses (Case 24.3). In other cases, the surgeon may believe that the patient will be able to function well in spite of the elimination of the prism prescription.

Case 24.3 Previous Prism Wear

History

K.P., a 36-year-old woman, had uneventful LASIK surgery in both eyes. Although her visual acuity was excellent, she complained of intermittent double vision associated with reading almost immediately after the surgery. The patient was sent for binocular vision management.

At her examination about 10 weeks after the refractive surgery, she still complained of intermittent vertical diplopia. We were unable to obtain her previous records. However, she did have three pairs of eyeglasses, which she brought with her. All three glasses had 3 Δ base-down OD (split between the two eyes). She remembered that her former doctor had prescribed a special lens to make her eyes work better, but was unaware of the diagnostic condition for which the prism was prescribed. She also stated that this issue had not been discussed before she was referred for refractive surgery, nor did the refractive surgeon discuss the issue. Her eyeglass prescription before surgery was OD -3.50 , 1.5 base-down and OS -3.75 , 1.5 base-up.

Significant Clinical Findings

VA (uncorrected):	OD: 20/20– OS: 20/20
Near point of convergence:	7.5 cm break, 10 cm recovery
Cover test (distance, uncorrected):	2 Δ right hyperphoria
Cover test (near, uncorrected):	4 Δ right hyperphoria
Maddox rod testing in all fields of gaze	Right hyperphoria increases to 8 Δ in left gaze and decreases to 2 Δ in right gaze. The right hyperphoria increases with head tilted to the left.
Subjective:	OD: -0.25 , 20/20 OS: $+0.25$, 20/20

Distance lateral phoria:	Orthophoria
Distance vertical phoria:	2 Δ right hyperphoria
Associated phoria:	1 base-down OD
Near lateral phoria:	4 Δ exophoria
Near vertical phoria:	5 Δ right hyperphoria
Associated phoria:	3.5 base-down OD
–1.00 gradient:	Orthophoria
Base-in vergence (near):	X/8/6
Base-out vergence (near):	X/10/6
Vergence facility:	0 cpm; unable to fuse with 12 base-out or 3 base-in

Diagnosis

The cover test revealed a noncomitant right hyperphoria that was worse at near. Comitancy testing suggested a right superior oblique weakness. Step vergence and vergence facility were reduced, which is characteristic in the presence of a vertical deviation. These findings supported the diagnosis of a decompensated right superior oblique weakness. This problem was certainly present before the refractive surgery and was a strong contraindication for the surgery. Lack of attention to binocular vision is a potential risk factor for complications after refractive surgery, as evidenced by this case.

Treatment

We prescribed 2.0 base-down OD and 1.5 base-up for reading and computer work.

Outcome

K.P. reported almost immediate relief of her symptoms with the prism correction, and she could read for as long as necessary without diplopia.

ANISOMETROPIA AND ANISEIKONIA

Anisometropia and aniseikonia can be induced in several ways as a result of refractive surgery. A patient with isometric myopia may end up with anisometropia and aniseikonia because of surgeon error. A patient may be unhappy with the results of the first eye and decide not to have the second eye procedure done (Case 24.4). In other cases, anisometropia may be purposely planned by the surgeon with the objective of creating a monovision result. Another possible occurrence of aniseikonia would be in a situation in which the patient presents with anisometropia (which is axial) and is essentially comfortable, with no binocular vision issue with eyeglasses. When the anisometropia is eliminated by refractive surgery, the patient experiences induced aniseikonia because there is now a significant difference in axial length between the two eyes and no refractive error; the image sizes will be different and may cause binocular vision disorders.

Case 24.4 Surgically Induced Anisometropia

History and Significant Clinical Findings

A 38-year-old woman presented with a complaint of eyestrain and inability to concentrate when reading. These problems had been present since she had undergone PRK for myopia in the left eye 4 months prior. The postoperative pain from the PRK had made her decide to not have the second

(right) eye done. The pre-PRK refraction was -5.25 D in each eye; she reported that she had worn lenses of approximately this power since junior high school. The current (post-PRK) refraction was OD -5.25 D and OS $+0.50$ c -0.50×007 with 20/20 corrected vision in each eye. The unaided distance phoria was 2 exophoria at distance and near (IPD = 61 mm). The calculated AC/A ratio in this case was 6.1:1.

Diagnosis

All of the direct and indirect measures of fusional vergence and accommodation were normal. Because the AC/A ratio was also normal, these findings suggested that the most likely cause for the symptoms was the large anisometropia that had resulted from PRK on only one eye.

Treatment

Lens correction is indicated and should reduce the symptoms. She was fitted with a silicone hydrogel lens for the right eye. She was prescribed artificial tears as necessary.

Outcome

With the contact lens, she has mild symptoms remaining, partially related to dry eye and partially to residual image size difference. Artificial tears provide some relief for her dry eye, and she is currently considering whether to undergo further refractive surgery.

MONOVISION

The intentional optical correction of one eye for distance viewing and the other eye for near viewing is sometimes used by refractive surgeons for presbyopic patients who prefer not to wear reading glasses. This monovision correction is similar to that used in contact lens fitting for presbyopic patients so that they can read without glasses. The success rates for monovision contact lenses is about 70% (28), and similar results (from 73% to 97%) have been reported for monovision refractive surgery (21,29). However, if a patient has a preexisting binocular vision disorder, unilateral blur caused by monovision correction could result in decompensation (Case 24.5), similar to the diplopia discussed in Case 24.1 that had resulted after decompensated exodeviation from the blurred retinal monocular image of one eye.

Case 24.5 Decompensation of Strabismus Due to Unrecognized Preexisting Binocular Vision Problems

History and Significant Clinical Findings

A 48-year-old office manager presented for consultation prior to LASIK. She had been considering LASIK and wanted to know whether monovision would be an acceptable treatment for her. She had been told in the past that one eye occasionally turned out, but in her previous visits to eye doctors, no treatment other than glasses had been recommended. Her medical history was negative except for high blood pressure, which was controlled by medication.

Her refractive error was -1.50 in each eye with 20/20 corrected distance acuity and a near addition of $+1.75$. There was a 15 intermittent exotropia at 6 m. She felt that her eye only turned when she was very tired and estimated that this occurred no more than one or two times per month—the proportion of time aligned being more than 99%. Analysis of the results of vergence and accommodative testing revealed essentially normal amplitude, facility, and vergence responses, with reduced accommodation secondary to presbyopia.

Diagnosis

Testing her with a -1.50 contact lens on the dominant right eye and no lens on the left revealed that her intermittent exotropia occurred about 25% of the time in the office. She was advised to avoid monovision LASIK because the eye turn increase was so dramatic after only a brief monovision trial.

Treatment

She subsequently had LASIK surgery performed on both eyes for distance and wears glasses for reading.

Outcome

The LASIK result was excellent, and with her reading glasses she does not report any diplopia or increase in the amount of time her eye turns.

Pre-LASIK Monovision Trial

Because unilaterally blurred retinal images may cause decompensation of an existing heterophoria, it is important for the patient with a binocular vision problem (e.g., intermittent exotropia, vertical heterophoria) who is thinking of undergoing monovision LASIK to have a detailed evaluation prior to surgery. The goal of this evaluation is to determine, if possible, whether monovision LASIK will be a successful treatment. Westin, Wick, and Harrist (28) surveyed contact lens diplomates of the American Academy of Optometry and found that most of the diplomates feel that up to 4 weeks may be needed to determine whether monovision contact lens correction will be successful.

Based on the findings of Westin, Wick and Harrist (28), we suggest that all patients with binocular vision problems who are thinking of undergoing monovision LASIK have a 2- to 4-week monovision contact lens trial. If any symptoms that seem related to binocular vision problems are exposed during this trial, the patient can then participate in an informed decision-making regarding whether to continue with monovision LASIK or go for another refractive procedure, or not undergo refractive surgery at all.

Kushner and Kowal (5) reported on patients with preexisting and controlled intermittent exotropia and/or superior oblique paresis who had developed diplopia after refractive surgery. Another interesting condition is fixation switch diplopia (30), which may occur in a patient who has been a unilateral strabismic for many years. This patient fixates with the right eye, for example, at both distance and near. If refractive surgery creates a monovision situation, the patient may experience diplopia when forced to fixate with the nondominant eye (Case 24.6).

Case 24.6 Surgically Induced Monovision Causing Diplopia

History and Significant Clinical Findings

A 51-year-old woman presented with a complaint of intermittent binocular diplopia, blurred vision, and severe dry eye. These problems had been present since monovision LASIK for myopia 3 months prior. Unaided distance acuity was OD 20/30 and OS 20/50-. At near, her unaided acuity was OD 2 M and OS 0.75 M. The pre-LASIK refraction was OD -3.25 D and OS -4.50 . The current (post-LASIK) refraction was OD $+1.25$ D \times -1.25 \times 35 (20/20-) and OS -1.25 (20/20). The unaided distance phoria was 6 intermittent esotropia in primary gaze, with a restriction of the left eye in left gaze due to Duane syndrome in the left eye. She had single vision at distance when she fixated with her right eye and binocular diplopia at near when she fixated with her left eye.

Diagnosis

All measures of fusional vergence and accommodation were reduced, as was her stereopsis. These findings suggested that the most likely cause for the symptoms was fixation switch diplopia caused by the monovision LASIK–induced anisometropia, which forced her to alternate fixation from right eye fixation at distance to left eye fixation when reading.

Treatment

Lens correction is indicated for near so that she does not have to switch fixing eyes when reading. She was prescribed reading glasses with 3 base-out prism before the left eye. The dry eye was treated with Restasis and artificial tears with some success.

Outcome

With the lens, she has moderate remaining dry eye symptoms, but her diplopia was relieved. Artificial tears provide some relief of her dry eye, and she is currently considering whether to undergo punctal plug procedures.

The presence of a noncomitant deviation could cause a similar problem. In such a situation, the deviation may be controlled before surgery; however, after refractive surgery creates monovision, when the patient fixates with the eye with the affected muscle, the angle of deviation (secondary angle of deviation) will be larger and the patient may no longer be able to control the binocular vision problem.

ACCOMMODATIVE AND CONVERGENCE ISSUES

Several problems can occur when the refractive error is altered in patients with preexisting binocular vision disorders.

- *Exodeviations with intentional overminus corrections.* These patients use accommodative convergence to help control the exodeviation. If refractive surgery eliminates the myopia, the patient can no longer use accommodative convergence to supplement fusional vergence and may become symptomatic.
- *Accommodative esotropia secondary to hyperopia.* When wearing eyeglasses to correct the hyperopia, the esodeviation is reduced or eliminated, minimizing the need to use negative fusional vergence. The hyperopia must be totally eliminated after LASIK or the patient will be forced to rely on negative fusional vergence to control the esodeviation.
- *Convergence excess patient with myopia who reads without glasses or uses a bifocal.* Such a patient is comfortable when reading without the myopic correction or through a bifocal because it minimizes the esodeviation at near and allows the patient to use relaxation of accommodative convergence to supplement the inadequate negative fusional vergence. After refractive surgery, the patient can no longer benefit from removing the myopic prescription.
- *Accommodative spasm patients appear to have more myopia than they actually have.* These patients have distance blur caused by excessive accommodation. After refractive surgery, the patient may be significantly overcorrected unless he/she had been properly treated prior to surgery (Case 24.7).

Case 24.7 Accommodative Spasm

History

Sam, a 26-year-old stockbroker, was sent for evaluation prior to LASIK when the LASIK center found a significant mismatch between his dry and cycloplegic refractions. He presented with complaints of blurred distance vision and tired eyes at the end of his 14-hour workday. Sam felt that his vision was

better when driving to work and worse at night when coming home. He started his current job about 4 years ago, after graduating from college, and noted that his problems have been progressing. He had had his eyes examined several times as a child; on each occasion, his vision has been normal. Sam had recently been examined by his general physician, and all findings were normal. He was not taking any medication.

Examination Results

VA (distance, uncorrected):	OD: 20/40 −2 OS: 20/40 −2
VA (near, uncorrected):	OD: 20/20 OS: 20/20
Near point of convergence	
Accommodative target:	5 cm
Penlight:	5 cm
Cover test (distance):	Orthophoria
Cover test (near):	2–4 esophoria
Subjective:	OD: −1.00, 20/20 OS: −1.00 −0.25 × 90, 20/20
Cycloplegic subjective:	OS: PL −0.25 × 90, 20/20 OS: +0.25 −0.25 × 90, 20/20
Distance lateral phoria:	Orthophoria
Base-in vergence (distance):	X/6/3
Base-out vergence (distance):	10/20/9
Near lateral phoria:	2 esophoria
−1.00 gradient:	5 esophoria
Gradient AC/A ratio:	3:1
Calculated AC/A ratio:	6.8:1
Base-in vergence (near):	4/16/12
Base-out vergence (near):	18/25/16
Vergence facility	12 cpm
NRA:	+1.25
PRA:	−2.50
Accommodative amplitude (push-up):	OD: 10 D; OS: 10 D
MAF:	OD: 2 cpm; slow response with plus OS: 2 cpm; slow response with plus
BAF:	0 cpm; cannot clear plus
MEM retinoscopy:	−0.25 OD and OS

Pupils were normal; all external and internal health tests were negative; the deviation was comitant; and color vision testing revealed normal function.

Diagnosis

Because the phoria is eso, analysis should begin with the NFV group data. In this case, both the direct and indirect measures indicate adequate NFV. The smooth vergence findings are normal, as are the PRA and BAF findings. As we have suggested in Chapter 2, the next step is to analyze the data from the accommodative group. All accommodative testing revealed difficulty relaxing accommodation. The distance refractive measures were significantly less minus during cycloplegic evaluation; both NRA and MAF test findings were low; and MEM retinoscopy revealed overaccommodation. Based on this analysis, we reached a diagnosis of accommodative excess.

Treatment

We suggested postponing LASIK and prescribed a program of home vision therapy that lasted 3 months.

Outcome

Reevaluation at the end of therapy revealed that Sam was symptom free, with normal vergence and accommodative findings and a subjective refraction of OD PL and OS +0.25 with 20/20 acuity in each eye. LASIK was postponed indefinitely.

Optometric Role

The optometrist can play an important role in the comanagement of patients before and after refractive surgery to identify patients who may be at risk for binocular vision problems after refractive surgery and to diagnose and treat complications that occur after refractive surgery.

IDENTIFYING PATIENTS AT RISK FOR BINOCULAR VISION COMPLICATIONS ASSOCIATED WITH REFRACTIVE SURGERY

Diagnostic Evaluation before Refractive Surgery

The battery of tests for the general binocular vision evaluation, described in Chapter 1, provides the information required to identify patients at risk for binocular vision disorders after refractive surgery (Table 24.2).

TABLE 24.2 RECOMMENDED TEST BATTERY FOR THE IDENTIFICATION OF PATIENTS AT RISK FOR BINOCULAR VISION COMPLICATIONS AFTER REFRACTIVE SURGERY

General test battery	
<i>Binocular vision assessment</i>	
Measurement of the phoria, comitancy and AC/A ratio	Cover test at distance in all diagnostic fields of gaze, at near, and in the reading position
Assessment of positive fusional vergence (PFV) and negative fusional vergence (NFV)	
DIRECT MEASURES	Step vergence testing Vergence facility testing
INDIRECT MEASURES	Negative relative accommodation (NRA) Positive relative accommodation (PRA) Binocular accommodative facility (BAF) Monocular estimation method (MEM) retinoscopy
Convergence amplitude	Near point of convergence
Sensory status	Worth four-dot test Stereopsis testing
<i>Accommodative assessment</i>	
DIRECT MEASURES	Monocular amplitude of accommodation Monocular accommodative facility (MAF) testing
INDIRECT MEASURES	BAF testing NRA/PRA MEM retinoscopy
Other important testing	
Fixation disparity testing	
Double Maddox rod test	
Diagnostic occlusion	

Particular attention should be paid to conditions in which correction of the refractive error with eyeglasses or contact lenses appears to be assisting the patient in the control of any existing binocular vision disorder (e.g., accommodative esotropia, exodeviations treated with overcorrection of myopia).

Kushner and Kowal (5) and Kowalski et al. (6) developed a risk stratification to help identify patients who are at risk of developing binocular vision complications after refractive surgery. It includes three groups: a no-risk group, a moderate-risk group, and a high-risk group (Table 24.3).

No-risk Group for Binocular Vision Disorders After Refractive Surgery

History. Patients in this group are myopic, with no history of strabismus, amblyopia, or diplopia. They have never required prism in their eyeglasses or vision therapy to treat an accommodative or vergence disorder.

Evaluation. The binocular vision and accommodative evaluation reveals no evidence of any problem.

Current Spectacle Correction. The current spectacle prescription and dry and cycloplegic refraction are all within 1.00 D.

Moderate-risk Group for Binocular Vision Disorders after Refractive Surgery

History. If there is a history of strabismus, amblyopia, diplopia, prism in eyeglasses, or vision therapy, the patient is at moderate risk for binocular vision complications after refractive surgery even if the binocular vision disorder is now under control. This is particularly true for binocular conditions that have been controlled using lenses and prism that will be eliminated after refractive surgery. Examples

TABLE 24.3 RISK STRATIFICATION

No-risk group

Myopia
No history of strabismus
No history of amblyopia
No history of diplopia
No prism in eyeglasses
No history of vision therapy
Evaluation reveals no significant binocular vision disorder
Current eyeglasses prescription, dry and cycloplegic refraction are all within 1.00 D

Moderate-risk group

Habitually overcorrected myopia
Latent hyperopia
History of strabismus
History of amblyopia
History of diplopia
No prism in eyeglasses
No history of vision therapy
Evaluation reveals no significant binocular vision disorder
Current eyeglasses prescription, dry and cycloplegic refraction are all within 1.00 D

High-risk group

Strabismus
Amblyopia
History of diplopia
Prism in eyeglasses
History of vision therapy
Evaluation reveals significant binocular vision disorder

Modified from Kushner BJ, Kowal L. Diplopia after refractive surgery: occurrence and prevention. *Arch Ophthalmol* 2003;121:315–321; and Kowalski PM, Wang Y, Owens RE, et al. Adaptability of myopic children to progressive addition lenses with a modified fitting protocol in the Correction of Myopia Evaluation Trial (COMET). *Optom Vis Sci* 2005;82:328–337.

include partially accommodative esotropia controlled with plus lenses and prism (Case 24.2) and intermittent exodeviations controlled with refractive correction (Case 24.1).

Evaluation. The binocular vision and accommodative evaluation reveals any of the nonstrabismic binocular vision or accommodative disorders discussed in this text, or evidence of a strabismic problem. The identified problem appears to be under control and may not be causing any symptoms at this time.

Current Spectacle Correction. A difference of 1.00 to 2.00 D between the current eyeglasses prescription and the dry and cycloplegic refraction creates a moderate risk (Case 24.7).

High-risk Group for Binocular Vision Disorders after Refractive Surgery

History. If there is a history of strabismus (Case 24.6), amblyopia, diplopia, prism in eyeglasses (Case 24.3), or vision therapy, the patient is at high risk for binocular complications after refractive surgery if the binocular vision disorder is causing symptoms before refractive surgery. This is particularly true for binocular conditions in which lenses and prism have been attempted.

Evaluation. The binocular vision and accommodative evaluation reveals any of the nonstrabismic binocular vision or accommodative disorders discussed in this text, or evidence of a strabismic problem, and the identified problem appears to be currently causing symptoms.

Current Spectacle Correction. A difference of 2.00 D or more between the current eyeglasses prescription and dry and cycloplegic refraction creates a high risk.

The most valuable role the optometrist can play when comanaging patients considering refractive surgery is to prevent postoperative binocular vision complications by identifying the patients potentially at risk and counseling against refractive surgery in such cases.

DIAGNOSTIC EVALUATION OF BINOCULAR VISION COMPLICATIONS AFTER REFRACTIVE SURGERY

The battery of tests for the general binocular vision evaluation listed in Table 24.2 provides the information required to evaluate patients with binocular vision disorders after refractive surgery.

Sequential Management Considerations in the Treatment of Binocular Vision Complications after Refractive Surgery

Concepts discussed in previous chapters for the sequential management of binocular vision disorders also apply to problems related to binocular vision complications after refractive surgery (Table 24.4). Any of the nonstrabismic binocular vision and accommodative disorders described in Chapters 9 to 14 can occur after refractive surgery. The sequential treatment considerations are almost identical to those reviewed in those chapters. The following discussion describes some of the additional considerations for the post-refractive surgery population.

TABLE 24.4 SEQUENTIAL CONSIDERATIONS IN THE MANAGEMENT OF NONSTRABISMIC BINOCULAR VISION AND ACCOMMODATIVE DISORDERS

Optical correction of ametropia
Added lens power
Horizontal prism
Vertical prism
Occlusion for diplopia
Vision therapy
Surgery

RESISTANCE TO OPTICAL CORRECTION OF AMETROPIA, ADDED LENSES, AND PRISM

Three of the primary treatment options in the sequential management approach we have recommended require the use of eyeglasses. However, when treating patients who have had refractive surgery, we are dealing with a select population of patients who have decided that they no longer want to wear contact lenses or eyeglasses and have chosen to undergo refractive surgery. These patients have invested considerable time and effort into making this decision, and in most cases have made a significant economic investment as well. In our experience, such patients may be resistant to treatment recommendations that involve wearing glasses or contact lenses again. Other options, such as vision therapy and surgery, although more time-consuming and complex, may seem more desirable to this patient population. Nevertheless, optical correction of ametropia, added lenses, and/or prism may be necessary for resolving the patient's problem. In such cases, the optometrist can educate the patient about the most appropriate treatment options, and the patient must ultimately make the decision to proceed when ready.

OPTICAL CORRECTION OF AMETROPIA

Optical correction of ametropia may be necessary when a significant degree of anisometropia remains after LASIK or when an esodeviation is present along with residual hyperopia. Another situation that may require eyeglasses or contact lenses is that a patient is uncomfortable with monovision after refractive surgery.

ADDED LENSES

If a patient with accommodative esotropia secondary to a high AC/A ratio is esotropic at near after refractive surgery, added plus lenses may be required.

PRISM

Prism is the treatment of choice for patients with decompensated vertical or esodeviation at distance (divergence insufficiency or basic eso). Such prescriptions can sometimes be made for task-specific use, such as driving in the case of divergence insufficiency or reading in the presence of a decompensated fourth-nerve paresis.

OCCCLUSION

Occlusion can be used if double vision cannot be eliminated using lenses, added lenses, or prism. It is generally preferable to restore binocular vision, fusion, and stereopsis rather than to simply occlude one eye. However, there may be cases in which fusion is not comfortable and the patient is left with intractable diplopia. In such instances, occlusion becomes an important treatment option. As a long-term solution, it is desirable to find an approach with the least cosmetic effect (Case 24.8). The various options are discussed in Chapter 14.

Case 24.8 Contact Lens Occluder To Treat Intractable Diplopia

History and Significant Clinical Findings

A 23-year-old Iranian woman presented with a complaint of constant monocular diplopia and inability to concentrate when reading. These problems had been present since she had bilateral PRK for myopia in Russia 4 years prior. The pre-PRK refraction was OD -4.25 D c -2.75×161 and OS -4.25 DS. She reported that her right eye had been changing significantly and she had hoped that surgery would slow down the changes. The current (post-PRK) refraction was OD -7.25 D c -7.75×13 (20/100-)

and OS $+0.50 \text{ c} -0.50 \times 007$ (20/20). Keratometry readings were OD 54.5×10 , 59.75×90 (irregular) and OS 39.25×180 , 39.50×90 . Topography showed significant inferior steepening in the right eye. The unaided distance phoria was 2 exophoria at distance and near (IPD = 61 mm). The calculated AC/A ratio in this case was 6.1:1.

Diagnosis

All of the direct and indirect measures of fusional vergence and accommodation were normal. Because the AC/A ratio was also normal, these findings suggested that the most likely cause for the monocular diplopia was the irregular cornea and large anisometropia. This was probably a result of PRK on a keratoconic eye that then had too thin a cornea, resulting in a further increase in corneal steepening.

Treatment

Contact lens correction was unsuccessful for the right eye, and the patient did not want further corneal surgery, such as corneal transplant. Occlusion was prescribed using a soft occlusion lens with an 8-mm black central opaque area.

Outcome

With the contact lens, she has no diplopia and is satisfied with the cosmesis of the dark occluder contact lens on her dark iris. She is currently considering further corneal surgery for the right eye.

VISION THERAPY

All of the concepts described in earlier chapters apply to binocular vision complications after refractive surgery. Patients who are reluctant to wear eyeglasses again after refractive surgery are likely to be motivated toward a follow-through with a vision therapy program (Case 24.9).

Case 24.9 Vision Therapy Used To Treat Post-Refractive Surgery Convergence Insufficiency

History

E.W., a 28-year-old man, wanted refractive surgery because he did not want to wear glasses anymore. He had tried contact lenses several times in the past but was unable to wear them. About 1 month following uneventful LASIK surgery in both eyes, he started complaining of eyestrain, headaches, blurred vision, and double vision associated with reading and computer work. The doctors at the LASIK center prescribed pencil push-ups, but the patient was still uncomfortable.

We examined him about 6 months after the refractive surgery, and he still had the same complaints. We were able to obtain his previous records. His eyeglass prescription before surgery was OD -6.50 and OS -5.75 . There was limited information about binocular vision in the previous record,

although the cover test indicated orthophoria at distance and 10 exophoria at near. There was no information about the near point of convergence or vergence ranges.

Significant Clinical Findings

VA (uncorrected):	OD: 20/20 OS: 20/20
Near point of convergence:	25 cm break, 35 cm recovery
Cover test (distance, uncorrected):	Orthophoria
Cover test (near, uncorrected):	10 to 12 Δ , intermittent alternating exotropia at near (deviated 1% of the time)
Subjective:	OD: +0.25 -0.25 \times 180, 20/20 OS: +0.25, 20/20
Near lateral phoria:	15 Δ exophoria
-1.00 gradient:	12 Δ exophoria
Gradient AC/A ratio:	3:1
Base-in vergence (near):	X /14/12
Base-out vergence (near):	X /8/-2
Vergence facility:	0 cpm; unable to fuse with 12 base-out
NRA:	+1.50
PRA:	-2.50
Accommodative amplitude (push-up):	OD: 7 D; OS: 7 D
MAF:	OD: 8 cpm; OS: 8 cpm
BAF:	6 cpm
Stereopsis:	20 seconds on Wirt circles, 250 seconds of random dot stereopsis

Pupils were normal; all external and internal health tests were negative; the deviation was comitant; and color vision testing revealed normal function.

Diagnosis

The cover test revealed orthophoria at distance and an intermittent exotropia at near. The direct (step vergence and vergence facility) and some indirect (NRA) findings of PFV were low. These findings support the diagnosis of symptomatic convergence insufficiency. He also had convergence insufficiency without symptoms before refractive surgery, based on the previous record notation of significant near exophoria without distance phoria.

Treatment

We prescribed a program of office-based vision therapy supplemented by the Home Therapy System (HTS) computer software for home therapy and followed the sequence recommended in Chapter 9 for convergence insufficiency.

Outcome

E.W. required ten office visits to complete the vision therapy program. At the reevaluation, he reported elimination of all symptoms, and he could now read for as long as necessary without headaches or eyestrain.

Summary

Given the growing popularity of refractive surgery, the optometrist can play an important role in the management of patients before and after surgery. Our primary responsibility should be to identify patients who may be at risk for binocular vision problems after refractive surgery and thereby prevent such complications. In some cases, however, we may only see the patient after binocular vision complications have occurred. In such situations, our role is to determine the nature of the problem and use the sequential management plan suggested throughout this book to resolve the symptoms.

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SECTION

V

Vision Therapy and Optometric Practice

Patient and Practice Management Issues in Vision Therapy

Throughout this text, we have emphasized the importance of considering a variety of treatment options in a sequential manner for all accommodative, ocular motor, and binocular vision disorders. Once the diagnosis has been determined and the specific treatment selected, the other critical aspects of the care we provide are communicating this information to the patient and implementing the treatment options. This is true irrespective of whether the diagnosis and treatment are simple, such as accommodative insufficiency and reading glasses, or more complicated, such as intermittent esotropia requiring prism and a bifocal, or convergence insufficiency needing vision therapy. This chapter reviews the information and skills necessary for successful communication of the various diagnostic and treatment alternatives, as well as practice management issues related to vision therapy.

Successful communication and implementation of treatment for accommodative, ocular motor, and binocular vision disorders depend on a number of factors, including the clinician's ability to do the following:

- Communicate the nature and extent of the disorder
- Communicate the nature of the proposed treatment to the patient or parents of the patient
- Communicate with other professionals verbally and in writing about the diagnosis and proposed treatment
- Deal with the practice management aspects of vision therapy

Case Presentation

The clinician's ability to communicate his/her thoughts about diagnosis and treatment to the patient is critical to the success of any treatment plan. In all cases of accommodative, ocular motor, and binocular vision disorders, this presentation will require more time and effort than required in more routine-type vision care.

Most people have little to no knowledge of these vision problems and have not had any personal experience with them. It is therefore necessary to educate the patient or parents about the nature of these conditions. It is best to speak to both parents at the case conference. If this is not possible, then, after the parents receive your report, the parent who was unable to attend the conference should be encouraged to call with any questions.

We have organized the case presentation into a number of phases (Table 25.1). Each phase of the presentation has a specific objective.

SAMPLE CASE PRESENTATION FOR A CHILD REQUIRING VISION THERAPY

The following is an example of a presentation to the parents of a 10-year-old child (fifth grade) with convergence insufficiency.

Phase 1: Review the Symptoms and Reasons for the Visit

Beginning the presentation with a review of why the patient was brought in to see you is an important starting point and allows you to build a relationship between the visual complaints and the diagnostic findings.

I am going to begin by first reviewing the various problems and complaints that Jimmy has been reporting. As you remember, he has been complaining of eyestrain, blurred vision, and words moving on the page after

TABLE 25.1 CASE PRESENTATION SEQUENCE

1. Review the symptoms and reasons for the visit
2. Explain the vision disorder and the relationship between the problems detected and incoming complaints
3. Explain the treatment and prognosis for improvement
4. Explain the time and financial commitment
5. Open questions

reading for about 5 to 10 minutes. When he is tired or tries to read at the end of the day, he occasionally experiences double vision. Although Jimmy complained about these problems last year, he definitely feels that they are getting worse. You also mentioned that Jimmy is doing much more reading and homework this year.

When he complained last year, you took Jimmy to a different eye doctor, who said he couldn't really find a problem. He did prescribe weak reading glasses, which Jimmy felt made things worse. Does that seem like a reasonable summary of why you brought Jimmy to see me?

You should give the parents an opportunity to add any additional information or to agree that the key elements of the problem have been reviewed.

Phase 2: Explain the Nature of the Vision Problem

I want to spend a little more time than usual reviewing my findings, because Jimmy has a type of vision problem with which many people are not familiar. Most people are aware of vision problems such as nearsightedness or farsightedness, which affect our ability to see clearly. You know that we treat these conditions using eyeglasses. In Jimmy's case, he sees clearly. In fact, he has perfect 20/20 vision in both eyes, his eyes are healthy, and he is neither nearsighted nor farsighted.

However, I want to stress that good vision is more than being able to see 20/20. It is possible to have excellent vision in each eye and still have a significant vision problem. For example, focusing, eye teaming, and tracking problems can all be present, even if an individual has 20/20 vision. People who have problems like these often see clearly, but they have uncomfortable vision, eyestrain, headaches, double vision, and similar symptoms when reading.

In Jimmy's case, he has an eye teaming problem. I am sure that you have seen children with severe eye teaming problems in which an eye actually turns in or out. Jimmy does not have a severe problem like this. However, when he reads or does any close work, his eyes have a very strong tendency to drift out and his ability to compensate for this is inadequate.

With a convergence insufficiency patient, we usually demonstrate the receded near point of convergence to the parent at this time.

If Jimmy's eyes actually turned out, he would experience double vision. Therefore, whenever he reads, he has to use excessive muscular effort to prevent his eyes from drifting out. This constant need to use excessive muscular effort can lead to the types of symptoms described by Jimmy. Patients with eye teaming disorders complain of a variety of problems, including eyestrain, headaches, blurred vision, double vision, sleepiness, difficulty concentrating on reading material, loss of comprehension over time, a pulling sensation around the eyes, and movement of the print.

Do you have questions about Jimmy's vision problem?

You may stop at this point to give the parents or patient an opportunity to ask any questions about the nature of the problem and how it may cause symptoms. It is a good idea to ask the parents to summarize what they feel the problem is, after hearing your presentation.

Phase 3: Explain the Proposed Treatment Plan

I have been stressing that Jimmy's vision problem is different from the usual vision problems that are treated with eyeglasses. Jimmy does not have an optical problem such as nearsightedness or farsightedness. As a result, standard optical treatment, using eyeglasses alone, would not be successful. Rather, I am recommending that we treat Jimmy using an approach called "vision therapy."

Vision therapy is a treatment approach involving a series of office visits in which we use a variety of instruments and procedures to teach Jimmy how to overcome this eye teaming problem. I am sure you have heard of children receiving therapy or tutoring for speech, reading, or math. You know that, with an effective therapist or tutor, these skills can be improved.

The good news is that vision therapy has also been shown to work very well and will almost always lead to improved eye teaming, focusing, and tracking skills. In fact, we are successful in about nine out of ten patients. The key to success is motivation and a commitment to attending the therapy sessions and performing the recommended home therapy techniques. Treatment for the type of vision problem that Jimmy has generally requires about 3 months of vision therapy. We will need to see Jimmy two times each week, and each visit will last 45 minutes. I will give you a packet of information about vision therapy as you leave today.

Once vision therapy is complete, we ask all of our patients to work on their own at home with several procedures. For example, for the first 3 months following the completion of vision therapy, we ask the patient to work three times a week, 5 minutes each time. We reevaluate the patient at this time and, if everything seems fine, we ask the patient to work once a week for 5 minutes for the next 6 months. If, at this 6-month reevaluation, the patient is still comfortable and the vision findings are normal, we ask the patient to check his eyes once a month, using one very simple procedure.

Do you have any questions about my recommendations?

You may stop and give the parents an opportunity to clear their doubts about vision therapy. If you are not sure whether the parent has understood, it is useful to ask the parent to summarize the treatment plan.

Phase 4: Discuss the Time and Financial Commitment

If vision therapy has been recommended, it is particularly important for the optometrist to spend time discussing the time and financial commitment that will be necessary.

The treatment approach that I am recommending is going to require both a time and a financial commitment on your part. To successfully treat Jimmy's eye teaming problem, we will need to work with him for about 3 to 4 months. As a general rule, we need to see the child twice a week over this period of time, and each visit lasts 45 minutes. Vision therapy visits are scheduled Monday through Thursday, late afternoon and early evening.

The fee for each therapy visit is \$100. In some cases, medical insurance may cover part of the cost of vision therapy. However, please be aware that we do not participate in any health insurance plans. This means that you will have to pay for the therapy and then seek reimbursement from your insurance company. My staff will be happy to assist you in finding out whether your insurance company will cover Jimmy's therapy.

One important idea to keep in mind, when discussing this with your insurance company, is that the treatment we have recommended is not considered vision care. Rather, Jimmy has a medical condition and we have recommended medical treatment called vision therapy or orthoptics. This distinction is important because most medical insurances will only cover one vision examination once a year or every 2 years and some do not cover routine vision care at all. Vision therapy, however, is not routine vision care and, for insurance purposes, it is considered a form of medical treatment. It is very important that you use the correct terminology when you communicate with your insurance company. In my correspondence to you, I will include a letter with a full explanation of the diagnosis and treatment plan, which you can forward to your insurance company for a predetermination of benefits.

Do you have any questions about scheduling or the cost of vision therapy or insurance? (Appendix I provides sample correspondence.)

Phase 5: Open Questions and Discussion

This last phase is designed to allow the parents one more opportunity to ask you questions about any issues discussed in the case presentation. It is also your opportunity to summarize the presentation and determine whether the parents would like you to send a report to the school or other professionals. This is an excellent public relations opportunity, and you should try to communicate with as many individuals as possible after each evaluation.

At this time, we tell the parents that we will send a report summarizing the evaluation, diagnosis, and recommended treatment. If vision therapy has been recommended, we also send a letter of predetermination of benefits to the insurance company.

SAMPLE CASE PRESENTATION FOR CONDITIONS NOT REQUIRING VISION THERAPY

Regardless of the diagnosis and treatment, we follow the case presentation sequence described in Table 25.1 for all accommodative, ocular motor, and binocular vision disorders. If added lenses in a bifocal format or prism are recommended, the explanation of the proposed treatment and prognosis for improvement will require additional time. Most people have no personal experience with the use of prism, and bifocals are almost universally associated with the vision problems of middle-aged and older people. It is necessary, therefore, to educate the patient or parents about the use of these treatment options.

The presentation is significantly shorter and less complex when vision therapy is not necessary. However, even if the only treatment necessary is a single vision prescription for reading, time should be spent in each of the five phases outlined.

Sample Explanation of Proposed Treatment Using Prism

Phases 1 and 2, reviewing symptoms and reasons for the visit and explaining the vision disorder, are similar to those in the previous sample presentation.

Phase 3: Proposed Treatment and Prognosis for Improvement

I have been stressing that Billy's vision problem is different from the usual vision problems that are treated with traditional eyeglasses. Billy does not have an optical problem such as nearsightedness or farsightedness. As a result, standard optical treatment alone, with regular eyeglasses, would not be successful. Rather, I am recommending that we treat Billy using eyeglasses that contain a special lens called prism.

Prism is used when an individual has a particular type of eye teaming problem. As we discussed earlier, Billy has a problem, which is, his eyes have a strong tendency to drift in. To control this tendency, he has to use excessive amounts of muscular effort. A prism is a special type of lens that decreases the amount of effort that an individual must use to control an eye teaming problem. The glasses will not look very different from regular glasses, although, if you look closely, you will see that one edge will be thicker than the other. It is important for you to realize that although prism will help Billy when he wears the glasses, the underlying problem will still be present. Prism does not correct the eye teaming problem. Rather, it will allow Billy to function more comfortably, in spite of the eye teaming problem.

Sample Explanation of Proposed Treatment Using a Bifocal

Phases 1 and 2, reviewing symptoms and reasons for the visit, and explaining the vision disorder, are similar to those in the sample presentation above for the patient requiring vision therapy.

Phase 3: Proposed Treatment and Prognosis for Improvement

I have been stressing that Paul's vision problem is different from the usual vision problems that are treated with traditional eyeglasses. Paul does not have an optical problem such as nearsightedness or farsightedness. As a result, standard optical treatment alone would not be successful. Rather, I am recommending that we treat Paul using glasses with a special lens called bifocals.

We often prescribe bifocals for people who have focusing or eye teaming problems. Bifocals are used when the power of the lens necessary for reading is different from the power of the lens needed for looking at a distance. Bifocals are useful for focusing problems because they decrease the amount of focusing effort the patient must use. They are also helpful for some eye teaming problems. In Paul's case, for example, his eyes have a tendency to drift in and his ability to compensate is inadequate. He must therefore use muscular effort to control the eye teaming problem. The bifocals I am prescribing will reduce the amount of muscular effort that Paul must use. It is important for you to realize that although the bifocal lens will help Paul while he wears the glasses, the underlying problem will still be present. Bifocals do not correct the eye teaming problem. Rather, they will allow Paul to function more comfortably in spite of the eye teaming problem.

Communicating Your Findings to Other Professionals

Communication with other professionals is important for two reasons. First, communication can help develop your reputation in the community. Sending reports allows you to let other professionals know that your practice is different and unique. Your reports will inform them that you practice full-scope optometric care, including the use of vision therapy when appropriate. Appendix I includes several sample reports to psychologists, school personnel, physicians, and parents.

Communication is also important because of some of the misconceptions that persist about vision therapy. In spite of the extensive scientific support for the efficacy of vision therapy for the conditions described in this text, some professionals persist in their opposition to vision therapy. Parents often rely on the judgment of such professionals when decision-making about health issues is necessary.

It is therefore essential that you use handouts, reports, and copies of articles to provide as much educational information as possible at the time of your presentation to the patient or parents to prepare them for the negative advice they may receive. Appendices II and III include sources for brochures and articles that can be provided to your patients.

COMMUNICATING THROUGH WRITTEN CORRESPONDENCE

Because most people have little or no knowledge of accommodative, ocular motility, and binocular vision problems or vision therapy, it is important to follow up your case presentation with a written report. After each evaluation we write a report that summarizes the symptoms, diagnosis, and proposed treatment plan. From a public relations point of view, if the patient is a child, it is also helpful to send a copy of this report to other professionals who are dealing with the child. We often send reports to teachers, reading specialists, school psychologists, and pediatricians. If you practice in a small- to medium-sized community, after a short amount of time, these professionals will soon understand that your practice is unique, and they may begin to refer patients to your office when they encounter children with similar problems. Appendix I includes examples of this type of correspondence.

Practice Management Aspects of Vision Therapy

Throughout this text, we have tried to establish the clinical basis for the importance of vision therapy as one of the treatment considerations for accommodative, ocular motility, and binocular vision disorders. We have emphasized that vision therapy is necessary to meet the needs of patients. At least 10% to 15% of patient problems cannot be treated with lenses, added lenses, or prisms alone, and vision therapy is required. We have also stressed that vision therapy has been proven to be an effective treatment approach. Studies of the efficacy of vision therapy for accommodative, ocular motility, and binocular vision disorders have revealed success rates between 85% and 95% (Chapters 3, 9–13).

From a practice management perspective, it is also important to realize that offering vision therapy as a service often makes a practice unique in a community. With many practices looking for a niche to make their practice special and to find new sources of revenue, vision therapy is an excellent service to offer.

Like any other optometric service we offer in our practices, however, vision therapy must be delivered in a cost-effective manner. Each practitioner must make a personal decision about the amount of income that is necessary from a particular service to make it financially viable. If vision therapy, or any other service, fails to meet this criterion, then, regardless of how much the treatment is needed or how effective it may be, it becomes impossible to offer such a service.

Fortunately, vision therapy is not only necessary and effective, but can also be an economically viable service when administered appropriately. We believe that many optometrists choose not to provide vision therapy in their practices because they are under the misconception that it cannot be done in a financially viable manner. Our objective is to provide a model for the implementation of vision therapy that is economically viable in a primary care practice.

MODEL FOR THE ESTABLISHMENT OF VISION THERAPY IN A PRIMARY CARE PRACTICE

Decisions about several key issues are required to establish an economically viable vision therapy service in a practice. These include decisions about the following: who administers the therapy, whether the therapy is

done at home or as in-office therapy, the therapist-to-patient ratio, establishment of hours and fees, salaries for therapists, and management of third-party claims.

Who Should Administer the Vision Therapy?

The most basic decision is whether vision therapy should be administered by optometrists or whether technicians or vision therapists should be allowed to do the therapy. This decision has the greatest impact on the economic viability of vision therapy in a practice. Our preference is that therapists, rather than optometrists, should administer the vision therapy.

The actual administration of vision therapy procedures requires a technical knowledge of how to do the procedure and how to interpret the patient's behavior and responses. The number of activities that are used is small, and the same procedures are used repeatedly. We therefore believe that the actual administration of the therapy can be effectively performed by therapists. On the other hand, decisions about which procedures should be used, sequencing of procedures, and how to overcome obstacles that impede progress should be the responsibility of the optometrist. The role of the optometrist in vision therapy is to develop an initial vision therapy program for each patient, supervise the administration of the therapy, plan or program subsequent visits after each therapy session, and troubleshoot or help the therapist overcome any unusual obstacles that interfere with progress for a particular patient.

The decision to use therapists is important for the financial viability of a vision therapy service. Although vision therapy fees vary from one region of the country to another, they are usually approximately equivalent to the practice fee for an intermediate examination or a comprehensive examination. However, a vision therapy visit generally requires 45 to 60 minutes of direct contact time, whereas most optometrists complete a routine comprehensive examination in less time than this. In addition, other revenue from additional procedures, eyeglasses, or contact lenses are generally related to a comprehensive vision examination. With vision therapy this additional revenue is not available. Thus, it is unlikely that an optometrist administering the vision therapy himself/herself will be able to achieve the expected income per hour based on the usual vision therapy fees collected. Of course, if the vision therapy fee is set at a higher level, the economic picture changes. Unfortunately, raising the fee to a level at which it becomes economically feasible for the optometrist to administer the therapy may make the cost of vision therapy too high for the patient. It also affects the competitiveness of a practice as compared to others in the area.

Although there is no research to support this statement, we feel that many optometrists who have tried to offer vision therapy in their practices and have failed have been unsuccessful because they did not use ancillary personnel; as a result, it became economically impossible to offer the service to their patients.

SHOULD VISION THERAPY BE PERFORMED ON AN INDIVIDUAL BASIS OR WITH MULTIPLE PATIENTS PER SESSION?

Patients undergoing vision therapy generally are asked to work on four to five procedures during a given therapy session. This means that they spend 10 to 15 minutes working on each procedure. Often patients work on procedures that have been explained to them during previous visits. Thus, most motivated, cooperative patients do not need the therapist to stay with them for the entire 45 minutes. It is therefore quite possible for a therapist to work with more than one patient at a time. We suggest a patient-to-therapist ratio of 2:1. When therapy is administered in this way, it is referred to as *multiple* or *group vision therapy*—in contrast to individual vision therapy, in which the therapist works with only one patient at a time.

Multiple or group vision therapy does require an experienced therapist, carefully programmed therapy plans, appropriate selection of patients, and adequate equipment. Computerized vision therapy techniques are a very significant positive development that enables therapists to more effectively manage more than one patient at a time.

Home versus In-office Vision Therapy

Vision therapy is currently practiced in three basic formats. In some practices, the vision therapy procedures to be performed are explained in the office by the optometrist or therapist, and the patient then takes home the necessary equipment and practices the therapy procedures at home. This is referred to as *home vision therapy*. Other practices do not expect their patients to do any therapy at home, and all procedures are explained and performed in the office. This mode of vision therapy practice is called *in-office vision therapy*. Finally, there are practices that use a combination of in-office and home therapy.

Advocates of home vision therapy stress the concept that in order to produce a change in visual status, vision therapy must be done as often as possible. They argue that the in-office approach only provides the patient with 1.5 to 2 hours of vision therapy per week. If the patient performs the therapy at home for 30 minutes each day, the therapy time more than doubles. Using the home vision therapy approach, office visits are scheduled every 2 weeks and are designed as progress evaluations and an opportunity to resolve any questions or problems that the patient may have with a particular technique. These visits can be scheduled with an assistant or the optometrist, although the arguments presented above suggest that a therapist should spend the maximum amount of the time with the patient.

Proponents of in-office vision therapy point out several weaknesses of this home therapy approach. When the patient is a child, the success of home therapy is dependent on the parents' ability to learn how to administer the therapy procedures, monitor progress, motivate, and overcome obstacles that interfere with progress. In our experience, it is often difficult to train children well enough to do therapy by themselves at home. Further, many parents are not able or willing to work with their children at home and, with time, vision therapy becomes another area of conflict between the parent and child. Home therapy is more likely to be successful with adult patients. However, even adult patients often need help with issues such as motivation and overcoming obstacles that interfere with progress. Compliance may also be poorer with home therapy, thereby leading to a higher dropout rate.

One of the important innovations in vision therapy has been the development of computer software designed for home vision therapy. Programs are now available that contain techniques to train accommodation, fusional vergence, saccades, pursuits, and various visual perceptual functions. These computer programs offer a number of important advantages over traditional home vision therapy.

Traditional noncomputerized techniques used for home therapy have the following disadvantages:

- Traditional techniques require an experienced doctor or technician to interpret patients' responses and to use that information to alter stimulus conditions in order to improve the binocular or accommodative response.
- With young children or with older patients who are not responding accurately for any of a variety of reasons, traditional techniques become difficult and unreliable to use. The child who "learns" the expected response and has a strong desire to please the parent may "give the right response," even though he/she is not achieving the desired objective.
- For learning to occur, feedback should be accurate, immediate, consistent, and unbiased. With traditional therapy techniques, the feedback must be provided by a parent, who generally will not be knowledgeable about vision. The feedback may therefore not always be as consistent and immediate as desired.

The advantage of computerized home-based vision therapy is that it overcomes each of the problems listed above. In addition, both children and adults seem to enjoy and look forward to computer techniques as compared to traditional procedures.

Supporters of in-office vision therapy stress the importance of having a professional constantly overseeing the therapy. In this format, patients are scheduled two times per week and do only minimal amounts or no therapy at home. Each visit lasts 45 minutes, under direct supervision of the therapist. The argument against this approach is that, for therapy to be successful, a certain number of total hours of treatment are necessary. Limiting the treatment to only in-office therapy would therefore be expected to prolong vision therapy.

A reasonable compromise approach, and the one we suggest, is to combine both treatment approaches. We feel that it is important to have the patient come to the office at least once per week. This allows us to motivate, directly observe progress, and overcome any obstacles to success. It also allows us sufficient time to train the patient and parent on how to perform a particular technique to be used at home. In addition to in-office therapy, we have our patients spend about 15 minutes, five times per week, doing home vision therapy. We believe that this approach leads to the most rapid and effective outcome for patients with accommodative, ocular motor, and binocular vision disorders. Recently completed randomized clinical trials provide support for this approach and have demonstrated that this combined method is the most effective treatment for convergence insufficiency (1–8) and is effective for accommodative problems (2). Although there have not been any clinical trials performed for other diagnoses, it is likely that similar results would be found.

Vision Therapy Schedule

The following schedule is based on the use of the combination in-office and home therapy mode of practice we recommend. In a typical primary care practice, two afternoons would be required to meet the needs of the

patients in the practice. We suggest setting aside two afternoons per week for therapy. For example, Tuesdays and Thursdays could be established as the days for vision therapy, between 3:30 P.M. and 6:30 P.M. A sample schedule could be as follows:

<i>Tuesday</i>	<i>Thursday</i>
3:30 to 4:15	3:30 to 4:15
4:15 to 5:00	4:15 to 5:00
5:00 to 5:45	5:00 to 5:45
5:45 to 6:30	5:45 to 6:30

There would therefore be eight sessions of in-office vision therapy each week, with four patients per session, for a total of 32 patient visits per week of vision therapy. The optometrist would have to hire and train two vision therapists to administer the vision therapy. Two therapists work together, in the same room, for these 6 hours per week.

Would this number of vision therapy slots be sufficient to meet the needs of the typical practice? Prevalence information about accommodative, ocular motility, and binocular vision disorders suggests that 10% to 15% of patients in a typical practice require vision therapy. In an average practice, with 2,000 examinations per year, or 40 examinations per week, we would estimate that about 4 to 6 patients each week, or 200 to 300 per year, would be identified as requiring vision therapy. In our experience, only about 75% of patients who need vision therapy accept this recommendation. Thus, this average practice would be expected to identify about 150 to 225 patients a year who would accept a treatment recommendation of vision therapy.

According to the schedule described above, 32 visits are available per week, or 1,600 visits per year (50 weeks). Some adult patients and older cooperative children can successfully complete vision therapy in 12 to 14 visits, whereas others may require as many as 20 to 24 visits. If we take 16 visits as an average, our model schedule could accommodate about 100 patients per year (1,600/16). Thus, in the average practice described above, with 2,000 examinations per year, this model would be able to accommodate the needs of 5% of the patients. If more vision therapy visits are required, of course, additional hours can be added as needed.

It is reasonable to assume, therefore, that using a conservative estimate of a 5% referral rate for vision therapy, 32 treatment slots would easily be filled in an average practice.

Office Space

To work with four patients per session, with two therapists, we suggest a minimum of about 150 to 180 sq ft of office space. A room 12 × 15 ft can easily accommodate the counter space, chairs, and six people. We recommend installing laminated countertop along two or three of the walls in the room. The countertop should be about 18 to 20 inches in depth and about 28 inches high. In addition, one area will be necessary for the computer. Laminated countertop or a ready-made computer table can be used. If countertop is used, the depth should be about 36 inches. It is also helpful to place shelves above the countertop for storage and organization of the equipment.

Although some practitioners may at first be reluctant to devote this much amount of space to vision therapy, it is clear from the expenses–revenue analysis below that the net revenue per square foot is probably higher for vision therapy than for any other service offered by optometrists.

Fees

The fee for a session of in-office vision therapy varies from one region of the country to another. Fees tend to be higher in the larger cities than in more rural areas. A general guideline is that fees for in-office vision therapy in any particular area of the country tend to be approximately equal to the fee for a comprehensive vision examination in that region. Of course, the same guidelines that an optometrist uses to establish the fees for other services should be applied to the fee for vision therapy. Such guidelines (9) usually include the following:

- Customary charges in the community
- Current value of the dollar
- Time required for the service

Revenue and Expenses

It is evident that, if all 32 vision therapy slots are filled each week for an entire year (1,600 visits per year), the revenue potential of vision therapy is substantial. In addition to the direct revenue generated from vision therapy, most optometrists also bring patients back for a second office visit if an accommodative, ocular motor, or binocular vision disorder is detected at the initial visit. This examination is often called a *vision therapy evaluation*, and a fee needs to be established for this visit. As a general rule, the fee for this visit is twice that for a routine comprehensive vision examination. Expected revenue for our model vision therapy practice is shown in Table 25.2.

Expenses would include salaries for the therapists, replacement cost of equipment, and secretarial expenses related to vision therapy activities. Salaries for vision therapists are generally equivalent to those paid to optometric technicians. We also suggest paying each therapist for 1 (additional) hour each week for paperwork and preparation time. If a practice has 6 hours of vision therapy per week and two therapists, the annual cost would be equal to 700 (14 hours per week for 50 weeks) multiplied by the hourly rate.

Another cost is toward secretarial help. When vision therapy is offered in a practice, there is an additional need for support staff to handle scheduling, bookkeeping, billing, insurance claims, and correspondence related to vision therapy. In our experience, this averages to about 1 hour for each 1 hour of vision therapy scheduled. In the model we have proposed, one would expect to pay for about 6 hours of secretarial help per week, or 300 hours per year.

We have included a recommended vision therapy equipment list later in this chapter. Some of this equipment needs to be replaced on an annual basis. We estimate that equipment replacement costs would average to about \$500 per year.

The net revenue derived from vision therapy services (Table 25.2), in the typical practice we have described, would be about 90% of the gross. This net revenue compares favorably with the average net in optometric practice, which is closer to 25% of the gross revenue.

Who Pays for the Vision Therapy?

Of the various services that optometrists can offer in a practice, vision therapy may require the maximum financial commitment from the patient. Twenty-four visits of vision therapy, at \$100 per visit, would cost the patient about \$2,400. Although some health insurance plans provide benefits for vision therapy, there have been significant changes over the past 10 years. Many insurance companies no longer cover vision therapy. The companies that continue to cover vision therapy have reduced the number of allowable visits or reduced the actual reimbursement, or both. In addition, in our personal experience, there has been an increase in the timeframe it takes for the optometrist to receive reimbursement from the insurance companies.

Insurance coverage of vision therapy has become such a significant problem that many optometric practices providing vision therapy services have discontinued participation in many, if not all, insurance programs. Nevertheless, it is important to have an understanding of the issues related to insurance coverage of vision therapy so that we can assist our patients in obtaining reimbursement, if possible.

TABLE 25.2 REVENUE AND EXPENSES RELATED TO VISION THERAPY

Revenue	
(Assume a therapy fee of \$100/visit, and a vision therapy evaluation fee of \$150)	
1,600 visits of therapy	\$160,000
100 vision therapy evaluations	\$15,000
<i>Total vision therapy revenue</i>	\$175,000
Expenses	
(Assume therapist salary of \$20/h, secretary salary of \$12/h)	
700 h (2 therapists, 14 h/wk, 50 wk)	\$14,000
300 h (secretarial)	\$3,600
Equipment (replacement)	\$500
Total expenses	\$18,100
Gross vision therapy revenue	\$175,000
Expenses	\$18,100
<i>Net vision therapy revenue</i>	\$156,900

Understanding Insurance Coverage for Vision Therapy

Basic Issues

Vision Therapy Is Considered Medical Treatment, Not Vision Care. The insurance coverage for vision therapy comes from the patient's major medical insurance and not from a vision care plan. This is a critical issue and one that is often misunderstood by patients and their insurance carriers. It is common for a patient to receive a rejection from an insurance carrier stating that routine vision care is not a covered service. Such a rejection is simply a clerical error in which the individual reviewing the claim assumes that all care performed by an optometrist is routine vision care or refraction.

Since April 1987, when optometry became more involved with Medicare, we have learned the importance of using the correct terminology, including diagnostic and procedure codes, to distinguish our routine care and refraction from eye care that is specific for medical conditions. The same concepts apply to vision therapy. The conditions we are treating are medical conditions, and the procedure (vision therapy) is therefore often a covered service. When a claim is mistakenly rejected stating the reason that it is routine vision care, the clinician should send a letter to the insurance carrier to clarify the nature of vision therapy. Appendix I includes a sample of such a letter. It is actually more desirable to anticipate this problem before it occurs. We recommend routinely writing a predetermination of benefits letter whenever vision therapy is recommended (Appendix I). *Use of Appropriate Procedure and Diagnostic Codes.* The use of appropriate diagnostic and procedural codes allows the insurance carrier to understand that the service described is not refraction or routine vision care. We strongly recommend the use of a "fee slip" that includes the diagnostic and procedural codes that will generally need to be used. Two excellent monographs are available that contain many samples of fee slips that can be used to describe both procedures and diagnoses (10,11). The College of Optometrists in Vision Development (COVD) website also has up-to-date information about insurance coverage for vision therapy services (12).

These fee slips also help decrease the amount of time necessary to complete insurance forms. In most instances, these forms can simply be attached to the patient's major medical form for submission. Completion of the fee slip requires very little writing. The vision therapist or receptionist simply needs to circle the appropriate procedural and diagnosis code and write in the patient's name, date, and fee. Calendars often found in standardized printed bills are particularly useful when submitting a claim for the multiple visits used in vision therapy programs. The calendar allows you to use one form for many visits over a 3-month period.

Most practices are now using computer-generated fee slips and billing which work well. It is important that the fee slip generated for vision therapy be separate from that used for routine eye care.

Dealing with Denial of Benefits. Occasionally, even when appropriate terminology is used, an insurance carrier mistakenly denies benefits. In such cases, an appeal letter must be sent. The most common reasons for denial are as follows:

- The policy does not cover routine vision care.
- This service is only covered if performed by a physician.
- This service will only be covered if a medical doctor refers the patient.
- This service is excluded in the patient's policy contract.
- This service is not covered in the setting indicated.

The first three reasons for rejection can generally be successfully appealed, and sample appeal letters are included in Appendix I. If the patient's policy specifically excludes vision therapy or vision therapy in an outpatient setting, appeals are usually ineffective.

Payment Systems

The most desirable system is to require the patient to pay the fee and have the patient submit a claim to the insurance company for reimbursement. We use this approach and assist the patient with the claim forms and any letters of explanation or appeal that might be necessary.

The other decision that must be made is how often to have the patient pay for the therapy. Several systems are currently in use. The following approaches are the two most popular payment systems, although there are probably many other variations.

- *Per-visit method.* The patient pays the established fee at the time of visit. The advantage of this system is its simplicity and high level of acceptance by patients. The disadvantage is that if a patient does not keep the appointment for some reason, the fee for that visit is lost. Some optometrists establish a policy requiring

the patient to pay for such a visit if there had been no cancellation within 24 hours. In our experience, this type of policy is often resented by patients, thereby leading to a negative relationship with the office.

- *Monthly fee.* The patient makes one-time payment of the fee for all visits for the month. For instance, if the patient is being seen twice a week, he/she would be liable to pay for eight visits at the beginning of the month. Generally, payment is expected by the tenth of the month. The advantage of this system is that the patient pays in advance for all visits for the month. Therefore, if a visit is missed for some reason, payment would have still been received. Of course, the patient is given the opportunity to make up for the missed visit at another time during the month. Some patients have difficulty paying this amount of money in advance and may resent this approach.

Equipment

BASIC EQUIPMENT

The following is a recommended list of basic equipment to begin vision therapy in a practice.

- Accommodative flippers^a
 - +0.50/−0.50 (2)
 - +1.00/−1.00 (2)
 - +1.50/−1.50 (2)
 - +2.00/−2.00 (2)
- Lens holder^a (1)
- Uncut plastic lenses from +2.50 to −6.00 (2 of each) in 0.25 D increments
- Red/green bar readers^a (4)
- Variable tranaglyphs,^a BC 515, BC 520 (3 of each), 600-tranaglyph kit (3)
- Nonvariable tranaglyphs (50-tranaglyph kit)^a
- Quoit vectogram^a
- Dual Polachrome illuminated trainer^a
- Aperture Rule trainer^a (2)
- Barrel convergence card^a (2 dozen)
- Brock strings^a (2 dozen)
- Loose prisms^a (2 to 16 in 2 A increments)
- Eccentric Circles^a or Free Space Circles^a—opaque (2 dozen sets)
- Eccentric Circles^a or Free Space Circles^a—transparent (2 dozen sets)
- Brewster-type stereoscope (Bernell-O-Scope^a)
- Wheatstone-type stereoscope (Bernell Variable Prismatic Stereoscope^a)
- Hart chart accommodative rock chart set^a
- Accommodative rock cards^a

COMPUTER SOFTWARE

The benefits of using computer software are significant. It greatly enhances your ability to handle multiple vision therapy. Two systems are currently available.

- Computer Orthoptics^b is a system that has software for remediation of accommodative, binocular, ocular motor, and perceptual disorders. The random dot stereopsis program, which can be used for both tonic and phasic vergence training, makes this system particularly desirable.
- Computer Aided Vision Therapy (CAVT)^a is a system that also has software for the treatment of ocular motility, binocular, and perceptual disorders.

SOURCES OF EQUIPMENT

(a) Bernell Corporation: 4016 North Home Street, Mishawaka, IN 46545; 800-348-2225.

(b) Computer Orthoptics: 6788 Kings Ranch Rd, Ste 4, Gold Canyon, AZ 85218; 800-346-4925; www.visiontherapysolutions.net.

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Appendices

I. Samples of Correspondence and Forms

Letters to Parents and Professionals about Evaluation and Treatment Recommendations

RE: John Smith
Date of birth: 1/1/99
Grade: 7

Dear Mr. and Mrs. Smith:

I recently examined John, and this letter is a summary of my findings and recommendations. The first part of this report summarizes only the most important aspects of the examination and my recommendations. This is followed by a more detailed description of all evaluated areas and specific test results.

John is a 9-year-old boy who was referred to my office because he had been complaining of eyestrain, blurred vision, and watery eyes after only short periods of reading. These problems have been bothering him for the last 2 to 3 months, since he started seventh grade. He never had his eyes examined before.

My examination of John revealed that he has a mild amount of farsightedness (hyperopia) and his eyes are healthy. He does have a significant problem in the area of eye tracking, focusing, and eye teaming. Inadequate eye movement control may cause him to lose his place when reading, have difficulty copying from the blackboard, and to skip or omit small words when reading. Symptoms of a focusing problem may include blurred vision while reading, inability to clear vision at distance after reading, and fatigue or headaches while reading. When the two eyes do not work together, it may result in double vision, frequent loss of place when reading, headaches or eyestrain, and inability to sustain a visual task for any prolonged period of time.

I therefore recommended a vision therapy program that is designed to remediate the eye teaming, eye movement, and focusing deficiencies. Such a therapy program would be expected to last approximately 3 months and would require us to see John two times per week.

If you have any questions or need additional information, please feel free to contact me.

Sincerely,

SPECIFIC VISUAL EFFICIENCY TEST RESULTS FOR JOHN

Visual Acuity

Entering visual acuity was:

At distance: right eye, 20/20; left eye, 20/20

At near: right eye, 20/20; left eye 20/20

Eye Tracking

Eye tracking was below the level of adequacy to support maximum academic achievement.

DEVELOPMENTAL EYE MOVEMENT (DEM) TEST

Errors: twentieth percentile

Time: tenth percentile

Accommodation or Focusing Skills

He cannot maintain focus at the reading distance. His focusing system has lost its flexibility.

Binocular Vision or Eye Teaming

John's eyes have a tendency to turn out, and the ability to compensate is inadequate.

DESCRIPTION OF VISUAL EFFICIENCY TESTING

When we examine an individual who is complaining about eyestrain and discomfort associated with reading, we do more than just examine the health of the eyes and decide whether eyeglasses are necessary. Skills such as tracking, focusing, and eye teaming must also be assessed. This evaluation is referred to as a *visual efficiency examination* and is described below.

Visual Acuity

The Snellen fractions (20/20, 20/30, etc.) are measures of sharpness of sight. They relate to the ability to identify a letter of a certain size at a specified distance. They give no information as to whether or not meaning is obtained from visual input, how much effort is needed to see clearly or singly, and whether or not vision is less efficient when using both eyes, as opposed to each eye individually.

Eye Tracking

Eye tracking is the ability to track a moving target or switch fixation from one target to another. This skill permits easy shifting of the eyes along the line of print in a book, a rapid and accurate return to the next line, and quick and accurate shifts between desk and chalkboard, or from one distance to another.

Tracking ability was evaluated using the developmental eye movement (DEM) test, which simulates reading on a written page. Inadequate eye movement control may cause an individual to lose his place when reading, have difficulty copying from the blackboard, and skip or omit small words when reading.

Accommodation

Another skill that is important for school, work performance, and reading is focusing ability. This skill allows rapid and accurate shifts, with instantaneous clarity, from one distance to another (e.g., from desk to chalkboard). It also permits the individual to maintain clear focus at the normal reading distance.

Symptoms of a focusing problem may include blurred vision while reading, inability to clear vision at distance after reading, and fatigue or headaches while reading.

Binocular Vision

In order for an individual to have comfortable vision, the two eyes must work together in a very precise and coordinated fashion. If this does not occur, the result may be double vision, frequent loss of place

when reading, headaches or eyestrain, and inability to sustain a visual task for any prolonged period of time.

There are several different types of eye teaming problems that can occur. In one common form, one eye may actually turn in or out intermittently or even all of the time. This type of problem is rather easy for an observer to notice. A more common form of eye teaming problem occurs when the eyes have a tendency to turn out, in, up, or down and the ability to compensate for this tendency is inadequate.

Insurance Letters

PREDETERMINATION LETTER

RE: John Smith

Policy number: 111-222-333

To whom it may concern:

The above patient was recently examined in my office. The diagnostic examination revealed the following medical diagnoses and their appropriate ICD-9-CM codes:

378.23 Intermittent exotropia

378.83 Convergence insufficiency

This diagnosis was reached on 1/1/08.

Note: The treatment for the above problems is medically necessary and is referred to as orthoptic therapy (CPT Code 92065). This treatment is specific for the neuromuscular anomaly and is being done to correct the above condition(s) or as an alternative to surgery and is not connected in any way with routine eye care, refractive error, or glasses.

Specific Treatment Program: Binocular Vision Disorders

Use the following for binocular vision disorders.

The treatment program for accommodative excess typically requires 24 to 30 visits and is divided into several phases.

Phase 1: designed to restore normal accommodative amplitude and ability to both stimulate and relax accommodation

Phase 2: designed to normalize accommodative dynamics, including the velocity and latency of the accommodative response

Phase 3: designed to restore normal accommodative and vergence facility

Each of these three phases generally requires about eight to ten visits, resulting in a total requirement of approximately 24 to 30 visits.

The fee for each treatment session (CPT #92065) is \$_____.

Thank you for your consideration of this information. If you have any additional questions, please contact me.

Sincerely,

Specific Treatment Program: Accommodative Disorders

Use the following for accommodative disorders.

The treatment program for convergence insufficiency typically requires 24 to 30 visits and is divided into several phases.

Phase 1: designed to restore normal “positive” negative fusional vergence (NFV) amplitudes, near point of convergence, and accommodative amplitude

Phase 2: designed to normalize fusional facility in both the positive fusional vergence (PFV) and the NFV systems

Phase 3: designed to restore normal vergence facility and amplitude during sustained versions

Each of these three phases generally requires about eight to ten visits, resulting in a total requirement of approximately 24 to 30 visits.

The fee for each treatment session (CPT #92065) is \$_____.

Thank you for your consideration of this information. If you have any additional questions, please contact me.

Sincerely,

INSURANCE APPEAL LETTERS

Reason for Denial: Routine Vision Care

RE: Jill Smith

Group number: 123456

Social Security number: 111-222-333

Claim number: 789101112

To whom it may concern:

I recently received correspondence from your office in which you denied benefits to Jill Smith for services that she received in my office. The reasons for denial were that “routine vision care is not covered by your plan.”

It is therefore important for me to clarify the service that was provided and her medical condition for which she is being treated.

The service provided was coded as 92060, which is a sensorimotor examination. This is *not a refraction for glasses and is not routine vision care*. This examination is designed to determine the nature and severity of any neuromuscular binocular disorder. In Jill’s case, a significant medical condition called “convergence insufficiency” was detected; it requires treatment referred to as Orthoptics (92065). Again, this is not routine vision care and should be covered under any major medical plan.

Sincerely,

Reason for Denial: Additional Information Requested—Is Vision Therapy an Alternative to Surgery?

Re: John Smith

Group number: 123456

Social Security number: 111-222-333

Claim number: 789101112

To whom it may concern:

I recently received your request for additional information about John Smith. Diagnosis: ICD-9-CM: 378.83, convergence insufficiency.

You asked for answers to the following questions.

1. Is the problem one that can be corrected surgically? Answer: Convergence insufficiency is a condition that can be corrected surgically. Surgery is generally reserved as a last resort for this condition.
2. Is therapy being given as an alternative to surgery? Answer: Yes. Orthoptics is a less invasive procedure than surgery and has been recommended as a viable alternative to surgery in this case.

I hope this information is adequate and enables you to complete the review process.

Thank you for your consideration of this information. If you have any additional questions, please contact me.

Sincerely,

Reason for Denial: Will Only Cover Vision Therapy if Performed by a Medical Doctor

RE: John Smith

Group number: 123456

Social Security number: 111-222-333

Claim number: 789101112

To whom it may concern:

I am responding to your recent correspondence to Mr. Smith regarding the above claim for his son, John. In this letter you state: "Vision therapy is only considered a covered benefit if performed by a medical doctor."

I must call to your attention that the state of Pennsylvania has a "freedom of choice law" [PA State Ann tit. 40, 1502 (Purdon)] that gives a patient the right to select an optometrist for any service within the scope of practice of that optometrist. The same is true for New York [NY Ins Law 250(1), 221(5) (c), 3216(i)(1), 4235(f)(C) (Consol.)]. You should also be well aware that, for insurance purposes, the term "physician" refers to optometrists, podiatrists, and psychologists, as well as medical doctors.

It is therefore inappropriate for you to consider vision therapy a covered benefit only if performed by a medical doctor. This patient's claim for reimbursement for this medical treatment (orthoptic therapy, 92065) for the diagnoses (convergence insufficiency, 378.83; intermittent exotropia, 378.23) cannot be denied because I am an optometrist, rather than a medical doctor. I am licensed to diagnose and treat these disorders and I have already submitted a detailed description of the diagnosis and proposed treatment plan, including a statement of medical necessity.

Mr. Smith and I would appreciate your prompt attention to this matter. If you have any additional questions, please contact me.

Sincerely,

cc: Pennsylvania State Insurance Commission

Information to be Included with Report to Parents about Financial Aspects of Vision Therapy

RE: John Smith

Dear Mr. and Mrs. Smith:

I have enclosed a summary report of John's recent evaluation. I have tried to describe the many different aspects of the visual system that I evaluated and the important results in each area.

From my past experience, I know that, at times, after parents go home and try to explain the vision problem to a spouse, things may not seem totally clear. I hope that this report will be of help. In addition, either my associate or I will be calling shortly to find out if you have any additional questions.

I have enclosed information about insurance coverage for vision therapy. Please read this information carefully. You will find that most Health Maintenance Organization (HMO) type plans do not cover vision therapy, while most major medical plans do. If a major medical plan does cover vision therapy services, it will reimburse you for your expenses. *Companies generally do not reimburse us directly for vision therapy.*

I have also enclosed a letter that you can send to your insurance company if you would like to inquire about your coverage. Simply write in the name and address of the insurance company along with the policy number.

Vision Therapy Office Policy

We would like you to know about our office policy concerning fees. Please read this **carefully** and discuss any questions you might have with a member of our staff.

Financial Arrangements

Financial arrangements must be made prior to starting therapy.

1. All fees for the original examination must be paid in full before the first therapy visit.
2. Payment for vision therapy is expected on a weekly basis. The fee for two weekly sessions is payable at the first visit of the week.
3. **ALL FEES FOR THERAPY ARE THE RESPONSIBILITY OF THE PATIENT, PARENT, OR GUARDIAN.** However, our office will be happy to help you complete and submit the necessary forms so that you may be properly reimbursed by your insurance company. If you experience any problems with the insurance company, we will be happy to assist you in overcoming these difficulties. **Please notify our office immediately if your insurance company rejects a claim for vision therapy.**

Please read the insurance information that accompanies this document.

Canceled or Missed Appointments

Please understand that vision therapy programs are individualized and time is spent programming your therapy, as well as the time reserved for your in-office visits. Because this time is reserved, please notify us as soon as possible if you are unable to keep your appointment.

Insurance Coverage for Vision Therapy Services

When the results of our evaluation indicate that vision therapy is appropriate to treat your vision problem, an individualized program of therapy is designed. The fee for this therapy is generally covered by major medical insurance plans and third-party payment plans. Approximately 75% of our patients have medical insurance that covers vision therapy.

Although it is often difficult for us to tell you at the time of your initial visit whether or not your insurance will cover vision therapy, there are some general rules that apply most of the time:

1. Vision therapy is not considered a form of "VISION CARE." **It would not be covered under a vision or eye care plan.** Rather, it is a type of medical treatment, and therefore would be covered under the major medical portion of your health care plan.
2. HMO plans often do not cover vision therapy.
3. If your health insurance plan has a major medical portion, it will generally reimburse you for 80% of the fee. It is still your responsibility to pay the fee for the visit. After paying the fee for the visit, you can then attach the receipt we give you to your insurance form and the insurance company will reimburse you.
4. We will be happy to assist you in your efforts to determine whether vision therapy is a covered service. We will write any necessary explanations needed initially. If you receive any negative reply, it is vital

that you notify us and send us a copy of the rejection. In our experience, a rejection is often a misunderstanding or lack of understanding about vision therapy. With the proper appeal letter, we can often achieve a reversal in the company's decision.

5. Some insurance companies will "assign benefits" directly to the doctor, meaning that they will send a check directly to us. Others will only reimburse the patient. For example, **most Blue Shield/Blue Cross plans cover vision therapy; however, most will only reimburse the patient and will not pay the doctor directly.** We will generally be able to tell you, at the time vision therapy is recommended, whether your health plan will assign benefits.
6. It is important that you refer to the specific diagnosis and terminology that we use when you interact with your insurance company. If you refer to the problem as a vision disorder, services may be denied.

II. Sources of Additional Information

Recommended Articles

1. Ciuffreda K. The scientific basis for and efficacy of optometric vision therapy in nonstrabismic accommodative and binocular vision disorders. *Optometry* 2002;73:735–762
2. Scheiman M, Mitchell GL, Cotter S, et al. A randomized trial of the effectiveness of treatments for convergence insufficiency in children. *Arch Ophthalmol* 2005;123:14–24.
3. Scheiman M, Mitchell GL, Cotter S, et al. A randomized clinical trial of vision therapy/ orthoptics versus pencil pushups for the treatment of convergence insufficiency in young adults. *Optom Vis Sci* 2005;82:583–595.
4. Special report: position statement on vision therapy. *J Am Optom Assoc* 1985;56:782–783.
5. Special report: the efficacy of optometric vision therapy. *J Am Optom Assoc* 1988;59:95–105.
6. Scheiman M. Hidden eye problems can block learning. *Learning* 91. Springhouse, PA: Springhouse Corporation, 1991.

Sources for Brochures

1. American Optometric Association, 243 North Lindbergh Avenue, St. Louis, MO 63141; 314-991-4100.
2. Optometric Extension Program, 1921 E. Carnegie Avenue, Suite 3-L, Santa Ana, CA 92705-5510; 949-250-8070.

III. Home Vision Therapy Procedures; Patient Instructions

Red Lens and Penlight Technique to Eliminate Suppression

The purpose of this therapy is to help break suppression and enhance sensory and motor fusion so that you use both eyes together, at the same time, to see an object. The therapy will help you use both eyes together so that you may begin to obtain all the benefits of binocular vision. You will know that you are doing the therapy correctly when you can do the procedures quickly and easily, without suppressing.

Perform therapy _____ minutes per day and increase the number of procedures in each session as you can do them. In the beginning, you may experience discomfort (e.g., headaches, eye strain, etc.) and have to limit the time to a few minutes. As your ability improves, your discomfort will disappear and the time can be increased. Remember that 15 minutes per day is better than 2 hours once a week. Try to establish a routine, so that you always do the therapy at _____ o'clock each day.

Materials required: Red/green glasses, prism, bright light or candle, and a watch or clock.

Procedure 1: Sit _____ ft from a bright small light or candle in a darkened room. Put on the red/green glasses, with the red lens over your _____ eye and the prism, with the base down, over the same eye. Look directly at the light. You should see two lights, one red and one green, the green below the red. If you do not see two lights, blink your eyes several times and/or move closer to the light. Keep working until you can keep both lights in view constantly, without one disappearing for _____ minute(s).

Procedure 2: Move away from or closer to the light, until one of the lights disappears or you have moved all the way across the room. Concentrate on keeping both lights visible at all times. If you have trouble doing this, move a little closer to the light and blink your eyes.

Procedure 3: Using the same setup as in procedures 1 and 2, view the lights from at least 10 ft in a darkened room. Then, slowly increase the illumination in the room by turning on some lights or opening the shades or curtains. Concentrate your attention on keeping both lights present simultaneously. Work from dim lighting to normal daylight illumination. Repeat procedures 1 and 2 under these new conditions.

Procedure 4: Once you can hold both lights constantly in normal illumination, sit _____ ft from the light, wearing the red/green glasses with the red lens over the _____ eye and the prism over the _____ eye. Now, slowly turn the prism so that the base is _____. The red and green lights will move closer together as you do this. Concentrate on keeping both lights in view as they come closer together; if one disappears, rotate the prism back until you see both again. Continue moving the prism until you see the lights move into one and appear yellow, yellowish-red, or a changing color between green and red.

This is called a fusion response and it is extremely important to work diligently to attain it. The goal is to maintain a fused image, without suppression, for 1 minute.

Time and recording: Work on the assigned procedures for _____ minutes each day and record the time involved, the distance, illumination, and any problems or observations.

Television Trainer

The purpose of this therapy is to develop simultaneous perception from your two eyes when you are looking at a distance. You will know that you are using both eyes when you can see the television clearly through both parts of the therapy device. Remember, your task is to see the whole television picture through both parts of the device at once.

Perform therapy _____ minutes per day and increase the number of procedures in each session as you can do them. In the beginning, you may experience discomfort (e.g., headaches, eye strain, etc.) and have to limit the time to a few minutes. As your ability improves, your discomfort will disappear and the time can be increased. Remember that 15 minutes per day is better than 2 hours once a week. Try to establish a routine, so that you always do the therapy at _____ o'clock each day.

Procedure 1: Attach the therapy device to the television set with the suction cups; orient the device vertically with the red part on top. It is very important that the device be vertical; otherwise, the therapy may be ineffective. Put on the special glasses that have been provided, with the red lens over the right eye. Turn on the television, sit _____ ft away from it, and watch it. You should see the television picture through both parts of the therapy device at the same time. If one part of the therapy device is black (cannot be seen through), the visual information from one of your eyes is not being received (suppression). The result is like closing one eye. If first one part of the device is black and then the other is black, it is like alternately closing one eye and then the other. The visual information is still being received, only from one eye at a time. Your goal in this therapy is to become aware of the visual information from both eyes simultaneously.

If you find that only one eye is being used (suppression), then, in order to use both eyes: (a) blink your eyes rapidly, looking for the other eye's image between blinks; (b) cover one eye, then quickly remove the cover; (c) turn the room lights down or out; or (d) do any or all of the above in combination.

Ask yourself these questions and be sure to tell your doctor your answers:

1. Does one part of the television therapy device ever go black? If so, when and how often?
2. Does the black part of the therapy device jump from top to bottom?
3. If both parts of the device are easy to see through, is the picture on the television clear or blurry?
4. Does the therapy get easier as I do it more often?

Procedure 2: Repeat procedure 1 at a different distance, about _____ ft. Always try to maintain the correct response—clear, easy viewing through both parts of the therapy device at the same time.

Procedure 3: As procedure 2 becomes easy for you, move (closer) (farther) and continue trying to maintain the correct response.

Procedure 4: Repeat procedure 1, using the special lenses or prisms provided. These are designed to make the task more difficult. Always try to maintain the correct response—clear, easy viewing through both parts of the therapy device at the same time, while the lenses or prisms are being used.

Eccentric Circles: Divergence

The purpose of this therapy is to improve your ability to aim and focus your eyes together, which will result in more efficient vision for longer periods of time. The therapy will help you use both eyes together so that you can later obtain all the benefits of binocular vision. You will know that you are doing the therapy correctly when you can do the procedures quickly and easily, without suppressing.

Perform therapy _____ minutes per day and increase the number of procedures in each session as you can do them. In the beginning, you may experience discomfort (e.g., headaches, eye strain, etc.) and have to limit the time to a few minutes. As your ability improves, your discomfort will disappear and the time can be increased. Remember that 15 minutes per day is better than 2 hours once a week. Try to establish a routine, so that you always do the therapy at _____ o'clock each day.

Materials required: Set of Eccentric Circle cards (clear plastic), ruler, clock with second hand, and plus/minus flippers.

Setup: Hold the cards at your reading distance, one card in each hand, keeping them slightly separated. They should be held so that the "A's" are together on the bottom. Be sure the circles are not vertically displaced.

Look between the cards at some object in the distance, concentrating on keeping that object clear, but noticing the circles, which will be blurred, in the foreground. As you concentrate on the distant object, you will begin to be aware of four sets of circles. Now move the cards slowly together (toward each other) until the two central sets of circles superimpose or fuse into one, so that you see three sets. Once you can accomplish this (and don't get discouraged—it is not easy!), you will notice that the smaller inner ring of the central set of rings appears closer to you than the larger outer ring and the circles appear in depth, giving the effect of a stool.

If the circles appear blurred, don't worry—concentrate on keeping them fused and on noticing the appearance of depth. Once you can do this, begin concentrating on making the fused circles clear; if you gently jiggle the cards back and forth while trying to make them clear, you will soon be able to do this. Aim to keep the circles fused, clear, and in depth at all times.

Procedure 1: Once you can keep the circles in clear focus and maintain the depth effect, hold the cards at arm's length and slowly bring them closer to you, keeping them clear. You will notice that the space between the circles tends to diminish—the “stool” gets shorter. Bring the cards as close to yourself as you can, maintaining the fusion. Then, move the cards out and bring them in again. Aim to move them in and out smoothly, maintaining the fusion, clarity, and depth, and try to increase your range, bringing the cards as close as possible. Repeat the therapy _____ times, recording the closest distance you were able to achieve.

Procedure 2: Hold the cards with both hands at your reading distance and fuse the circles as before. Slowly move your hands apart, separating the cards. Continue moving the cards apart, keeping the circles fused as far as you possibly can. Move the cards back together when you have reached your limit, and then bring them apart again, repeating the therapy _____ times. Record the farthest separation you were able to achieve.

Procedure 3: Fuse the circles as before, holding the cards at your reading distance. Then, look across the room at an object, make sure it is clear and, when it is, look back at the circles and regain the fusion. Continue working in this manner, looking back and forth from the object across the room to the cards, only switching back when the circles have been fused and cleared. As this therapy becomes easier, hold the cards farther and farther apart. Repeat the therapy for _____ jumps, recording the distance at which you were holding the cards and their separation.

Procedure 4: Hold the cards at your reading distance and obtain fusion of the circles, while looking through one side of the plus/minus flipper lens bar. Now, quickly flip the bar so that you are looking through the lenses on the other side and regain the fusion, making sure that the circles are clear and appear as a stool. Repeat the alternations, working to re-fuse and clear the circles as quickly and smoothly as possible. Note the time that it takes for you to do 20 cycles (40 flips); do _____ sets of cycles each day and record your best time for one set of 20 cycles each day.

Time and recording: Record the amount of time spent and any problems or questions you have, along with your best measured effort for the procedure you did.

Eccentric Circles: Convergence

The purpose of this therapy is to improve your ability to aim and focus your eyes together, which will result in more efficient vision for longer periods of time. The therapy will help you use both eyes together so that you can later obtain all the benefits of binocular vision. You will know that you are doing the therapy correctly when you can do the procedures quickly and easily, without suppressing.

Perform therapy _____ minutes per day and increase the number of procedures in each session as you can do them. In the beginning, you may experience discomfort (e.g., headaches, eye strain, etc.) and have to limit the time to a few minutes. As your ability improves, your discomfort will disappear and the time can be increased. Remember that 15 minutes per day is better than 2 hours once a week. Try to establish a routine, so that you always do the therapy at _____ o'clock each day.

Materials required: Set of Eccentric Circle cards (paper), pencil, ruler, clock with second hand, and plus/minus flippers.

Setup: Hold the cards at your normal reading distance, side by side and touching, so that the “B's” are together on the bottom. Be sure the circles are not vertically displaced. Hold a pencil so that its point is between the two sets of circles. Slowly move the pencil toward your eyes, keeping the tip of the pencil clear. Notice the circles in the background behind the pencil. At a certain point, you should be aware that the circles are beginning to double.

As you continue to bring the pencil closer, the two inner sets of circles will approach each other and fuse into one so that you will see three sets. To achieve this, you must continue to concentrate on keeping the pencil clear, while being conscious of the circles in the background. When you have fused the center sets of circles, slowly take the pencil away, concentrating on keeping the center image fused. If you have trouble doing this, bring the pencil back in, until you can keep the circles fused more easily. This is not an easy task. Don't get discouraged if you have some trouble; it may take you some time to learn to do it. The circles will

appear blurred at first. Once you can keep the center circles fused, notice that the set of circles will appear in depth—the smaller inner circle will seem farther away from you than the larger outer circle; the effect will be like a bucket.

If the circles appear blurred, continue concentrating on them and gently jiggle the cards back and forth, trying to clear them; the circles will begin to clear and you will be able to read the print. Keep the circles fused, clear, and in depth at all times.

Procedure 1: Once you can keep the circles in clear focus and maintain the depth effect, hold the cards at arm's length and slowly bring them closer to yourself, keeping them clear. You will notice that the space between the rings appears to diminish—the “bucket” gets shallower. Bring the cards as close as you can, maintaining the fusion. Then, bring the cards out and move them in again. Move them in and out smoothly, maintaining the fusion, clarity, and depth, and try to increase your range, bringing the cards as close as possible. Repeat the therapy _____ times, recording the closest distance you were able to achieve.

Procedure 2: Hold the cards with both hands at your reading distance and fuse the circles as before. Slowly move your hands apart, separating the cards. Continue moving the cards apart, keeping the circles clear and fused as far as you possibly can. Move the cards back together when you have reached your limit, and then bring them apart again, repeating the therapy _____ times. Record the farthest separation you were able to achieve.

Procedure 3: Fuse the circles as before, holding the cards at your reading distance. Then, look across the room at an object, make sure it is clear and, when it is, look back at the circles and regain the fusion. Continue working in this manner, looking back and forth from the object across the room to the cards, only switching back when the circles have been fused and cleared. As this therapy becomes easier, hold the cards farther and farther apart. Repeat the therapy for _____ jumps, recording the distance at which you were holding the cards and their separation. Record the time for ten jumps. Rest. Repeat _____ sets.

Procedure 4: Hold the cards at your reading distance and obtain fusion of the circles, while looking through one side of the plus/minus flipper lens bar. Now, quickly flip the bar so that you are looking through the lens on the other side and regain the fusion response, making sure that the circles are clear and appear in depth. Repeat the alternations, working to re-fuse and clear the circles as quickly and smoothly as possible. Note the time it takes for you to do 20 cycles (40 flips), and record your best time for one set of 20 cycles each day. Do _____ sets each day.

Time and recording: Record the amount of time spent and any problems or questions you have, along with your best measured effort for the procedure you did.

Eccentric Circles at 10 to 15 Feet

The purpose of this therapy is to improve your ability to aim and focus your eyes together, which will result in more efficient vision for longer periods of time. The therapy will help you use both eyes together so that you can later obtain all of the benefits of binocular vision. You will know that you are doing the therapy correctly when you can do the procedures quickly and easily, without suppressing.

Perform therapy _____ minutes per day and increase the number of procedures in each session as you can do them. In the beginning, you may experience discomfort (e.g., headaches, eye strain, etc.) and have to limit the time to a few minutes. As your ability improves, your discomfort will disappear and the time can be increased. Remember that 15 minutes per day is better than 2 hours once a week. Try to establish a routine, so that you always do the therapy at _____ o'clock each day.

Materials required: Set of enlarged Eccentric Circle cards (paper), yardstick, clock with second hand, and plus/minus flippers.

Setup: Place the Eccentric Circle cards on the wall, side by side and touching, so that the “B’s” are together on the bottom. Be sure that the circles are not vertically displaced. Hold a yardstick so that its point is between the two sets of circles. Slowly move the yardstick toward your eyes, keeping the tip clear. Notice the circles in the background, behind the yardstick. At a certain point, you should be aware that the circles are beginning to double.

As you continue to bring the yardstick closer, the two inner sets of circles will approach each other and fuse into one so that you will see three sets. To achieve this, you must continue to concentrate on keeping the yardstick clear, while being conscious of the circles in the background. When you have fused the center sets of circles, slowly take the yardstick away, concentrating on keeping the center image fused. If you have

trouble doing this, bring the yardstick back in until you can keep the circles fused more easily. This is not an easy task. Don't get discouraged if you have some trouble; it may take you some time to learn to do it. The circles will appear blurred at first. Once you can keep the center circles fused, notice that the set of circles will appear in depth—the smaller inner circle will seem farther away from you than the larger outer circle; the effect will be like a bucket.

If the circles appear blurred, continue concentrating on them and gently move your head back and forth, trying to clear them; the circles will begin to clear and you will be able to read the print. Keep the circles fused, clear, and in depth at all times.

Procedure 1: Once you can keep the circles in clear focus and maintain the depth effect, walk closer to them, keeping them clear. You will notice that the space between the rings appears to diminish—the “bucket” gets shallower. Move as close to the cards as you can, maintaining the fusion. Then walk closer and farther, maintaining the fusion, clarity, and depth, and try to increase your range, moving as close as possible. Repeat the therapy _____ times, recording the closest distance you were able to achieve.

Procedure 2: Have an assistant slowly move the cards apart. Continue moving the cards apart, keeping the circles clear and fused as far as you possibly can. Move the cards back together when you have reached your limit, and then bring them apart again, repeating the therapy _____ times. Record the farthest separation you were able to achieve.

Procedure 3: Fuse the circles as before, look at an object in your hand, make sure it is clear and, when it is, look back at the circles and regain the fusion. Continue working in this manner, looking back and forth from the object in your hand to the cards, only switching back when the circles have been fused and cleared. As this therapy becomes easier, move the cards farther and farther apart. Repeat the therapy for _____ jumps, recording the distance from the cards and their separation. Record the time for ten jumps. Rest. Repeat _____ sets.

Procedure 4: Obtain fusion of the circles while looking through the minus side of the plus/minus lens flipper. Now, quickly remove the bar, so that you are looking through no lenses, and regain the fusion response, making sure that the circles are clear and appear in depth. Repeat the alternations, working to re-fuse and clear the circles as quickly and smoothly as possible. Note the time that it takes for you to do 20 cycles (40 flips), and record your best time for one set of 20 cycles each day. Do _____ sets each day.

Time and recording: Record the amount of time spent and any problems or questions you have, along with your best measured effort for the procedure you did.

Tranaglyph Slides

The purpose of this therapy is to improve the smoothness and range of your eye alignment ability when looking at objects. This skill will help you greatly in performing demanding visual tasks. You will know that you are doing the therapy correctly when you can do the procedures quickly and easily, without suppressing.

Perform therapy _____ minutes per day and increase the number of procedures in each session as you can do them. In the beginning, you may experience discomfort (e.g., headaches, eye strain, etc.) and have to limit the time to a few minutes. As your ability improves, your discomfort will disappear and the time can be increased. Remember that 15 minutes per day is better than 2 hours once a week. Try to establish a routine, so that you always do the therapy at _____ o'clock each day.

Materials required: Tranaglyph slides (Bernell sets BC500 and/or BC600), red/green glasses, tranaglyph holder, and/or a single or dual Polachrome orthoptic trainer.

Procedure 1: Put the red/green glasses on over your regular or training glasses. Place the selected tranaglyph pair in the tranaglyph holder or in a single or dual Polachrome orthoptic trainer. Make sure you have good lighting and that a plain background is directly behind the tranaglyph.

Position yourself _____ distance in front of the tranaglyph and begin with the setting of _____. Alternately open one eye and close the other. You will notice that certain objects on the slide are seen only by the right eye, whereas others are seen only by the left eye. These are suppression clues. The correct response is one in which all the objects on the slide are single and clear and all the suppression clues are seen at the same time. When you have this correct fusion response, you are using your two eyes together. Move one tranaglyph, if necessary, to achieve this.

Slowly move the top tranaglyph to the right/left, keeping the picture single and clear with both (each eye's) suppression checks present. Keep moving the top tranaglyph in the same direction until the images double.

When this happens, move the top tranaglyph back to the right/left, until you again have one clear image with all suppression checks present. Repeat this procedure, trying to move the top tranaglyph further to the right/left before the image doubles. Note the maximum number on the setting. This is your “record,” which you should always strive to beat or match.

Goal: Be able to move the tranaglyph to setting _____ without its doubling or becoming blurred.

Procedure 2: Repeat the above procedure, but this time move the top tranaglyph in the opposite direction, to the right/left. Again, note the maximum number achieved.

Procedure 3: Once you have been able to reach the goals set for you, place the tranaglyph at the maximum setting to the right/left. Look at the tranaglyph, keeping it clear and single. Look across the room at a small target (e.g., printed letters). Then, look back at the tranaglyph. If the tranaglyph is double or the suppression checks are not present, decrease the separation slightly and try it again at this new setting. Repeat until you are able to look back and forth between the tranaglyph and across the room with the tranaglyph set at the maximum setting to the right/left.

Procedure 4: Repeat procedure 3, but this time move the top tranaglyph in the opposite direction (right/left). Again, note the maximum number achieved.

Procedure 5: Once you are able to do procedures 3 and 4 with ease, position the tranaglyph on setting _____. Make sure that the image is single and clear and that all suppression checks can be seen. Flip the tranaglyph end for end and try to make it single again. If you are unable to get the tranaglyph single, decrease the separation slightly and try again.

Goal: Be able to flip the tranaglyph and rapidly regain fusion in each position with the tranaglyph set at number _____.

ADDITIONAL ACTIVITIES

1. Arrange two sets of tranaglyphs, set in opposite directions (right/left), one on the top display of the dual Polachrome orthoptic trainer, one on the bottom display. Look back and forth from one to the other, fusing the image quickly, without suppression, each time.
2. Incorporate loose prism jumps, while viewing the tranaglyph.
3. Incorporate plus/minus flippers, while viewing the tranaglyph.
4. Use BOP (base-out plus)/BIM (base-out minus) flippers with the tranaglyph.
5. Vary the viewing distance.
6. Repeat in different positions of gaze.

Beads and String

The purpose of this therapy is to develop better coordination between your eyes when you look at objects located at different distances. You will know that you are using both eyes correctly, in each therapy, when you can look at a small object and see it as one, while noticing that all the other small objects in front and behind it are doubled. Remember, your task is to see one of what you are looking at and two of what you are not looking at.

Perform therapy _____ minutes per day and increase the number of procedures in each session as you can do them. In the beginning, you may experience discomfort (e.g., headaches, eye strain, etc.) and have to limit the time to a few minutes. As your ability improves, your discomfort will disappear and the time can be increased. Remember that 15 minutes per day is better than 2 hours once a week. Try to establish a routine, so that you always do the therapy at _____ o'clock each day.

Procedure 1: Attach one end of the string to an object (such as a doorknob) and hold the other end close to your nose, in the midline between your eyes. Place a bead on the string, at 4 in. from your eyes. Look at the bead and try to make both eyes pull in (converge) together. Then the bead will be seen as one and the string will be seen as two. Repeat the therapy five times by closing your eyes and then opening them to look at the bead.

If you see only one bead and string, then (a) move the bead slightly to the right and left of the midline or (b) move the bead on the string closer or further from yourself, until you obtain the correct response.

Correct Response: Looking at the bead, you will see one bead and two strings. Close the right eye; you see one bead and one string on the right. Close the left eye; you see one bead and one string on the left. During this therapy, if you see only one of the bead and string (although both your eyes are open), the visual

information from one of your eyes is not being received (suppression). The result is like closing one eye. One of your goals is to become aware of the visual information from both eyes. In addition, if you should see two of both the bead and the string, then you are receiving the visual information, but your eyes are not aimed correctly at the bead. Your second goal is to move your eyes correctly, by repeatedly trying to pull the eyes inward.

If you find that only one eye is being used (suppression), then, in order to use both eyes:

1. Blink your eyes rapidly.
2. Wiggle the string horizontally or vertically.
3. Cover one eye, then quickly remove the cover.
4. Do any or all of the above, in combination.

Ask yourself the following questions as you do each therapy, and be sure to tell your doctor your answers when he or she evaluates your progress.

1. Can I feel both eyes moving when I look at the bead?
2. Can I see the bead and string correctly at all times?
3. Do I ever see one or both of the string and bead? If so, where and when?
4. Do I ever see two of the bead as well as two of the string? Where and when?
5. Does the therapy get easier as I do it more often?

Procedure 2: Put another bead on the string, at 10 in. from yourself. Look from the front bead to the back bead _____ times, trying to see one of what you are looking at and two of what you are not.

Correct Responses: Looking at a bead, you will see one of the beads you are looking at and two of the other beads. The string should go through the bead you are looking at; make an “X” through the other bead.

Procedure 3: Put a third bead on the string, 16 in. from yourself (beads are now at 4, 10, and 16 in.). Practice looking from one bead to another, as rapidly as possible, while still obtaining the correct response.

Correct Responses: Looking at a bead, you will see one of the beads you are looking at and two of the other beads. The string should go through the bead you are looking at; make an “X” through the other beads.

Procedure 4: Select a small object (such as a light switch) across the room and hold the string in line with it. Alternately look from the far object to one bead on the string (the position of the bead can be changed), obtaining the correct response. Repeat this procedure, selecting other small objects at different distances in the room. Try to do this therapy quickly and easily.

Procedure 5: Remove all beads from the string. Practice looking along the string, from distance to near and as slowly as possible, while still obtaining the correct response. It is sometimes helpful to pretend that you are following the course of an imaginary “bug” as it walks the length of the string. It is for this reason that this procedure is often called “bug on a string.”

Correct Response: Looking at the string, you will see the string cross where you are looking; make an “X” at that point.

Colored Circle Cards for Convergence

The purpose of this therapy is to develop the coordination and focusing ability of your eyes when you are looking at near objects and when you look from far to near objects. You will know you are doing the therapy correctly when you can fuse the two red and green circles into a single brownish one.

Perform therapy _____ minutes per day and increase the number of procedures in each session as you can do them. In the beginning, you may experience discomfort (e.g., headaches, eye strain, etc.) and have to limit the time to a few minutes. As your ability improves, your discomfort will disappear and the time can be increased. Remember that 15 minutes per day is better than 2 hours once a week. Try to establish a routine, so that you always do the therapy at _____ o'clock each day.

Procedure 1: Hold the card of colored circles about 16 in. from yourself. Hold a pencil centered between the bottom circles. Look at the tip of the pencil and observe the circles on either side, without looking directly at them. Slowly move the pencil toward your nose (always look at the tip and keep it centered) until you see four circles (or more than two). Continue moving the pencil. Observe the inner circles approaching each other until you see them overlap (superimpose). You will then see three circles—one red, one green, and one in the middle, under the pencil. Stop moving the pencil at this point. Through concentration, keep both

colors present in the middle circle. If it turns green, then your left eye is not seeing correctly; if it turns red, your right eye is not seeing correctly. Concentrate and make both colors appear at the same time, a mixture of color that appears greenish or reddish brown.

If you find that only one eye is being used (suppression), then do the following in order to use both eyes:

1. Blink your eyes rapidly.
2. Cover one eye, then quickly remove the cover.

Next, try to clear the letters. While you continue to maintain a mixture of both colors in the middle circle, concentrate on holding the letters clear. When procedure 1 is done correctly, you should see three circles—one red, one green, and one in the middle, under the pencil. The center circle should be clear and brownish.

Procedure 2: Repeat procedure 1 and go on to the more widely separated circles. Continue until you can do all four sets of circles. Notice the letters in the circles—they should be visible at all times. If some letters are missing (suppression), blink your eyes rapidly and look for the missing letters between blinks.

Procedure 3: Repeat procedures 1 and 2 without the aid of the pencil. When you can fuse all four sets of circles (always maintaining the correct response), begin to turn your head slowly from side to side while you keep the middle circle clear and single and with both colors present. Vary the head movement by rotating it slowly, clockwise, and up and down.

Note: Keys to improvement:

1. When you can see the central fused circle
2. When you can perform the procedure without using a pencil
3. When the central fused circle is a “mixture” in the color of the red and green circle and appears a shiny or lustrous brown
4. When all of the letters are present in the words “clear these letters”
5. When you can perform the procedure with ease

Procedure 4: Look at a detailed distant object (more than 10 ft away) and make it clear. Then, look at the card and fuse the bottom circle, making it clear and single. Repeat this procedure until you can look easily from a distant object to the card and easily fuse and clear the most widely separate circles. No pencil is to be used in this therapy. Remember, clear the distance object, then look at the card and fuse the colored circles. When you can do this easily, move the card closer each time you do the therapy. You should fuse the circles at 4 to 6 in. and maintain the correct responses when looking from distance to near. Each time you fuse the circles, the center brownish circle should be clear. When you look at a distance, it should be clear. Do not look from one place to the other until the first place is clear.

First- or Second-Degree Targets at 10 to 15 Feet

The purpose of this therapy is to improve your ability to aim and focus your eyes together, which will result in more efficient vision for longer periods of time. The therapy will help you use both eyes together so that you can later obtain all of the benefits of binocular vision. You will know that you are doing the therapy correctly when you can do the procedures quickly and easily, without suppressing.

Perform therapy _____ minutes per day and increase the number of procedures in each session as you can do them. In the beginning, you may experience discomfort (e.g., headaches, eye strain, etc.) and have to limit the time to a few minutes. As your ability improves, your discomfort will disappear and the time can be increased. Remember that 15 minutes per day is better than 2 hours once a week. Try to establish a routine, so that you always do the therapy at _____ o'clock each day.

Materials required: Set of enlarged first-degree (nonfusible) or second-degree targets (fusible with suppression checks), yardstick, clock with second hand, and plus/minus flippers.

Setup: Place the second-degree targets on the wall, side by side and touching. Be sure they are not vertically displaced. Hold a yardstick so that its point is between the two targets. Slowly move the yardstick toward your eyes, keeping the tip clear. Notice the targets in the background, behind the yardstick. At a certain point, you should be aware that the targets are beginning to double.

As you continue to bring the yardstick closer, the targets will approach each other and fuse into one so that you will see three sets. To achieve this, you must continue to concentrate on keeping the yardstick clear, while being conscious of the targets in the background. When you have fused the center target, slowly take

the yardstick away, concentrating on keeping the center image fused, with the suppression checks present. If you have trouble doing this, bring the yardstick back in until you can keep the targets fused more easily. This is not an easy task. Don't get discouraged if you have some trouble; it may take you some time to learn to do it. The targets will appear blurred or you may suppress at first.

If the targets appear blurred, continue concentrating on trying to clear them; the circles will begin to clear and you will be able to read the print. Keep the circles fused and clear at all times.

Procedure 1: Once you can keep the targets in clear focus, walk closer to them, keeping them clear. Move as close to the card as you can, maintaining the fusion. Then walk closer and farther, maintaining the fusion and clarity, and try to increase your range, moving as close as possible. Repeat the therapy _____ times, recording the closest distance you were able to achieve.

Procedure 2: Have an assistant slowly move the cards apart. Continue moving the cards apart, keeping the targets clear and fused as far as you possibly can. Move the cards back together when you have reached your limit, and then bring them apart again, repeating the therapy _____ times. Record the farthest separation you were able to achieve.

Procedure 3: Fuse the targets as before, look at an object in your hand, make sure it is clear and, when it is, look back at the targets and regain the fusion. Continue working in this manner, looking back and forth from the object in your hand to the cards, only switching back when the targets have been fused and cleared. As this therapy becomes easier, move the cards farther and farther apart. Repeat the therapy for _____ jumps, recording the distance from the cards and their separation. Record the time for ten jumps. Rest. Repeat _____ sets.

Procedure 4: Obtain fusion of the targets while looking through the minus side of the plus/minus lens flipper. Now, quickly remove the flipper so that you are looking through no lenses and regain the fusion response, making sure that the targets are clear and appear in depth. Repeat the alternations, working to re-fuse and clear the targets as quickly and smoothly as possible. Note the time it takes for you to do 20 cycles (40 flips), and record your best time for one set of 20 cycles each day. Do _____ sets each day.

Procedure 5: Repeat procedures 1 to 4, with the first-degree (nonfusible) targets.

Time and recording: Record the amount of time worked and any problems or questions you have, along with your best measured effort for the procedure you did.

Hart Chart: Saccadic Therapy

The purpose of this therapy is to help increase your ability to change the focus of your eyes so that you use each eye to clearly see objects at different distances. The therapy will help you use both eyes together so that you may begin to obtain all of the benefits of binocular vision. You will know that you are doing the therapy correctly when you can do the procedures quickly and easily.

Perform therapy _____ minutes per day and increase the number of procedures in each session as you can do them. In the beginning, you may experience discomfort (e.g., headaches, eye strain, etc.) and have to limit the time to a few minutes. As your ability improves, your discomfort will disappear and the time can be increased. Remember that 15 minutes per day is better than 2 hours once a week. Try to establish a routine, so that you always do the therapy at _____ o'clock each day.

Materials required: Large Hart chart for distance viewing, small Hart chart for near viewing, and an eye patch.

Procedure 1: Place the Hart chart about 5 to 10 ft away. Occlude the _____ eye with an eye patch. Call out the first letter in column 1 and then the first letter in column 10, the second from the top letter in column 1 and the second letter from the top in column 10, the third letter from the top in column 1 and the third letter from the top in column 10, and so forth. Continue until you have called out all letters from column 1 and 10. As you call out the letters, have an assistant write down your responses and, when the task is completed, check your accuracy. Checking for errors is, in itself, another saccadic therapy technique because you will have to make saccades from far to near to check for errors. Repeat the procedure with the other eye patched.

Procedure 2: Once you can complete procedure 1 in about 15 seconds, without any errors, you can increase the level of difficulty several ways. Continue calling out letters in the other columns. Specifically, after completing columns 1 and 10, call out columns 2 and 9, 3 and 8, 4 and 7, and 5 and 6. The inner columns are more difficult because they are surrounded by other targets.

Procedure 3: An even greater level of difficulty can be achieved by making saccades from the top of one column to the bottom of another. Instead of a left-to-right and right-to-left saccade, you will have to make an oblique saccade. For example, call out the top letter in column 1 and then the bottom letter in column 10, the second letter from the top in column 1 and the second letter from the bottom in column 10. Continue this pattern through the entire chart.

Procedure 4: Many other variations to increase the level of difficulty are possible, including incorporating the beat of a metronome and maintaining balance on a balance board while engaged in the task.

Procedure 5: Repeat the previous procedures, looking from the distance chart to the near one.

Ann Arbor Letter Tracking

The purpose of this therapy is to help increase the accuracy of eye movements from place to place so that you use your eyes as accurately as possible to look at an object. The therapy will help you make accurate movements of your eyes between objects so that you may begin to obtain all of the benefits of accurate vision. You will know that you are doing the therapy correctly when you can do the procedures quickly and easily.

Perform therapy _____ minutes per day and increase the number of procedures in each session as you can do them. In the beginning, you may experience discomfort (e.g., headaches, eye strain, etc.) and have to limit the time to a few minutes. As your ability improves, your discomfort will disappear and the time can be increased. Remember that 15 minutes per day is better than 2 hours once a week. Try to establish a routine, so that you always do the therapy at _____ o'clock each day.

Materials required: Ann Arbor letter tracking workbooks, 8.5 × 11 in. plastic sheet, paper clip, pen used for overhead transparencies (washable type), eye patch, and a stop watch.

Procedure 1: To permit the repeated use of the workbooks, cover the page being used with a plastic sheet and secure the plastic with a paper clip. Each page of letter tracking has two or more paragraphs of what appear to be random letters. Occlude the _____ eye. Begin at the upper right and scan from left to right to find the first letter “a”; make a line through the letter “a.” Find the very first “b,” cross it out, and continue through the entire paragraph, finding the letters in alphabetical order. The goal is to complete this task as quickly as possible; time the therapy procedure and evaluate your accuracy. If you are scanning for the very first letter “d,” for instance, and inadvertently miss it and find a “d” later in the paragraph, you will be unable to find the entire alphabet sequence in the paragraph.

After you find and mark a specific letter, lift the pen off the page so that you will have to use eye movements to find the next letter. Repeat the procedure, with the other eye occluded.

Procedure 2: The workbook has letters in five different sizes, creating other levels of difficulty.

Endpoint: Discontinue this technique when the performance in each eye is approximately equal and when you can successfully complete the paragraphs in about 1 minute.

Visual Tracing

The purpose of this therapy is to help increase the accuracy of eye movements from place to place so that you use your eyes as accurately as possible to look at an object. The therapy will help you make accurate movements of your eyes between objects so that you may begin to obtain all of the benefits of accurate vision. You will know that you are doing the therapy correctly when you can do the procedures quickly and easily.

Perform therapy _____ minutes per day and increase the number of procedures in each session as you can do them. In the beginning, you may experience discomfort (e.g., headaches, eye strain, etc.) and have to limit the time to a few minutes. As your ability improves, your discomfort will disappear and the time can be increased. Remember that 15 minutes per day is better than 2 hours once a week. Try to establish a routine so that you always do the therapy at _____ o'clock each day.

Materials required: Percon visual tracing workbooks, 8.5 × 11 in. plastic sheet, paper clip, pen used for overhead transparencies (washable type), and an eye patch.

Procedure 1: The workbook contains tracing tasks that gradually increase in level of difficulty from the beginning to the end of the book. Two therapy methods can be used. The easiest procedure is to occlude the _____ eye, place the pen on the letter “A,” and trace along the line until the end of the line. The objective is to determine the number at the end of the line beginning with the letter “A.” Continue until you have found the answer for each line.

Procedure 2: As your accuracy and speed improve, the next level of difficulty can be added. In this technique, perform the same task, using only your eyes. Make an eye movement without the support of following the line with the pencil.

Loose Lens Rock (Monocular)

The purpose of this therapy is to help increase your ability to change the focus of your eyes so that you use both eyes together to clearly see an object. The therapy will help you use both eyes together so that you may begin to obtain all of the benefits of binocular vision. You will know that you are doing the therapy correctly when you can do the procedures quickly and easily.

Perform therapy _____ minutes per day and increase the number of procedures in each session as you can do them. In the beginning, you may experience discomfort (e.g., headaches, eye strain, etc.) and have to limit the time to a few minutes. As your ability improves, your discomfort will disappear and the time can be increased. Remember that 15 minutes per day is better than 2 hours once a week. Try to establish a routine so that you always do the therapy at _____ o'clock each day.

Materials required: Age-appropriate reading material of varying sizes (from 20/80 to 20/30), uncut plastic lens blanks (from -6.00 to $+2.50$, in 0.25 D increments), and an eye patch.

Procedure 1: Occlude the _____ eye and clear and read print that is held at 40 cm, through plus/minus lenses that are alternately held in front of the unoccluded eye. The lenses that will be given to you are based on the results of the diagnostic testing. In the initial phase of this technique, you have as much time as necessary to clear and read the print. The goal is merely to achieve clear vision, without regard to the time factor. Repeat the procedure with the other eye patched. Once you can clear the lenses with both eyes, speed becomes the next objective.

Procedure 2: Now, regain clarity as quickly as possible. Begin with low-powered lenses and clear the print through $+0.50$ and -0.50 , 20 cycles per minute. When you can accomplish this, increase the power of the lenses until you can perform 20 cycles per minute with $+2.00$ and -4.00 .

A

- ABI. *See* Acquired brain injury
- Abnormal binocular competition, 472–473
- AC/A. *See* Accommodative convergence to accommodation ratios
- ACC system analysis. *See* Accommodative system analysis
- Accommodation
- blur and, 616–618, 616f, 625
 - Brewster stereoscope determining demands of, 188–189
 - control of
 - for AC/A test, 10, 119
 - for cover test, 5, 118–119
 - for modified Thorington technique, 7–8
 - for von Graefe test, 7
 - ill-sustained, 57, 65, 65t, 71, 73t, 124, 336
 - case study of, 347–348
 - description of, 338
 - diagnostic findings summary for, 73t
 - difficulty diagnosing, 348
 - signs and symptoms of, 71
 - importance of, 688
 - lag, 128, 455, 455f, 462, 468, 631–632, 633f
 - nystagmus and, 497
 - paralysis of, 337–338
 - plane of, 152–154, 153f–154f, 178–180, 180f, 182–183, 182f
 - relative, 462–463
 - spasm of, 280
 - stimulus-response curve and, 616–618, 617f
 - unequal, 338
 - vergence interactions with, 344, 354, 361, 430
 - analysis approaches to, 451–452, 452f
 - binocular vergence, 456–460, 457f–459f, 460t
 - clinical testing and, 460–467, 464f–467f
 - dual interactive model of, 616–617, 617f
 - key concepts of, 452–453, 454f
 - lens therapy and, 467
 - myopia and, 632
 - prism therapy for, 467
 - relative fusional vergence and, 461
 - tests of, 63, 460
 - theoretical, 453, 454f
 - tonic vergence, 453, 454f
- Accommodative amplitude assessment, 73t
- minus lens amplitude, 18, 18t–19t, 19–20, 45
 - pull-away method, 45
 - push-up amplitude, 19–20, 18t–19t, 121–122, 121t
- Accommodative convergence to accommodation (AC/A) ratios, 58, 60, 76, 77f–78f, 76, 89, 127, 453, 454f, 467. *See also* High AC/A conditions; Low AC/A conditions; Normal AC/A conditions
- added lenses and, 95, 95t–96t, 126–128, 127t, 458
 - in binocular vergence interactions, 456–460, 458f–459f, 460t
 - binocularly derived, 436–437, 438f
 - CA/C ratios' relationship with, 460, 616–617, 617f
 - calculated, 9–10, 119, 127–128, 127t, 459
 - gradient, 9–10, 458–459
 - heterophoria and, 56–57, 64, 124, 234–236, 273–277, 460t
 - importance of, 9
 - measurement of, 3, 3t, 9–10, 39, 56–57, 119, 458–459, 460t
 - near, 126–128, 127t
 - phoria size and direction assessment with, 9–10, 39
 - test of, accommodation control for, 10, 119
- Accommodative disorders, 57, 83, 86f. *See also specific disorder*
- from ABI, 574
 - assessment of
 - diagnostic testing, 18–23, 18t–19t, 22f–23f
 - expected values for, 19t, 121t
 - general considerations in, 18, 18t–19t, 121, 121t
 - in primary care optometry, 112–134, 113t–114t
 - basic exophoria present with, 329t, 330
 - classification of, 56, 64–65, 65t, 70–71
 - common, analysis of, 124
 - misdiagnosis of, 311
 - prevalence of, 335
 - sequential management of, 133–134
 - treatment of, 89, 129t
- Accommodative dysfunction. *See also* Accommodative excess; Accommodative infacility; Accommodative insufficiency
- children with, 338
 - prevalence of, 335
 - refractive error and, 335–336
 - treatment of
 - added lenses, 133, 335–336, 343
 - general strategies for, 336–337
 - prism, 134, 336
 - prognosis of, 336–337
 - sequential management considerations in, 133–134, 335–336
 - surgery, 336
 - vision therapy, 336–337
- Accommodative excess, 57, 64–65, 65t, 124
- accommodative spasm v., 349
 - background information about, 349
 - binocular and accommodative data analysis and, 350–351
 - binocular disorders associated with, 350
 - case studies of, 79–80, 83f, 351–352, 357
 - diagnostic findings summary for, 73t
 - differential diagnosis of, 353, 353t
 - esophoria and, 350
 - exophoria and, 350
 - PFV and, 350
 - secondary to convergence insufficiency, 251–253, 357
 - signs and symptoms of, 71, 350, 350t
 - spasm of the near reflex v., 349, 353
 - terminology of, 349
 - tests for, 350
 - treatment of
 - added lenses, 354
- lenses, 353
- vision therapy, 354–357, 354t–356t
- Accommodative facility assessment, 18t, 19t, 20–23, 22f, 46–47, 121t, 122, 123t. *See also* Binocular accommodative facility test; Monocular accommodative facility test
- age and, 20, 122
 - direct and indirect measures of, 358t
 - monocular v. binocular testing in, 19t, 21, 122
- Accommodative fatigue. *See* Ill-sustained accommodation
- Accommodative infacility, 50, 58, 62, 64, 65t, 124
- background information about, 357–358
 - binocular and accommodative data analysis and, 359
 - case study of, 364–365
 - diagnostic findings summary for, 73t
 - differential diagnosis of, 359, 360t
 - difficulty diagnosing, 311, 357, 365
 - nonfunctional causes of, 360t
 - prevalence of, 358
 - reading influenced by, 597–598
 - signs and symptoms of, 71–72, 358–359, 358t
 - tests for, 358–359
 - treatment of
 - added lenses, 360–361
 - lenses, 359–360
 - vision therapy, 361–364, 361t–363t
- Accommodative hopping cards, 212, 213f
- Accommodative insufficiency, 57, 64–65, 65t, 96t, 124. *See also* Ill-sustained accommodation; Paralysis of accommodation
- background information about, 337–338
 - binocular and accommodative data analysis and, 339–340
 - binocular disorders associated with, 340
 - case history of, 340–341
 - case studies of, 79–82, 347–349
 - diagnostic findings summary for, 73t
 - differential diagnosis of, 341–343, 342t
 - etiology of, 342–343
 - NFV and, 340
 - presbyopia v., 338
 - pseudoconvergence insufficiency and, 241–242, 257–258, 339, 349
 - signs and symptoms of, 338–339, 339t
 - tests for, 339
 - treatment of
 - added lenses, 343
 - lenses, 343
 - vision therapy, 343–347, 344t–345t
 - unequal accommodation, 337, 338
- Accommodative relaxation
- direct measures of, 350t
 - improvement of, 361
 - indirect measures of, 350t
- Accommodative response
- amplitude of, 357–359
 - assessment of
 - by fused cross-cylinder test, 19t, 24
 - by MEM retinoscopy, 18t, 19t, 23–24, 24f, 121, 121t, 455, 555, 555f
 - speed of, 344, 354

- Accommodative Rock Cards, 20, 22f, 214f
- Accommodative spasm, 280
- accommodative excess v., 349
 - myopia and, 664–666
- Accommodative system (ACC) analysis, 83f, 76
- by fused cross-cylinder test, 62
 - group data analysis and, 341
 - by MAF test, 61
 - by MEM retinoscopy, 61–62, 122–123
 - monocular conditions for, 61, 64
- Accommodative therapy
- anaglyphs, Polaroids, and liquid crystal filters, 209–212, 210f, 211t
 - binocular therapy integrated with, 359, 372
 - for cyclovertical heterophoria, 418
 - difficulty modified in, 211t
 - direction of difficulty stressed in, 155
 - factors to emphasize in, 211t
 - lenses, prisms, and mirrors, 212–218, 213f, 214f, 215f, 217f–218f
 - NFV in, 155
 - paper, pencil, and miscellaneous tasks, 218–219
 - PFV in, 155
 - specific guidelines for, 154–156
- Accommodative vergence, 461–462
- Accuracy disorders, of saccades, 374–375
- Achievement testing, 602
- Acquired brain injury (ABI)
- accommodative disorders from, 574
 - active rehabilitation stage of, 573
 - binocular vision disorders from, 573–574
 - case studies of
 - convergence insufficiency and vertical deviation treated with prism and lenses, 582–584
 - convergence insufficiency complicated by right hemianopia, 584–586
 - convergence insufficiency complicated by visual processing defects, 584t–588t, 586–588
 - intermittent exotropia treated with vision therapy, 580–582
 - sensory fusion disruption syndrome, 588–590, 590t
 - evaluation of vision problems associated with, 575, 576t
 - eye movement disorders from, 574–575
 - optometric role in, 572–573
 - overview of
 - CVA, 572
 - TBI, 571–572
 - postrehabilitation stage of, 573
 - symptoms of, 575, 575t
 - treatment of vision problems associated with
 - added lenses, 578, 582–584
 - ametropia optical correction, 578, 578t
 - cognitive function, 577
 - occlusion treatment, 578–579
 - prism, 578, 582–584
 - sequential considerations in, 577, 577t
 - variability of findings and potential recovery, 577
 - vision therapy, 579–580, 579t, 584t–586t, 588t, 590t

Active amblyopia therapy, 483–485, 485f

Added lenses, 131, 133, 132t. *See also* Minus lenses; Plus lenses

- ABI and, 578, 582–584
- AC/A ratios and, 95, 95t–96t, 126–128, 127t, 458

- accommodative dysfunction treated with, 133, 335–336, 343
- accommodative excess treated with, 354
- accommodative infacility treated with, 360–361
- accommodative insufficiency treated with, 343
- amblyopia treated with, 481
- basic esophoria treated with, 320, 320t
- basic exophoria treated with, 328
- complications of refractive surgery treated with, 667
- convergence excess treated with, 280–281, 281, 281t
- CUC treated with, 550, 556–557
- divergence excess treated with, 295, 295t
- effectiveness of, 95–96, 96t–96t, 104, 126
- high AC/A conditions and, 273–276
- normal AC/A conditions and, 307
- nystagmus treated with, 504–506
- ocular motor dysfunction treated with, 371–372
- PAL, 558, 558f
- part time, 328
- prescribing of, 95–97, 95t–97t, 126–128, 127t, 281t, 328
- resistance to, 669

ADRNNet Dynamic Reader

- HTS and, 231
- moving text dynamic reading with, 231
- standard dynamic reading with, 231
- whole line dynamic reading with, 231

Afferent infantile nystagmus, 501

Afterimages

- in biofeedback therapy for ocular control, 510
- classification of, 140
- description of, 230–231
- devices for creating, 140t, 143
- equipment needed for, 230
- Hering-Bielschowsky test, 293
- instrumentation, 140, 140t, 143, 230–231
- objectives of, 230
- types of, 140t, 143

Against-the-rule (A-T-R) astigmatism, 647

Alcohol, 342t, 376t

AL/CR ratio. *See* Axial length to corneal radius ratio

Alternate cover test, 36, 522

Alzheimer disease, 375, 375t

Amblyopia, 2, 101. *See also* Anisometropic amblyopia; Isoametropic amblyopia

- astigmatism and, 475
- in binocular vision–based model for refractive error management, 645
- case studies of
 - isoametropic amblyopia, 478
 - refractive correction alone, 479–480
 - sequential management, 483–484
- classification of, 472, 472t
- clinical characteristics of
 - crowding phenomenon, 475–476
 - electrodiagnostic tests, 477
 - fixation characteristics, 475
 - refractive error, 474–475
 - suppression characteristics, 475
- course of, 477
- definition of, 471
- etiology of
 - abnormal binocular competition, 472–473
 - critical and sensitive periods, 473
 - plastic period, 473

- functional, unequal accommodation caused by, 338
- nonstrabismic binocular vision disorders and, 236, 275
- prevalence of, 471–472
- prognosis of, 477
- sequential management treatment of, 89, 154
 - active therapy, 483–485, 485f
 - added lenses, 481
 - compliance determined in, 479
 - duration of results of, 486
 - key points of, 486
 - passive therapy, 481–483, 482f
 - prism, 481
 - protocol for, 478–479, 478t, 483–484
 - refractive correction, 479–480
 - suppression therapy, 483–485, 485f
 - surgery, 485–486
 - vision therapy, 485
- signs and symptoms of, 474
- study of, 471

American Academy of Optometry, 593

American Optical (AO) vectographic chart, 16

American Optical (AO) vectographic slide, 54, 131, 395, 396f, 432f

American Optometric Association, 593

Ametropia

- optical correction, 92–95, 92t, 235, 275, 307, 578, 578t, 669
- ABI and, 578, 578t
- for complications of refractive surgery, 668
- for CUC, 550
- resistance to, 669
- rate of progression of, 626–628, 627f–628f

Amplitude scaled facility, 21t, 123t

Anaglyphs. *See also* Tranaglyphs

- accommodative therapy with, 209–212, 210f, 211t
- advantages of, 141
- categorization of, 138, 141
- disadvantages of, 141
- fusional vergence therapy with, 160–176, 161f–163f, 164t–165t, 166f, 167t, 168f–171f, 174f, 175t
- instrumentation, 140, 140t
- recommended procedures for, 165t
- red-red rock, 209–210, 210f
- testing with, 17, 138
- types of, 140t

Analytical analysis. *See* Optometric Extension Program analytical case analysis

Ancillary vergence testing, 122–124

Aniseikonia, 83, 86f, 400

- case studies of
 - Aniseikonia Inspector, 524
 - contact lenses, 529
 - design from estimation, 540–542
 - small axis power alterations, 530
- clinically significant, 517
- definitions of, 517–518
- determination of presence of
 - with alternate cover test, 522–523
 - with Aniseikonia Inspector, 524, 524f
 - with Maddox rod and two-point light sources, 523
 - with New Aniseikonia Test, 524, 524f
 - with size comparison of diplopic images, 522
 - with space eikonometer, 525–528, 526f–527f
 - with Turville test, 523, 523f

- diagnosis of
 clip-on aniseikonia correction, 521, 522t
 corneal curvature, 519–520
 history, 518–519
 occlusion, 521
 refractive condition, 519
 dynamic, 517, 529, 529
 historical perspective of, 517–518
 iseikonic lenses for, 517
 antireflective coating of, 535–536
 bitoric, 542
 design examples of, 539–542
 inadvertent corrections and, 543, 544f, 544t
 lens edge coating of, 535
 magnification by changing base curve, 533, 534t
 magnification by changing eyewire distance and bevel, 532–533, 532t, 532f, 533t
 magnification by changing lens thickness, 535, 536t–536t
 prescription considerations for, 535, 539t
 recommendations for, 529–531, 545
 management of, 94–95
 lens prescription, 528–529, 535, 539t
 practical considerations, 528
 refractive error and, 519
 as refractive surgery complication, 656–659, 661–662
 signs and symptoms of, 518–519
 static, 517, 519, 529
- Aniseikonia Inspector, 524, 524f
- Anisometropia, 89, 92t, 101, 328. *See also*
 Anisometropic amblyopia
 accommodative fatigue secondary to, 335–336
 in binocular vision–based model for refractive error management, 642–647
 divergence insufficiency present with, 236
 hyperopic, 644–645
 management of, 94–95, 132t
 myopic
 development of, 642–643
 facial symmetry and, 644
 head position and, 643
 suppression of one eye in, 643
 as refractive surgery complication, 659–660, 661–662
 treatment of, 645–647
- Anisometropic amblyopia, 131–132, 132t, 275, 308, 471, 645
 etiology of, 472–473
 prevalence of, 473
 sequential management protocol for, 478–479, 478t
 suppression and, 475
 treatment of, 479–485, 645–647
- Ann Arbor letter tracking, patient instructions for, 703
- Anterior chamber depth, 621, 621f
- Anticholinesterase agents, 278
- Anticonvulsants, 376, 376t
- Antihistamines, 342t
- Antireflective (AR) coating, 535, 559
- Antisuppression therapy, 156–158
 bar reader, 199–201, 200f
 for cyclovertical heterophoria, 418
 for divergence excess, 296–297
 fusion enhancement, 508
 mirror superimposition, 205, 205f–206f
 red/green glasses and pen light, 203
 specific guidelines for, 156–158
- TV trainer, 201–202, 201f
 vertical prism dissociation, 204
- AO vectographic chart. *See* American Optical vectographic chart
- AO vectographic slide. *See* American Optical vectographic slide
- Aperture Rule, 140t
 for BAF therapy, 217–218, 218f
 cards for, 177–178, 177f–178f
 description and setup of, 177–178, 177f–178f
 for divergence excess vision therapy, 298, 301f
 with double aperture, for divergence therapy, 177, 177f, 180–181, 298, 301f
 endpoint of, 180
 equipment needed for, 176
 as free space technique, 138, 139f
 localization technique used with, 178
 objectives of, 176
 with single aperture, for convergence therapy, 177, 177f–178f, 180
 targets for, 298, 301, 301f–302f
 therapy procedures for, 178–180, 188f–190f
- Apertures
 advantages of, 141
 classification of, 147
 definition of, 141
 disadvantages of, 142
 fusional vergence therapy with, 176–181, 177f–181f
 instrumentation, 138, 139f, 140t, 141
 types of, 139f, 140t
- Appeal letters, for insurance coverage, 683, 689–690
- AR coating. *See* Antireflective coating
- Artane, 342t
- Associated testing, dissociated testing v., 453
- Asthenopia, 70–71, 293, 518, 606, 613
- Astigmatism, 92t, 236, 328
 accommodative fatigue secondary to, 335–336
 against-the-rule, 647
 amblyopia and, 475
 in binocular vision–based model for refractive error management, 647–649
 children with, 647–648
 infantile nystagmus and, 504
 oblique, 400
- A-T-R astigmatism. *See* Against-the-rule astigmatism
- Atropine treatment, 131–132, 132t, 482–483, 618–619, 636–637
- Attention therapy, 371
- Audiological/speech and language testing, 604t
- Auditory biofeedback, 105–106, 140t, 371, 510–511
- Automatic rotator, 225, 226f
- Autorefracton, 2
- Axial length
 growth of, 619–620, 632–624, 623f–624f, 631
 RS related to, 619, 620, 620f–621f
- Axial length to corneal radius (AL/CR) ratio, 623, 623f–624f, 632
- B**
- Baclofen, 513
- BAF test. *See* Binocular accommodative facility test
- Bagolini striated lenses, 16
- Bailey-Love chart, 495, 495f
- Bar reader, 140t
 in BAF therapy, 199, 200f
 description and setup of, 199, 200f
 equipment needed for, 199
 objectives of, 199
 Polaroid, 199–200
 procedures for, 200
 red/green, 199, 200f, 217, 217f
- Barbiturates, 376t
- Barrel card, 140t, 197, 198f
- Basal ganglia degenerations, 375–376, 375t–376t
- Base-in prism (BIM), 167–168, 329
- Base-in to blur, 49, 50f
- Base-in to break, 49, 50f
- Base-out Bioptograms, 188f
- Base-out prism (BOP), 168, 320
- Base-out to blur, 49, 50f
- Base-out to break, 49, 50f
- Basic esophoria, 97t, 260–261
 background information about, 318
 binocular and accommodative data analysis and, 319
 case study of, 324–326
 deviation characteristics of, 318–319
 diagnostic findings summary for, 73t
 differential diagnosis of, 319, 319t
 functional basis of, 319
 hyperopia associated with, 318
 NFV and, 309, 318, 318t, 321
 PFV and, 309, 323
 prevalence of, 318
 refractive error and, 318
 sequential management considerations of, 308t
 signs and symptoms of, 67, 318, 318t
 treatment of
 added lenses, 320, 320t
 lenses, 320
 prism, 320
 surgery, 324
 vision therapy, 320–324, 321t–323t
- Basic exophoria, 293–294
 accommodative disorders present with, 327
 background information about, 326
 binocular and accommodative data analysis and, 327
 deviation characteristics of, 327
 diagnostic findings summary for, 73t
 differential diagnosis of, 328, 328t
 hyperopia associated with, 328
 myopia associated with, 328
 NFV and, 330
 NPC and, 326
 PFV and, 309, 330
 prevalence, 326
 refractive error and, 326
 sequential management considerations of, 308t
 signs and symptoms of, 66, 326, 326–327, 327t
 treatment of
 added lenses, 328
 lenses, 328
 prism, 328
 surgery, 333
 vision therapy, 329–333, 329t, 331t–332t
- Beads and string, patient instructions for, 699–700
- Bender Gestalt Test, 611
- Bernell lantern slide, 54
- Bernell No. 9 vectogram, 22, 23f
- Bernell Variable Prismatic Stereoscope, 192f, 193, 193f, 420

- Bernell-N-Stein Bears cards, 177f, 178
 Bernell-O-Scope stereoscope, 139f, 187f
 Bevel changes, in isekonic lenses, 533, 533t
 Bifocal lenses, 97, 126
 explanation of proposed treatment using, 677
 flattop, 558
 plus, 97, 126, 287
 prescribing of, 287
 BIM. *See* Base-in prism
 Binocular accommodative facility (BAF) test, 3t, 3, 18, 19t, 20, 60, 73t, 121t
 for accommodative insufficiency, 339
 with minus lenses, 60, 319
 NFV tested by, 60, 279, 311, 548
 PFV tested by, 58, 237, 311, 327
 with plus lenses, 58, 327
 red/green glasses used in, 218
 Binocular accommodative facility (BAF) therapy
 in accommodative insufficiency vision therapy program, 344
 Aperture Rule for, 217–218, 218f
 bar reader used in, 199, 200f
 description and setup of, 217–218, 217f
 endpoint of, 218
 equipment needed for, 217
 objectives of, 217
 with variable tranaglyphs, 166
 Binocular vergence interactions, 456–460
 ACA ratio in, 456–460, 458f–459f, 460t
 CAVC ratio in, 456–458, 457f
 Binocular vision
 fixation disparity analysis and, 5–9, 54, 120
 nystagmus and, 498
 testing for, 3–15, 3t, 4f, 5f, 6t, 8t, 14f, 19t, 19–22, 24
 zone of singular, 463
 Binocular vision disorders, 56–57. *See also*
 High ACA conditions; Low ACA conditions; Nonstrabismic binocular vision disorders; Normal ACA conditions
 from ABI, 573–574
 accommodative excess associated with, 350
 accommodative insufficiency associated with, 340
 asymptomatic, 318, 326
 classification of, 56–57, 65–70, 65t, 73t, 103t, 113t–114t, 124, 129t, 292–293
 primary care of, 112–120, 113t–114t, 124
 treatment of, 92, 129t
 vertical, 70, 129t
 Binocular vision therapy
 accommodative therapy integrated with, 359, 372
 computerized procedures for, 172
 direction of difficulty stressed in, 154–156
 factors to emphasize during, 175t
 NFV in, 155
 office-based computer vision software for, 172–176, 174f, 175t
 PFV in, 155
 specific guidelines for, 154–158
 underlying concepts of, 152–154, 152f–154f
 Binocular vision–based model, for refractive error management, 616–618, 617f, 649
 amblyopia and, 645
 anisometropia and, 642–647
 astigmatism and, 647–649
 case studies of
 hyperopia treatment, 641–642
 myopia treatment for patient with IXT, 643–644
 myopia treatment incorporating atropine, 636–637
 myopia treatment with atropine and contact lenses, 636–639
 refractive treatment of hyperopia concurrent with treatment of anisometropic amblyopia, 645–646
 successful myopia treatment, 634
 treatment of myopia and astigmatism with RGP lenses, 648–649
 unsuccessful myopia treatment, 635
 clinical aspects of, 629
 dual intersecting feedback loops in, 618f
 genetically programmed ocular growth, 623–625, 623f–624f, 625t, 629
 hyperopia and, 641–642, 644–647
 myopia and, 630
 accommodation-vergence interactions, 632
 amount and direction of peripheral retinal blur, 631–632
 amount of lag, 631
 amount of near work performed, 632
 case studies of, 634–639, 643–644
 normal visual acuity, 631
 range of sensitivity to blur, 631–632
 treatment of, 632–640, 633f
 ocular component growth in, 619–622, 621f–622f, 626
 propositions of, 618f, 619, 622–623, 625–626, 640
 rate of refractive change in, 626–628, 627f–628f
 refractive error distribution in, 619, 620f
 sequential management protocol for, 629
 visually driven growth in, 625
 Biocular loose lens rock
 description and setup of, 216
 endpoint of, 216
 equipment needed for, 216
 Biofeedback
 auditory, 105, 140t, 144, 371, 510–511
 in cyclovergence therapy, 425
 therapy for ocular control, 510–511, 511f–513f
 Bioptograms, 188f
 Bitoric isekonic lenses, 542
 Blephamide SOP. *See* Prednisolone/sulfacetamide SOP
 Blur, 350–351, 351–352, 401–402
 accommodation and, 616–618, 616f, 625
 allowing of, 155
 base-in to, 49, 50f
 base-out to, 49, 50f
 enhanced detection of, 640
 feedback from, 145, 618
 range of sensitivity to, 631
 source of, 616, 616f–617f
 sustained retinal, 625
 Boder Test of Reading-Spelling Patterns, 595
 Book retinoscopy, 372
 BOP. *See* Base-out prism
 Brain injury. *See* Acquired brain injury
 Brewster stereoscopes, 140t, 143
 accommodative and convergence demands determined with, 188–189
 convergence demand, 189
 description and setup of, 187–188, 187f–188f
 endpoint of, 190
 equipment needed for, 187
 objectives of, 186
 therapy procedures for, 190
 Brock string, 140t, 142f, 381
 description and setup of, 194, 195f
 endpoint of, 197
 equipment needed for, 194
 objectives of, 194
 for physiologic diplopia, 142
 task difficulty changed with, 197
 therapy procedures for
 explanation of, 195–196
 other types of, 196–197, 197f
 steps of, 195–196, 195f
 as voluntary convergence procedure, 194–197, 195f, 197f
 B-type case, 51
 “Bug on string” procedure, 196
C
 C/A/C ratios. *See* Convergence accommodation to convergence ratios
 Calculated ACA, 9–10, 119, 127–128, 127t, 459
 Case analysis
 fixation disparity, 54
 graphical
 accommodation-vergence interactions in, 451–452, 452f
 advantages of, 49
 disadvantages of, 50–51
 NPC in, 50, 50f
 sample worksheet of, 50, 50f
 Sheard’s criterion in, 51–52
 integrative, 468
 details of, 54–55
 expected findings for optometric tests and, 55
 optometric data grouping in, 55
 steps of, 55, 85
 normative, 50, 52, 429
 accommodation-vergence interactions in, 452
 advantages of, 53
 disadvantages of, 54
 expected findings in, 52, 53t
 three groups in, 52, 53t
 OEP analytical
 advantages of, 52
 disadvantages of, 52, 55
 expected findings of, 51, 51t
 requirements of, 51
 primary entry points to, 76, 77f–78f, 133
 prism in, 57–59, 62
 of specific groups, 57–64
 system used in, 72–85, 74f, 77f–79f, 83f, 85f
 decision-making process, 75f
 initial testing, 72–76, 74f, 75b
 phoria not present, 83–85, 85f
 sample cases, 79–84, 83f–84f
 significant phoria present at distance or near, 76–83, 77f–79f, 83f
 vision disorder classification and identification in, 57, 64–65, 65t
 Case history, 72, 75, 74f, 75b, 84, 87, 113t, 494
 of accommodative insufficiency, 341
 of deviation, 319, 328
 importance of, 319, 343, 601
 for learning-related vision disorders, 602, 603t–604t, 607f–609f
 Case presentation
 for child requiring vision therapy, 674–676

- for conditions not requiring vision therapy, 677
- importance of, 674
- sequence of, 675t
- Case reports, 102, 102f
- Case typing, 51
- CAVT. *See* Computer Aided Vision Therapy
- Center of symmetry, 431, 431f, 433, 439
- Central nervous system stimulants, 342t
- Central tranaglyph targets, 162f, 163
- Central vestibular nystagmus, 499
- Cerebellar disease, 389–390, 376t
- Cerebrovascular accident (CVA), 572
- Cheiroscope, 140t, 420
 - diagnostic procedure for, 190, 191f
 - interpretation and, 191–192, 191f
 - Keystone Correct-Eye-Scope, 190, 191f
 - in red-red rock therapy procedure, 210f
 - therapy procedures for, 192, 192f
- Cheirosopic tracings, 16
 - in divergence excess vision therapy, 302
 - drifting during, 191, 191f
 - forms for, 191f
 - interpretation of, 191–192, 191f
 - scribbling during, 192, 192f
 - short pencil strokes used during, 192, 192f
 - suppression and, 192
- Chiastopic fusion, 177, 183, 183f, 184
- Children
 - with accommodative dysfunction, 338
 - with astigmatism, 647–648
 - bifocal prescriptions for, 287
 - contact lenses worn by, 637–638
 - with convergence insufficiency, 674–677
 - with CUC, 547
 - developmental milestones of, 606t
 - with divergence excess, 295, 495
 - with learning-related vision disorders, 594–597, 600–606
 - myopia development in, 620, 626, 627f–628f
 - noncomputerized techniques for, problems with, 172
 - with nystagmus, children with, 491–492, 494–495, 503
 - with ocular motor dysfunction, 156, 376
 - “off-task looking time” of, 373
 - parallax and, 152
 - parents of, 605–606, 607f–609f, 686–688, 690–691
 - preschool, 295, 495
 - vision therapy for, 103, 148, 675–676
- Chloral hydrate, 376t
- Chlordecone, 376t
- ChromaGen lenses, 620
- Chromatic aberration error signal, 637–638
- Chronic hyperinsulinemia, 640
- Ciliary muscle, tonus of, 93
- Ciliary spasm. *See* Accommodative excess
- CISS. *See* Convergence Insufficiency Symptom Survey
- CITT. *See* Convergence Insufficiency Treatment Trial
- Classification system, of common vision problems
 - accommodative, 56, 64–65, 65t, 70–71
 - alternative system of, 64, 65t
 - binocular, 56–57, 65–70, 65t, 73t, 103t, 113t–114t, 124, 129t, 292–293
 - case analysis and, 57–59, 64–65, 65t
 - Duane’s, 64, 124, 309, 335
 - ocular motor, 57, 63, 65t, 72, 73t
 - vertical, 57, 62, 65t, 70
- Clinical interview, 602
- Clinically significant aniseikonia, 517
- Clip-on aniseikonia correction, 521, 522t
- Cognitive testing, 601–602
- Cogwheeling, 376, 376t
- College of Optometrists in Vision Development
 - Development Quality of Life Outcomes Assessment (COVD-QOL), 91–92, 91f, 239
- Colored circle cards for convergence, patient instructions for, 700–701
- Colored filters
 - effectiveness of, 598–599
 - reading and, 598–600
 - studies on, 598–600
- Communication
 - in case presentation, 674–677, 675t
 - insurance letters, 683–684, 688–690
 - letters to parents, 686–688, 690–691
 - with other professionals, 678, 686–688
- Complications, of refractive surgery, 657t
 - case studies of
 - accommodative spasm, 664–666
 - contact lens occluder to treat intractable
 - diplopia, 669–670
 - decompensation of strabismus, 662–663
 - previous prism wear, 660–661
 - residual hyperopia causing decompensated esotropia, 659–660
 - surgically induced anisometropia, 661–662
 - surgically induced anisometropia causing aniseikonia, 657–659
 - surgically induced monovision causing diplopia, 663–664
 - vision therapy used to treat post-refractive surgery convergence insufficiency, 670–671
 - monovision
 - accommodative issues, 664–666
 - convergence issues, 664–666
 - decompensation and, 662–663
 - diplopia caused by, 663–664
 - pre-Lasik trial and, 663
 - prevalence of, 655
 - risk stratification of, 667t
 - sequential management considerations
 - for, 668t
 - added lenses, 669
 - occlusion, 669
 - optical correction of ametropia, 669
 - prism, 669
 - resistance and, 669
 - resistance to optical correction of ametropia, added lenses, and prism, 669
 - vision therapy, 670–671
 - surgery-associated
 - aniseikonia, 656–659, 661–662
 - anisometropia, 656–659, 661–662
 - causes of, 657t
 - esodeviation, 656
 - exodeviation, 656
 - fourth nerve weakness, 656
 - test battery for identification of, 666t
- Computer Aided Vision Therapy (CAVT)
 - benefits of, 684
 - Computer Vergences program of, 175, 175t, 206, 231
 - description and setup of, 226–230
 - home use of, 175, 175t, 206
 - ocular motor dysfunction treated with, 377
 - Random Dot Stereograms in, 175, 206, 231
 - Track and Read program of, 228, 231
 - Wayne engineering, 228
 - Wayne membrane saccadic fixator, 229–230
- Computer home therapy procedures, 231, 206
 - advantages and disadvantages of, 679–680
 - for ocular motility, 231
- Computer orthoptics, 231
 - home therapy system, 231
 - computer-aided vision therapy, track and read, 231
- Computer Orthoptics VTS3 Liquid Crystal System
 - accommodative program of, 211
 - benefits of, 684
 - description and setup of, 211
 - factors to emphasize with, 175, 175t
 - Jump-Jump Vergence program, 175
 - multiple choice vergence program, 172–175, 174f
 - ocular motor dysfunction treated with, 377–378
 - random dot stereopsis in, 174f, 175
 - Step-Jump Vergence program, 174
- Computer Orthoptics VTS4 Liquid Crystal System, 172, 226
- Computer software/Advanced technology procedures
 - Computer Orthoptics Liquid Crystal Automated Vision Therapy (VTS4), 226–227
 - Computer Perceptual Therapy (CPT), 227
 - instrumentation, 684
 - neurovision rehabilitator (NVR), 228, 228f
 - office-based, 172–176, 174f, 175t
 - Sanet Vision Integrator (SVI), 227
 - Wayne membrane saccadic fixator, 229f–230f
 - description and setup of, 230
 - equipment needed for, 230
 - objectives of, 229
- Computer use complex (CUC), 547
 - binocular and accommodative data analysis and, 548
 - case studies of
 - added lenses for near, 556–557
 - ergonomic issues, 564–566
 - medical treatment, 563–564
 - prism correction, 559–560
 - vision therapy, 561–562
 - children with, 547
 - clinical evaluation of
 - accommodative ranges (NRA/PRA), 555
 - accommodative accuracy, 555
 - history and symptoms, 554
 - tests in, 555–556, 556f
 - workstation, 554, 570
- Computer Use Questionnaire for, 553, 559–560, 568–571
- differential diagnosis of, 548, 549t
- etiology of, 547
- NFV and, 548
- prevalence of, 547
- signs and symptoms of, 548, 549t, 566, 568–569
- terminology of, 547
- treatment of
 - added lenses, 550, 556–557
 - ametropia correction, 550
 - best refractive correction, 556–558
 - computer monitors, 553
 - course and prognosis, 554
 - ergonomic issues, 551, 552f, 562, 564–566
 - key points of, 554
 - lens design issues in, 558–559, 558f

- Computer use complex (CUC) (*continued*)
 lighting conditions and glare, 551
 ocular health, 551, 556
 prism, 550, 559–560
 refresh rate, changing of, 553
 rest breaks, 553
 seating position, 552
 sequential management protocol for, 549–550, 550t, 556
 surgery, 551
 vision therapy, 551, 560–562
 working distances and positions, 552
- Computer Use Questionnaire, 553, 559–560, 568–571
- Computer Vergences program, 175, 175t, 206, 231
- Computer vision syndrome, 547–548.
See also Computer use complex
- Computerized binocular therapy procedures
 advantages of, 173
 programs for, 172
- Computerized Perceptual Therapy, 371
- Computerized tomography (CT) scans, 499
- Conjugate prism, 507
- Contact lenses, 481, 504
 aniseikonia and, 529–530
 children wearing, 637–638
 intractable diplopia treated with, 669–670
 myopia treated with, 638–639
 occluder, 669–670
 in pre-Lasik monovision trial, 663–664
 reverse geometry, 638–639, 648–649
 rigid gas-permeable, 504, 637–639, 648–649
 soft, 637, 640, 647
- Contour stereopsis, 17, 17f
- Convergence. *See also* Near point of convergence
 amplitude of, 3t, 4
 Brewster stereoscope determining demands of, 188–189
 colored circle cards for, 700–701
 cyclophoria associated with, 400–401
 decreased nystagmus with, 506
 divergence alternated with, 250, 285
 jump, 13, 240
 spasm of, 280
 training techniques of, 313
- Convergence accommodation to convergence (CA/C) ratios, 57, 59, 292, 444, 453, 454f, 461–463, 467
 AC/A ratios' relationship with, 460, 616–617, 617f
 in binocular vergence interactions, 456–458, 457f
 lag of accommodation minimized through, 632–633, 633f
 significance of, 11
 stimulus v. response, 11
 test for, 3t, 10–11, 57
- Convergence excess, 78t–79t, 97t, 261
 binocular and accommodative data analysis and, 279
 case studies of, 80–82, 285–290, 286–290
 classification of, 64
 deviation characteristics of, 277
 diagnostic findings summary for, 73t
 differential diagnosis of, 279–280, 280t
 hyperopia associated with, 278, 280–281
 NFV and, 278
 PFV and, 282t
 prevalence of, 277, 290
 reading and, 664
 refractive error and, 278
- sequential management considerations of, 274t
 signs and symptoms of, 68–69, 277–279, 278t
 treatment of, 105
 added plus lenses, 280–281, 281, 281t
 lenses, 280
 pharmacologic, 278
 prism, 281
 surgery, 285
 vision therapy, 281–285, 282t, 283t–284t
- Convergence insufficiency, 293
 binocular and accommodative data analysis and, 240
 case studies of, 241
 convergence insufficiency and vertical deviation treated with prism and lenses, 582–584
 convergence insufficiency complicated by right hemianopia, 584–586
 convergence insufficiency complicated by visual processing defects, 586–588, 588t
 with hyperopia, 253–255
 with presbyopia, 255–257
 pseudoconvergence insufficiency, 257–258
 with secondary accommodative excess, 251–253, 357
 vision therapy used to treat post-refractive surgery convergence insufficiency, 670–671
- children with, 674–677
 classification of, 64
 definite, 237
 definition of, 237
 deviation characteristics of, 240
 diagnostic findings summary for, 73t
 differential diagnosis of, 241–242, 242t
 hyperopia associated with, 235–236, 235t, 242, 253–255
 management of, 235–236, 235t
 myopia associated with, 235–236, 242
 NFV and, 249–250
 NPC and, 239
 PFV and, 240–241
 prevalence of, 237
 pseudoconvergence insufficiency v., 241–242, 257–258, 339, 349
 refractive error and, 239
 symptoms and signs of, 65–66, 65t, 90–92, 90f, 237–240, 238t
 treatment of, 105
 lenses, 242–243, 582–584
 prism, 243–244, 582–584
 surgery, 251
 vision therapy, 244–251, 246t–250t, 670–671, 674–676
- Convergence Insufficiency Symptom Survey (CISS), 90–92, 90f, 112, 115, 115f
 two-factor symptom analysis in, 238
 validity of, 238
- Convergence Insufficiency Treatment Trial (CITT), 90, 133, 244–246
- Convergence paralysis, 242, 328t
- Convergence therapy
 in accommodative excess vision therapy program, 356
 in accommodative infacility vision therapy program, 361
 in accommodative insufficiency vision therapy program, 344
- Aperture Rule with single aperture for, 177, 177f–178f, 180
- for cyclovertical heterophoria, 424, 425f
 difficulty increased and decreased in, 167–168, 167t
 Eccentric Circles for, 182–183, 182f, 696–697
 float and, 148
 Free Space Fusion Cards A for, 182–183, 182f
 Free Space Fusion Cards B for, 185
 Lifesaver cards for, 186
 localization and, 148
 planes of accommodation and vergence during, 152–154, 153f–154f, 178–180, 180f, 182–183, 182f
- Corneal curvature
 in aniseikonia, 519–520
 RS related to, 621, 621f
- Corneal radius, 623, 623f–624f, 634
- Corneal refractive therapy (CRT), 638
- Cosmesis, 293
- Counseling, patient, 415, 503–504
- COVID-QOL. *See* College of Optometrists in Vision Development Quality of Life Outcomes Assessment
- Cover test, 3, 3t, 5, 56, 73t
 in absence of strabismus, 5, 5f, 118
 accommodation control for, 5, 118–119
 alternate, 36, 522
 objectivity of, 119
 for phoria size and direction assessment, 5–7, 5f, 6t, 36–37, 63, 118
 setup and administration of, 36–37
 unilateral, 36
 for vertical deviation assessment, 392
- Critical period, of amblyopia, 473
- Crossed eyes, 289, 325
- Crowding phenomenon, 475–476
- CRT. *See* Corneal refractive therapy
- CT scans. *See* Computerized tomography scans
- C-type case, 51
- CUC. *See* Computer use complex
- CVA. *See* Cerebrovascular accident
- Cyclodeviations, 389
- Cyclofixation disparity, 396
- Cyclofixation, 400
- Cyclopentolate hydrochloride, 93, 495
- Cyclophoria
 convergence associated with, 400–401
 definition of, 389
 double Maddox prism evaluation of, 392, 393f
 double Maddox rod evaluation of, 392–393, 393f
 incidence of, 390, 390t
 symptomatic, 400–401
- Cycloplegic refraction, 93, 252
- Cycloplegic retinoscopy, 495
- Cycloplegics, 342t
- Cyclovergence therapy
 biofeedback, 425
 case study of, 424
 dove prism, 425
 indications for, 430
 Maddox rod, 424–425
 rotating cylinder, 424–425
 stereoscope, 425, 425f
- Cyclovertical heterophoria
 case studies of
 cyclovergence therapy, 424, 425f
 latent hyperphoria, 408
 recent-onset vertical diplopia, 399
 secondary vertical deviation, 419
 slab-off prism correction, 410–412
 symptomatic cyclophoria, 400–401
 vertical diplopia treated with sector occlusion and counseling, 416
 vertical prism prescription, 414

- vertical vergence therapy, 421–422
 - well-compensated vertical deviation, 421
 - causes of, 390
 - diagnostic testing of
 - diagnostic occlusion, 397, 397t
 - dissociated, 392–393, 393f, 393f, 395f
 - fixation disparity, 393–395, 396f
 - out of phoropter, 396–397
 - differential diagnosis of, 397–340
 - historical perspective of, 389
 - incidence of, 390, 390t, 574
 - motor and sensory fusion and, 391
 - signs and symptoms of, 391–392
 - terminology of, 389
 - treatment of
 - convergence and accommodative facility procedures, 420
 - cyclovergence therapy, 423–425, 425f
 - management considerations
 - sequence for, 400t
 - prism, 401–416, 401t, 405f, 407f
 - refractive correction, 400–401
 - reluctance in, 389
 - stereoscope, 420
 - surgery, 425–426, 425
 - therapeutic occlusion, 416
 - vision therapy, 417–425, 418t, 423f, 425f
- Cyclovertical phoria, 83, 86f, 87
- D**
- Dartmouth Eye Institute, 517
 - Decompensated esodeviation, 656, 669
 - Decompensated exodeviation, 656
 - Decompensated fourth nerve weakness, 656
 - Definite convergence insufficiency, 237
 - DEM test. *See* Developmental eye movement test
 - Developmental eye movement (DEM) test, 25t, 27, 28f, 29–30, 56, 369, 687
 - Developmental milestones, 606t
 - DFP ointment. *See* Diisopropyl fluorophosphates ointment
 - Diabetes, 342, 342t
 - Diagnosis. *See also* Diagnostic testing
 - diagnostic evaluation, 117–118
 - history and symptoms, 112–117, 115f, 117f
 - Diagnostic codes, 683
 - Diagnostic occlusion, 397, 397t, 521
 - Diagnostic testing. *See also* specific tests
 - accommodative disorders assessment, 18–23, 18t–19t, 22f–23f
 - electrodiagnostic, 477
 - eye movement evaluation, 25–32, 25t–28t, 28f–29f, 31t
 - for learning-related vision disorders
 - defining problem in, 603, 603t
 - family history in, 605, 605t–606t, 607f–609f
 - infrared eye tracking in, 602
 - medical or developmental problems in, 605–606, 605t–606t
 - parent questionnaire in, 605–606, 607f–609f
 - previous testing for, 604, 604t
 - nonstrabismic binocular vision disorders
 - assessment, 3–15, 3t, 4f–5f, 6t, 8t, 117–118
 - refractive error determination, 2, 117–118
 - sensory status evaluation in, 3t, 4, 15–18, 16f–17f
 - Diazepam, 376t
 - Diet, myopia influenced by, 640
 - Diisopropyl fluorophosphate (DFP) ointment, 278
 - Diplopia, 436, 505t, 660
 - awareness of, 296–297
 - contact lenses for, 669–670
 - divergence excess and, 293, 296, 298
 - divergence insufficiency and, 260
 - feedback from, 145
 - fixation switch, 663–664
 - intractable, 669–670
 - pathologic, 296–297
 - physiologic, 142, 148–149
 - size comparison and, 522
 - surgically induced monovision causing, 663–664
 - vertical
 - recent-onset, 399
 - sector occlusion and counseling
 - treatment for, 416
 - Direct assessment of positive and negative fusional vergence, 119
 - Disparometer, 54, 396f, 432f, 433–434, 434
 - Dissociated phoria, 49, 50f
 - Dissociated testing
 - associated testing v., 453
 - cover, 392
 - Maddox double prism, 392, 393f
 - Maddox rod, 392–393, 393f
 - prism dissociation, 393, 395f
 - three-step, 392, 393t
 - Distance sphere modification, of forced vergence fixation disparity, 443–444, 445f
 - Divergence
 - convergence alternated with, 250, 285
 - localization and, 148–150, 148f, 152f
 - Divergence excess
 - background information about, 290
 - case studies of, 303–305
 - characteristics of, 291
 - children with, 295, 495
 - classification of, 64
 - cosmetic appearance of, 293
 - deviation characteristics of, 291
 - diagnostic findings summary for, 73t
 - differential diagnosis of, 293–294
 - diplopia and, 293, 296, 298
 - forced vergence fixation disparity curve of, 445f
 - NFV and, 298
 - PFV and, 292, 298
 - refractive error and, 293
 - sensory adaptations to, 293
 - sequential management considerations of, 274t
 - signs and symptoms of, 69–70, 291–293, 291t
 - simulated, 292, 294
 - treatment of
 - added minus lenses, 295, 295t
 - antisuppression therapy, 296–297
 - lenses, 294–295
 - prism, 295
 - surgery, 276, 294, 303
 - vision therapy, 276–277, 295–303, 297t, 299t–301t, 301f–302f
 - true, 292, 294
 - Divergence insufficiency
 - anisometropia present with, 236
 - background information about, 258
 - case studies of, 266–269
 - classification of, 64
 - clinical significance of, 269
 - comitancy and, 260
 - deviation characteristics of, 258–259
 - diagnostic findings summary for, 73t
 - differential diagnosis of, 260–262, 260t, 269
 - diplopia and, 260
 - divergence paralysis v., 260–262, 260t, 269
 - hyperopia present with, 236
 - management of, 236–237, 235t
 - NFV, 260
 - refractive error and, 260
 - signs and symptoms of, 66, 258–260, 259t
 - treatment of
 - lenses, 262
 - prism, 236–237, 262
 - surgery, 266
 - vision therapy, 263–266, 263t–265t
 - Divergence paralysis
 - divergence insufficiency v., 261–262, 261t, 269
 - etiology of, 261
 - signs and symptoms of, 261, 261t
 - Divergence therapy
 - in accommodative excess vision therapy program, 356
 - in accommodative infacility vision therapy program, 361
 - in accommodative insufficiency vision therapy program, 344
 - Aperture Rule with double aperture for, 177, 177f, 180–181, 298, 301f
 - difficulty increased and decreased in, 167–168, 167t
 - distance in, 323–324
 - Eccentric Circles for, 182–183, 695–696
 - float and, 148
 - Free Space Fusion Cards A for, 182–183
 - Free Space Fusion Cards B for, 185
 - Lifesaver cards for, 186
 - localization and, 148–150, 152f
 - Double Maddox rod, 392–393, 393f
 - Double mirror stereoscope, 138, 139f
 - Double vision, 325
 - Dove prism, 424
 - Duane's classification, of vision disorders, 64, 124, 309, 335
 - Dynamic aniseikonia, 517, 529, 529
 - Dynamic reading, 231
 - Dyseidnesia, 595t
 - Dyslexia
 - publicity of, 595
 - reading dysfunction v., 593, 594–595
 - tests for, 595
 - types of, 595, 595t
 - Dyslexia Determination Test, 595
 - Dyslexia Screener, 595
 - Dysmetria, 375, 375t, 503t
 - Dysnemesia, 595t
 - Dysphonia, 595t

E

 - Eccentric Circles, 140t, 182, 250–251
 - for convergence therapy, 182–183, 182f, 695–696
 - description and setup of, 182–184, 182f–183f
 - for divergence therapy, 182–183, 695–696
 - endpoint of, 185
 - equipment needed for, 182
 - misconceptions about, 183
 - objectives of, 182
 - patient instructions for, 695–698
 - at 10–15 feet, 697–698
 - therapy procedures for, 184
 - two or more sets of, 184
 - Eccentric fixation, 371

- Echothiophate iodide (Phospholine Iodide), 278
- Educational history, to determine nature of learning problem, 603t
- Educational testing, 602
- Educators, 613
- Efferent infantile nystagmus, 501
- Electrodiagnostic tests, 477
- Electrophysiologic techniques
 - classification of, 138, 140t
 - instrumentation, 140, 143
 - types of, 140t, 143
- Electroretinogram (ERG), 477
- Emmetropia, 620, 623–624, 624t, 641, 643, 649, 649t
- Emotional testing, 602
- Encephalitis, 342t, 343
- Encyclophoria, 389
- Entoptic phenomena
 - classification of, 140
 - types of, 140t, 143
- Epi-LASIK, 656
- Equipment. *See* Instrumentation
- ERG. *See* Electroretinogram
- Eserine, 280
- Esophoria, 50, 56, 57, 60, 63–64, 76, 93, 95t, 96, 97t, 98–100, 261, 460t. *See also* Basic esophoria
 - accommodative excess and, 350
 - computer-related vision problems and, 549t
 - at distance, 67–69, 65t, 89
 - in fixation disparity analysis, 431
 - near, 127–128
- Esotropia, 93, 259, 501–502, 659–660, 664
- Estimated magnification prescriptions, 529
- Evidence pyramid, 102, 102f
- Excyclophoria, 389
- Excyclotorsion, 580
- Exophoria, 49–50, 65t, 460t. *See also* Basic exophoria
 - accommodative excess and, 350
 - computer-related vision problems and, 549t
 - at distance, 66–68, 69, 65t, 89
- Exotropia, 277, 291, 580–581, 631, 643–644
- Expenses, 682, 682t
- Eye movement disorders. *See also* Ocular motor dysfunction
 - from ABI, 574–575
 - functional capability influenced by, 368–369, 385
 - other disorders associated with, 369–371
 - prevalence of, 369
 - primary care of, 112–134, 113t–114t
 - reading and, 368–369, 372–373, 381–383, 597, 598
 - treatment for, 104–106
- Eye movement evaluation, 499
- in diagnostic testing, 25–32, 25t–28t, 28f–29f, 31t
- fixation stability, 25–32, 25t–28t, 28f–29f, 31t
- important aspects of, 25, 25t
- pathological conditions in, 25t
- Eye tracking, 687
- Eyestrain, 87
- Eyewire distance changes, in isekonic lenses, 532–533, 532t, 532f, 533t
- from blur, 145, 618
- from diplopia, 145
- dual intersecting loops of, in binocular vision-based model for refractive error management, 618f
- from float, 148, 171
- from kinesthetic awareness, 146, 171, 178
- learning from, 172
- from localization, 148–150, 148f, 150f–152f
- from luster, 146
- from parallax, 152
- patients receiving, 145
- proportional-controller-based, 618
- from SILO response, 146–148, 147f
- from suppression, 145
- in vision therapy for convergence insufficiency, 247t
- Fees, 679, 681, 684
- Fine motor developmental milestones, 606t
- First-degree targets. *See* Superimposition targets
- Fixation disparity
 - case analysis of, 54
 - definition of, 429
 - nonlinearities in, 467f
 - phoria associated with, 431f, 432, 435
 - treatment of, 432, 444, 446f–447f, 447
 - vision therapy for, 432, 444, 446f
 - as y-intercept, 432, 438
- Fixation disparity analysis, 49, 54, 83, 86f, 120. *See also* Forced vergence fixation disparity curves
 - advantages of, 54, 63–64
 - analysis approaches to, 429–430
 - associated phoria in, 431f, 431–432, 435
 - for cyclovertical heterophoria, 393–396, 395f
 - disadvantages of, 54
 - esophoria in, 431
 - fusional vergence in, 430
 - horizontal prism in, 395, 404–406
 - Percival's criterion and, 99–100
 - prism and, 99, 429–430
 - sensory factor in, 429
 - Sheard's criterion and, 99
 - tests for, 56
 - accommodation-vergence interactions and, 464–466, 467f
 - associated phoria v. forced vergence fixation disparity assessment in, 9, 395, 406, 431
 - under binocular conditions, 5–9, 54, 120
 - equipment used in, 432f
 - horizontal, 395
 - issues of, 120
 - technique for, 3, 3t, 9
 - vertical, 395–397, 395f, 406
 - vertical relieving prism and, 100–101
 - x-intercept in, 431–432, 431f–432f, 431–432, 8, 438
 - y-intercept in, 432, 432, 438
- Fixation misalignment. *See* Fixation disparity
- Fixation stability evaluation, 56
- pursuit in, 25t, 30–31, 31t, 48
- saccades in, 25t–28t, 25–30, 28f–29f
- Fixation status test, 56, 63–64
- Fixation switch diplopia, 663–664
- Fixational pause, 368
- Flashlight tag, 226
- Flat fusion targets, 205–206, 205f–206f, 298, 301f, 701–702
- Flattop bifocal lenses, 558
- Flip lens test, 463
- Flip lenses, 140t, 165–166, 165t, 463
- Flip prism, 140t, 165, 165t
 - procedures for, 176
 - tests with, 404, 405f, 461
- Float, feedback from, 148
- Flutter, 375t, 503t
- Focus, depth of, 128, 455, 455f, 462
- Forced vergence fixation disparity curves, 396, 406, 407f
 - associated phoria assessment v., 9, 395, 406, 431
 - clinical usefulness for prescribing, 439
 - lateral prism correction design, 439–442, 440f–441f
 - vertical prism correction design, 442–443
 - of divergence excess, 445f
 - generation of
 - available instrumentation, 433–434, 434t
 - horizontal fixation disparity curve, 435–437, 435f–437f
 - with lens, 437, 438f
 - phoropter setup, 434
 - vertical associated phoria, 435
 - graphing findings of, 437–438
 - interpretation of, 439
 - parameters of
 - center of symmetry, 431, 431f, 433, 439
 - shape, 430–431, 430f
 - slope, 430f, 430, 437–441, 437f, 438f, 440f–441f
 - sphere modification in
 - distance sphere modification, 443–444, 445f
 - near addition determination, 443
 - vision therapy planning and monitoring, 444, 446f
 - vertical fixation disparity analysis and, 9, 396, 405–406
- Fourth nerve weakness, 656
- Foveations, 492
- Frame selection, 535
- Free Space cards, 140t, 149, 151f, 250–251
- Fusion Cards A
 - for convergence therapy, 182–183, 182f
 - description and setup of, 182–182
 - for divergence therapy, 182–183
 - endpoint of, 185
 - equipment needed for, 182
 - objectives of, 182
 - therapy procedures for, 184
 - two or more sets of, 184
- Fusion Cards B
 - for convergence therapy, 185
 - description and setup of, 185, 185f–186f
 - for divergence therapy, 185
 - endpoint of, 186
 - equipment needed for, 185
 - objectives of, 185
 - therapy procedures for, 186
 - in modified Remy separator, 181, 181f
- Free space training, 138
- Full refractive correction, 131, 132t, 481
- Full Scale IQ score, 601
- Functional amblyopia, unequal accommodation caused by, 338
- Fused cross-cylinder test, 3, 3t, 19t, 24, 56, 62
 - ACC analysis with, 62
 - for accommodative insufficiency, 339
 - accommodative response assessed by, 19t, 24
 - NFV tested by, 60
 - PFV tested by, 60

F

- Facial symmetry, 644
- Fee slip, 683
- Feedback. *See also* Biofeedback

- Fusion**
 chiasitic, 177, 183, 183f, 184
 cyclo-, 400
 horizontal, 391
 orthopic, 177, 182–184
 qualitative v. quantitative aspects of, 313, 330
 vertical, 62, 95, 391
- Fusion enhancement therapy**
 antisuppression, 508
 horizontal vergence, 508–509
- Fusional vergence. See also Negative fusional vergence; Positive fusional vergence**
 assessment of
 direct measures, 3–4, 3t, 8t, 11–12, 119
 indirect measures, 3–4, 3t, 13–15, 318t, 319, 327t
 suppression and, 15–16
 in fixation disparity analysis, 430
- Fusional vergence dysfunction, 83, 86f**
 background information about, 309–310
 binocular and accommodative data analysis and, 311
 case studies of, 84, 316–317
 deviation characteristics of, 310
 diagnostic findings summary for, 73t
 differential diagnosis of, 311, 312t
 dismissing of, 310
 Duane's classification not describing, 309
 NFV and, 313
 PFV and, 312–313
 prevalence of, 310
 refractive error and, 310
 sequential management considerations of, 308t
 signs and symptoms of, 67, 310, 311t
 terminology of, 310
 treatment of, 313t
 lenses, 312
 prism, 312
 surgery, 309, 316
 vision therapy, 154, 312–316, 313t–315t
- Fusional vergence therapy, 154**
 anaglyphs, Polaroids, and liquid crystal filters, 160–176, 161f–163f, 164t–165t, 166f, 167t, 168f–171f, 174f, 175t
 lenses, prisms, and mirrors, 176
 paper, pencil, and miscellaneous tasks, 182–186, 182f–183f, 185f–186f, 192–196, 192f–193f, 196f
 septums and apertures, 187f–191f, 176–181, 177f–181f
 stereoscope, 186–194, 187f–188f, 190f–194f
 with voluntary convergence procedures, 194–197, 195f, 197f–198f
- G**
- Gabapentin, 513**
 Ganglion blockers, 342t
 General skills case. *See* Fusional vergence dysfunction
- Genetically programmed ocular growth**
 heredity influencing, 624–625, 625t
 influence of, 629
 relative strength of, 623–624, 623f–624f, 626
- Genetics**
 counseling for, 501
 myopia influenced by, 623–625, 25t
 RS and, 618–619
- Glasses. See also Red/green glasses**
 learning-related vision disorders and, 598–600
 liquid crystal, 172–173
 reading and, 341, 598–600
- Global targets, 16, 16f**
- Gradient AC/A, 9–10, 458–459**
- Graphical analysis**
 accommodation-vergence interactions in, 451–452, 452f
 advantages of, 49
 disadvantages of, 50–51
 NPC in, 50, 50f
 sample worksheet of, 50, 50f
 Sheard's criterion in, 51–52
- Graphing, of forced vergence fixation disparity curves, 437–438**
- Groffman tracings, 31, 378**
- Gulden fixation sticks, 5, 5f, 36**
- H**
- Habitual spectacle lenses, 408, 414**
- Haidinger brush, 140t, 144**
- Hand-held acuity test cards, 495, 496f**
- Hand-held mirrors, 140t**
- Haploscope, 140t**
- Hart chart, 140t**
 distance-to-near accommodative rock (monocular)
 description and setup of, 218, 219f
 endpoint of, 219
 equipment needed for, 218
 objectives of, 219
 for saccadic therapy, 702–703
 description and setup of, 222
 equipment needed for, 222
 objectives of, 222
 patient instructions for, 703–704
- Hawthorne effect, 337**
- Hemianopia, 584–586**
- Heredity, genetically programmed ocular growth**
 influenced by, 624–625, 625t
- Hering-Bielschowsky afterimage test, 293**
- Heterophoria, 63, 89, 98. See also Cyclovertical heterophoria**
 AC/A ratio and, 56–57, 64, 124, 234–236, 273–277, 460t
 analysis of, 124
 horizontal, 64
 magnitude of, 402
 occlusion and, 101
 space eikonometer and, 525, 526f
 vertical, 57, 64, 124, 392, 393f, 401t
- High AC/A conditions, 68–70, 73t, 103t, 113t–114t, 124, 129t, 279, 292, 460t. See also Convergence excess; Divergence excess**
 added lenses and, 273–276
 general management principles for, 274–276, 274t, 305
 treatment of, 276–277
- Hofstetter's formula, 20, 337**
- Home Therapy System (HTS), 206, 231, 250–251**
 ADRI Net Dynamic Reader and, 231
 effectiveness of, 244
- Home-based vision therapy, 133, 172**
 for accommodation excess, 354t–356t, 356
 for accommodative infacility, 361, 363t
 for accommodative insufficiency, 344, 344t–345t
 accommodative therapy with, 219–220
 for basic esophoria, 322t–323t, 323
 for basic exophoria, 331t–332t, 332
- computer home therapy procedures in, 175, 175t, 206, 228, 231, 679–680
 for convergence excess, 283t–284t
 for convergence insufficiency, 251, 248t–250t
 for cyclovertical heterophoria, 420
 for divergence excess, 299t–301t, 303
 for divergence insufficiency, 262t–265t
 effectiveness of, 244–246
 for fusional vergence dysfunction, 314t–315t, 315
 HTS, 206, 231, 250–251
 in-office therapy v., 679–680
 modified Remy separator for, 181
 for ocular motor dysfunction, 378t–380t
 patient instructions for
 Ann Arbor letter tracking, 703
 beads and string, 699–700
 colored circle cards for convergence, 700–701
 Eccentric Circles at 10–15 feet, 697–698
 Eccentric Circles for convergence, 696–697
 Eccentric Circles for divergence, 695–696
 first- or second-degree targets at 10–15 feet, 701–702
 Hart chart for saccadic therapy, 702–703
 monocular loose lens rock, 704
 red lens and penlight technique to eliminate suppression, 694
 tranaglyph slides, 698–699
 TV trainer, 694–695
 visual tracing, 703–704
 PPT, 244–246
- Horizontal fixation disparity curve**
 examples of, 435–436, 436f, 437f
 measurement of, 435–436, 436f
 modified curve generation and, 436–437, 437f
- Horizontal fusion, 391**
- Horizontal prism, 236, 281, 295**
 basic esophoria treated with, 320
 basic exophoria treated with, 329
 description of, 97–100, 103t, 128–130
 in fixation disparity analysis, 393, 405–406
- Horizontal rectus tenotomy, 514**
- Horizontal vergence therapy, 417–418**
 cyclovertical heterophoria treated with, 417–418, 418t
 fusion enhancement with, 508–509
 nystagmus treated with, 508–509
 vertical vergence therapy v., 417–418, 418t
- Horror fusionis, 573**
- HTS. See Home Therapy System**
- Hyperopia, 92, 92t, 133, 616**
 accommodative esotropia secondary to, 664
 accommodative fatigue secondary to, 335
 amblyopia and, 474
 basic esophoria associated with, 318
 basic exophoria associated with, 328
 in binocular vision–based model for refractive error management, 641–642, 644
 convergence excess associated with, 278, 280–281
 convergence insufficiency associated with, 235–236, 235t, 243, 253–255
 divergence insufficiency present with, 236
 latent, 83, 86f
 rate of refractive change in, 626, 627f
 residual, causing decompensated esotropia, 659–660
 treatment of, 641–642

- Hyperopic anisometropia, 644–645
 Hyperphoria, 57, 64, 65t, 385
 definition of, 389
 incidence of, 390
 latent, 407–408
 Hypometra, 389, 375t
- I**
- Ill-sustained accommodation, 57, 65, 65t,
 71, 73t, 124, 336
 case study of, 347–348
 description of, 338
 diagnostic findings summary for, 73t
 difficulty diagnosing, 348
 signs and symptoms of, 71
 Inappropriate saccades, 374, 375t
 Inefficient binocular vision. *See* Fusional
 vergence dysfunction
 Infantile nystagmus, 491–492, 499–501
 afferent v. efferent, 501
 astigmatism associated with, 504
 characteristics of, 500t
 genetic counseling for, 501
 jerk nystagmus in, 501, 501f
 Infravergence test, 56, 62
 Initiation disorders, of saccades, 374, 375t
 Instrument training. *See* Stereoscopes
 Instrumentation
 afterimages, 140, 140t, 143, 230–231
 anaglyphs, 140, 140t
 apertures, 138, 139f, 140t, 141
 basic, 684
 categorization of, 138–144, 140t
 computer software, 684
 electrophysiologic techniques, 140, 143
 entopic phenomena, 140, 143
 for forced vergence fixation disparity
 curves generation, 433–434,
 434t
 lenses, 138–141, 140t
 for paper, pencil, and miscellaneous
 tasks, 140, 140t, 141–142,
 142f
 for phoria measurement, 433–434, 443t
 Polaroids, 140t, 141
 septums, 138, 140t, 141, 142f
 stereoscopes, 138, 139f, 140t, 143
 Insurance coverage, 691–692
 appeal letters for, 683–684, 689–690
 basic issues of, 683
 diagnostic codes for, 683
 payment systems of, 683–684
 predetermination letters for, 688–689
 problems with, 682
 Integrative analysis, 468
 details of, 54–55
 expected findings for optometric tests
 and, 55
 optometric data grouping in, 55
 steps of, 55, 85
 Intelligence Quotient (IQ) test, 601–602,
 604
 Interagency Committee on Learning
 Disabilities, 594
 Intermittent exotropia (IXT), 277, 291,
 580–581, 631, 643–644
 Intermittent photic stimulation, 512
 Internuclear ophthalmoplegia, 375, 375t
 Interpupillary distance (IPD), 434
 Interview, clinical, 602
 Intractable diplopia, 669–670
 Intuitive colorimeter, 599
 IPD. *See* Interpupillary distance
 IQ test. *See* Intelligence Quotient test
 Irlen filters, 599
 Iseikonic lenses, 525
 antireflective coating, 535
 bitoric, 542
 design examples of, 539–542
 inadvertent corrections
 frame eye size changes, 543–544,
 544f, 544t
 refractive index changes, 545
 lens edge coating, 535
 magnification by changing base curve,
 533, 533t
 magnification by changing eyewire
 distance and bevel, 532–533,
 532t, 532f, 533t
 magnification by changing lens
 thickness, 535, 536t–537t
 prescription considerations for, 535, 539t
 recommendations for, 529–542, 545
 Isoametropic amblyopia, 472–473
 case study of, 478
 etiology of, 472
 prevalence of, 473
 sequential management protocol for, 478
 suppression and, 475
 IXT. *See* Intermittent exotropia
- J**
- Jackson cross-cylinder (JCC) testing, 2, 118
 Jerk nystagmus, 493, 493f, 497, 501, 501f,
 505t
 Jump convergence, 13, 240
 Jump vergence training. *See* Phasic vergence
 training
 Jump vertical vergence therapy, 422
 Jump-Jump Vergence program, 175
- K**
- Keystone cards, 188f
 Keystone Correct-Eye-Scope, 190–191, 191f
 Kinesthetic awareness, feedback from, 146,
 171, 175
 King-Devick test. *See* New York State
 Optometric Association King-
 Devick test
 Knapp's law, 94, 518
- L**
- Lag, accommodation, 128, 455, 455f, 462,
 468, 631–632, 633f
 Language milestones, 606t
 Lasek. *See* Laser-assisted subepithelial
 keratectomy
 Laser in situ keratomileusis (Lasik),
 655–660, 662–663
 Laser-assisted subepithelial keratectomy
 (Lasek), 656
 Lasik. *See* Laser in situ keratomileusis
 Latent hyperopia, 83, 86f, 407–410
 Latent hyperphoria, 407–408
 case study of, 408
 prism prescriptions for, 407–408
 Latent nystagmus, 500t, 501, 508–509
 Late-onset myopia, 620, 626, 627f
 Lateral associated phoria, 432
 Lateral prism correction design, 439–442,
 440f–441f
 Learning-related vision disorders. *See also*
 Reading dysfunction
 case history for, 602, 603t–604t,
 607f–609f
 case studies of
 therapy directly improving reading
 performance, 609–610
 therapy unlikely to directly improve
 reading performance, 611–612
 children with, 594–597, 600–606
 classroom accommodations for, 613
 colored filters and, 598–600
 comanagement of, 594, 613
 definition of, 594
 diagnostic testing for
 defining problem in, 603, 603t
 family history in, 605, 605t–606t,
 607f–609f
 infrared eye tracking in, 602
 medical or developmental problems
 in, 605–606, 605t–606t
 parent questionnaire in, 605–606,
 607f–609f
 previous testing for, 604, 604t
 epidemiology of, 594
 glasses and, 598–600
 language disorders, 604
 optometrist's role in management of,
 593–594, 606, 613
 research on, 597–598
 signs and symptoms of, 597t
 three-component model of vision and,
 594, 594t
 treatment of
 challenges in, 613
 educational intervention v., 606
 educators and, 613
 objectives of, 606–613
 other professionals and, 613
 sequential treatment approach to,
 613
 vision therapy, 606, 608
 visual efficiency disorders, 603–604,
 606–613, 687–688
 visual information processing disorders,
 603–604
 Lens edge coating, 535
 Lens flipper testing, 463
 Lens sorting (monocular)
 description and setup of, 212
 difficulty level changed in, 214
 endpoint of, 214
 equipment needed for, 212, 213f–214f
 important factors in, 214
 objectives of, 212
 Lenses. *See also* Added lenses; Contact
 lenses; Iseikonic lenses
 accommodation-vergence interactions
 treated with, 467
 accommodative excess treated with,
 353–354
 accommodative infacility treated with,
 359–362
 accommodative insufficiency treated
 with, 343
 accommodative therapy with, 212–218,
 213f, 215f, 217f–218f
 advantages of, 141
 basic esophoria treated with, 320
 basic exophoria treated with, 328
 bifocal, 97, 126, 287, 558, 677
 categorization, 140, 140t
 ChromaGen, 620
 coatings of, 535–536, 559
 convergence excess treated with, 280
 convergence insufficiency treated with,
 242–243, 582–584
 disadvantages of, 141
 divergence excess treated with, 294–295
 divergence insufficiency treated with, 262
 fixation disparity curves generated with,
 437, 438f

- flip, 140t, 165–166, 165t, 463
 forced vergence fixation disparity curves
 generated with, 437, 438f
 fusional vergence dysfunction treated
 with, 312
 fusional vergence therapy with, 176
 habitual spectacle, 408, 414
 instrumentation, 140, 140t
 loose, 140t, 165, 165t
 ocular motility procedures with, 221
 phakic IOL, 656
 procedures for, 176
 rate of refractive change influenced by, 626
 sag of, 543–544, 544f, 544t
 SILO response associated with, 147
 TV trainer and, 202
 vision therapy prescribed after, 328
- Letter tracking, 140t
 Ann Arbor, 703
 description and setup of, 222–224, 223f
 endpoint of, 224
 equipment needed for, 222
 objectives of, 222
- Letters. *See* Written correspondence
- Lid-suture myopia, 619
- Lifesaver cards, 140t, 151f
 for convergence therapy, 186
 description and setup of, 185, 185f–186f
 for divergence therapy, 186
 endpoint of, 186
 equipment needed for, 185
 in modified Remy separator, 180, 181f
 objectives of, 185
 therapy procedures for, 186
- Liquid crystal filters, 172–175. *See also*
 Computer Orthoptics VTS3
 Liquid Crystal System
 accommodative therapy with, 209–212,
 210f, 211t
 fusional vergence therapy with,
 160–176, 161f–163f,
 164t–165t, 166f, 167t,
 168f–171f, 174f, 175t
- Liquid crystal glasses, 172–173
- Lithium, 376t
- Local stereopsis. *See* Contour stereopsis
- Localization
 Aperture Rule and, 178, 178f
 convergence and, 148–149
 divergence and, 149–150, 150f
 feedback from, 148–151, 148f,
 150f–152f
 patients' cues for, 148–151
- Loose lens rock. *See* Biocular loose lens rock;
 Monocular loose lens rock
- Loose lenses, 140t, 165, 165t, 176, 221
 Loose prism jumps, 221
- Low AC/A conditions, 56, 65t, 73t, 95–97,
 103t, 113t–114t, 124, 129t,
 240, 260, 460t. *See also*
 Convergence insufficiency;
 Divergence insufficiency
 case studies of, 234–236
 general management principles for,
 234–236, 235
 treatment of, 237
- Low refractive error, 94
- Luster, feedback from, 146
- M**
- M pathway. *See* Magnocellular pathway
- MA. *See* Meter angle
- Macrosquare wave jerk, 375, 375t
- Maddox double prism, 392, 393f
- Maddox rod
 for aniseikonia, 523
 cyclophoria evaluated with, 392–393,
 394f
 cyclovergence therapy with, 424–425
 dissociated testing with, 392–393, 393f
 single v. double, 392–393, 393f, 394f
 for vertical heterophoria, 392, 393f
- MAF test. *See* Monocular accommodative
 facility test
- Magnetic resonance imagery (MRI), 499, 501
- Magnocellular (M) pathway, 599
- MAIT. *See* Motor Alignment and Interaction
 Tests
- Malaria, 352, 342t
- Mallett unit, 16, 54, 131, 395, 396f, 432f
- Marijuana, 342t, 376t
- Marsden ball, 152f
- Maximum-plus refraction technique, 118
- Maxwell spot, 140t, 144
- Meares-Irlen syndrome, 598–600
- Measured aniseikonia prescriptions, 529
- Medial rectus weakness, 328t
- Medicare, 683
- MEM retinoscopy. *See* Monocular estimation
 method retinoscopy
- Memantine, 513
- Meta-analysis, 102, 102f
- Meter angle (MA), 457f
- Methadone, 376t
- Minification, 20
- Minus lens amplitude test, 18t, 20–22, 45–46
- Minus lenses
 AC/A ratio measured by, 458
 accommodative insufficiency treated
 with, 343
 amblyopia treated with, 481
 BAF test with, 60, 319
 bevel changes in, 533, 533t
 at distance, 295
 divergence excess treated with, 295, 295t
 MAF test with, 61
 nystagmus treated with, 506
 plane of accommodation influenced
 by, 153f
 PRA tests with, 319
 prescribing of, 95–97, 95t–97t, 126, 128
 retinal images minified by, 147
- Mirror superimposition
 description and setup of, 205
 endpoint of, 206
 equipment needed for, 205
 objectives of, 205
 targets used in, 205, 205f–206f
 therapy procedures for, 205–206,
 205f–206f
- Mirrors
 accommodative therapy with, 176,
 212–218, 213f–215f, 217f–218f
 advantages of, 141
 categorization of, 138–140
 disadvantages of, 141
 fusional vergence therapy with, 176
 hand-held, 140t
 ocular motility procedures with, 221
- Modified Remy separator
 description and setup of, 180–181, 181
 equipment needed for, 180
 in home-based vision therapy, 181
 objectives of, 180
 therapy procedures for, 181
- Modified Thorington test
 accommodation control for, 7–8
 phoria assessed by, 3, 3t, 7–8, 8t,
 38–40, 63
- Monocular accommodative facility (MAF)
 test, 18, 19t, 21, 56, 73t, 240
- for accommodative infacility, 358–359
 for accommodative insufficiency, 339
 accommodative system tested by, 61
 fusional vergence dysfunction and, 311
 with plus and minus lenses, 61
- Monocular estimation method (MEM) reti-
 noscopy, 3t, 3, 18, 47, 55, 73t,
 121t, 121t, 123t, 128
 for accommodative insufficiency,
 339
 accommodative response assessed
 by, 18t, 19t, 23–24, 24f, 121,
 121t, 455, 555, 555f
 accommodative system tested by,
 61, 122
 cards used for, 23, 24f
 issues of, 122
 NFV tested by, 58, 279, 327, 548
 for nystagmus, 497
 PFV tested by, 58–59, 240–241, 339
- Monocular loose lens rock, 214
 description and setup of, 215, 215f
 endpoint of, 215
 equipment needed for, 215
 patient instructions for, 704
- Monocular suppression, 527
- Monovision
 accommodative issues, 664–666
 convergence issues, 664–666
 decompensation and, 662–663
 diplopia caused by, 663–664
 pre-Lasik trial and, 663
- Monthly fee, 684
- Morgan's system of clinical analysis.
See Normative analysis
- Motor alignment
 analysis of, 63–64
 nystagmus and, 498–499
- Motor Alignment and Interaction Tests
 (MAIT), 56
- Motor milestones, 606t
- Moving text dynamic reading, 231
- MRI. *See* Magnetic resonance imagery
- Multiple choice vergence program, 173–175,
 174f
- Multiple sclerosis, 342t, 343
- Myasthenia gravis, 374, 375t
- Myopia, 92t, 616
 accommodative spasm and, 664–666
 amblyopia and, 474–475
 anisometropia and
 development of, 642–643
 facial symmetry and, 644
 head position and, 643
 suppression of one eye in, 643
 basic exophoria associated with, 328
 in binocular vision–based model for
 refractive error management
 accommodation–vergence interactions,
 632
 amount and direction of peripheral
 retinal blur, 631–632
 amount of lag, 631
 amount of near work performed, 632
 case studies of, 634–639, 643–644
 normal visual acuity, 631
 range of sensitivity to blur, 631–632
 treatment of, 632–640, 633f
 children developing, 620, 626,
 627f–628f
 convergence insufficiency associated
 with, 235–236, 242
 genetics influencing, 624–625, 625t
 late-onset, 620, 626, 627f
 lid-suture, 619
 overcorrection of, 625
 rate of refractive change in, 626, 627f

- Myopia (*continued*)
 risk factors for, 632–640
 treatment of
 contact lenses, 637–640
 diet, 640
 enhanced blur-detection ability, 640
 IXT and, 643–644
 pharmacologic, 636–637
 reduced amount of near work, 640
 successful, 634
 undercorrection, 640
 unsuccessful, 635
 unilateral high, 473
- N**
- National Institutes of Health (NIH), 594
 Near AC/A, 127–128, 127t
 Near addition power, 126, 128, 443, 633
 Near astigmatic axis shift, 390t
 Near Mallett unit, 16
 Near point of convergence (NPC), 55, 73t
 basic exophoria and, 326
 convergence insufficiency and, 239
 in graphical analysis, 50, 50f
 refractive error and, 326
 tests for, 3t, 6, 8t, 13–14, 15, 43
 accommodation-vergence
 interactions and, 461
 important issues in, 120
 PFV tested by, 58–59
 recovery point in, 239
 repetition of, 239
- Negative fusional vergence (NFV), 55, 96, 462
 accommodative insufficiency and, 340
 in accommodative therapy, 155
 analysis of, 69–60, 76, 78f, 80, 83f
 basic esophoria and, 309, 318, 318t, 321
 basic exophoria and, 330
 in binocular vision therapy, 155
 computer-related vision problems and, 548
 convergence excess and, 278
 convergence insufficiency and, 239
 CUC and, 548
 divergence excess and, 298
 divergence insufficiency and, 260
 fusional vergence dysfunction and, 313
 normalization of, 321, 380
 ocular motor dysfunction and, 380
 tests for
 BAF, 60, 279, 311, 327, 548
 direct, 318t, 319, 327t
 at distance, 318t, 327t
 fused cross-cylinder, 60
 indirect, 3–5, 3t, 13–15, 318t, 319, 327t
 MEM retinoscopy, 58, 279, 327, 548
 at near, 318t, 327t
 PRA, 59–60, 279, 319, 548
 smooth vergence, 59
 step vergence, 59
 vergence facility, 59
- Negative relative accommodation (NRA)
 testing, 3–4, 3t, 19t, 42–43, 49, 50f, 55, 59–60, 73t
 for CUC, 555
 PFV tested by, 58, 240, 311, 327
 plus lenses with, 327
- Neurologic testing, 604t
 Neurosurgery, 385
 New Aniseikonia Test, 524, 524f
 New York State Optometric Association
 King-Devick (NYSOA K-D) test, 27, 369
 Newcastle control score, 6
 NFV. *See* Negative fusional vergence
 NIH. *See* National Institutes of Health
 Nonfunctional etiology, testing to rule out, 72–76, 74f, 75b, 75
 Nonstrabismic binocular vision disorders
 amblyopia and, 236, 275
 anisometropia and aniseikonia managed in, 94–95
 assessment of, in primary care
 optometry, 118–120, 124
 common, analysis of, 124
 diagnostic testing of, 3–15, 3t, 4f, 5f, 6t, 8t, 117–118
 direct assessment of positive and negative fusional vergence in, 8t, 11–12, 119
 fixation disparity assessment in, 5–7, 9
 general considerations in, 3–5, 3t, 4f, 118
 indirect assessment of positive and negative fusional vergence in, 13–15, 120
 phoria size and direction assessment in, 3t, 5–11, 5f, 6t, 120
 sequential management
 considerations for, 235t
- Nonvariable tranaglyphs
 description and setup of, 170–171, 171f
 equipment needed for, 170
 objectives of, 170
 therapy procedures with, 171
- Normal AC/A conditions, 65t, 67–68, 73t, 100, 100t, 103t, 113t–114t, 129t, 292, 311, 319, 327, 460t.
See also Basic esophoria; Basic exophoria; Fusional vergence dysfunction
 added lenses and, 307
 differences among, 307
 general management principles for, 307–309, 308t
 treatment of, 307–309
 key points, 309
 sequential considerations, 308t
 vertical deviations and, 307
- Normative analysis, 50, 52, 429
 accommodation-vergence interactions in, 452
 advantages of, 53
 disadvantages of, 54
 expected findings in, 52, 53t
 three groups in, 52, 53t
- Nott retinoscopy, 18
 NRA. *See* Negative relative accommodation
 NSUCO oculomotor test, 25t, 26, 26t–27t, 30, 31t, 47–48, 63
- Null region, 501
 NYSOA K-D test. *See* New York State Optometric Association King-Devick test
- Nystagmus, 371–372, 375
 accommodation and, 497–498
 blockage syndrome, 501–502, 514
 case studies of
 biofeedback therapy, 509–510
 conjugate prism, 507
 high plus addition for near, 506
 intermittent photic stimulation, 512
 manifest latent nystagmus, 508–509
 vertical line counting, 511–512
 causes of, 494–495
 characteristics of, 492–494, 492t, 493f
 children with, 491–492, 494–495, 503
 clinical evaluation of, 494
 binocular vision, 497–498
 ocular health, 498–499
 ocular motility, 296, 498–499
 patient history, 494–495
 refractive error, 495
 systemic health, 498–499
 visual acuity, 495–497, 496f
 conditions mimicking, 503t
 decreased, with convergence, 506
 definition of, 491
 differential diagnosis of, 499–503, 500t, 501f, 503t
 difficulty diagnosing, 491, 514
 etiology of, 491
 genetic counseling for, 503–503
 infantile, 491–492, 499–501, 500t, 501f, 504
 jerk, 493, 493f, 497, 501, 501f, 505t
 latent, 501, 500t, 501, 508–509
 motor alignment and, 498–499
 OKN, 498–499
 pendular, 492, 493f, 505t
 physiologic, 500t, 502
 prevalence of, 491
 signs and symptoms of, 503t
 spasmus nutans, 502
 suppression and, 498
 treatment of
 added lenses, 504–506
 contact lenses, 504
 occlusion, 507–508
 pharmacologic therapy, 513
 pleoptics, 512
 prism, 506–507
 recommendations for, 514
 refractive correction, 504, 510
 surgery, 513–514
 vision therapy, 508–512, 511f–513f
 vestibular, 502–503, 500t, 499
 voluntary, 500t, 503
- Nystagmus blockage syndrome, 501–502, 514
- O**
- Oblique astigmatism, 400
 Occipitoparietal junction, 374, 376
 Occlusion
 for amblyopia, 481–482, 482f
 aniseikonia and, 521
 complications of refractive surgery
 treated with, 578–579
 for cyclovertical heterophoria, 397, 397t, 416
 diagnostic, 397, 397t, 521
 heterophoria and, 101
 prism, 507–508
 sector, 416
 test for, 294
- Occlusion therapy
 ABI and, 578–579
 cyclovertical heterophoria treated with, 416
 for nystagmus, 507–508
 as passive therapy, 89, 101, 131–132, 132t, 308, 481–482, 482f
- Occupational therapy, 604t
 Ocular bobbing, 503t
 Ocular flutter, 375, 375t, 503t
 Ocular growth
 component, 618–622, 621f–622f, 625
 genetically programmed, 623–625, 623f–624f, 625t, 629
 relative strength of, 626
 variations in, 620
 visually driven, 625
 Ocular inflammation, 280

- Ocular motility procedures
 afterimage techniques, 230–231
 computer home therapy, 231
 lenses, prisms, and mirrors, 221
 nystagmus and, 296, 498–499
 paper, pencil, and miscellaneous tasks,
 222–230, 223f–225f
- Ocular motor apraxia, 375, 375t
- Ocular motor dysfunction, 64–65, 65t, 72,
 83, 83f, 124
 added lenses, 372
 background information about,
 372–373, 373f
 case studies of, 87, 381–385
 children with, 156, 376
 classification of, 59, 64–65, 65t, 72, 73t
 diagnostic findings for, 73t
 differential diagnosis of, 374–376
 pursuit, 376, 376t
 saccadic, 375–376, 375t
 drugs and toxins influencing, 376, 376t
 functional v. medically significant, 376
 general management principles for, 371
 NFV and, 380
 PFV and, 380
 prevalence of, 369
 reading and, 387–388
 refractive error and, 372
 signs and symptoms of, 72, 373–374,
 374t
 terminology of, 368
 tests for, 373
 treatment of, 89, 104–105, 377
 added lenses, 371–372
 prognosis of, 369–371
 surgery, 385
 vision therapy, 104–105, 372,
 377–378, 377t–380t
 Visagraph II and, 372, 373f
- Ocular motor nerve palsy, 374, 375t
- Ocular motor system
 adaptability of, 370
 assessment of, 56
 OKN in, 498
 problems with, 57
 vestibular system in, 498–499
- Ocular motor therapy, specific guidelines for,
 156–157
- Oculomotor paresis, 370
- Oculomotor-based auditory biofeedback, 105
- OEP analytical case analysis. *See* Optometric
 Extension Program analytical
 case analysis
- OEP minus lens procedure. *See* Optometric
 Extension Program minus lens
 procedure
- Office policy, for vision therapy, 691–692
- Office space, 681
- OKN. *See* Optokinetic nystagmus
- Opsoclonus, 375, 375t, 503t
- Ophthalmoscopy, 261, 476f, 498
- Optokinetic nystagmus (OKN), 498
- Optometric Extension Program (OEP)
 analytical case analysis
 advantages of, 52
 disadvantages of, 52, 55
 expected findings of, 51, 51t
 requirements of, 51
- Optometric Extension Program (OEP) minus
 lens procedure, 18
- Optometrists
 learning-related vision disorders and,
 593–594, 606, 613
 primary care, 112
 refractive surgery and, 666–669, 666t
 therapists v., 678–679
- Orthokeratology, 638
- Orthophoria, 56, 65–68, 65t, 80–83, 84, 89
- Orthoptic fusion, 177, 182–183, 184
- Oscillopsia, 505t, 510, 513
- Out of phoropter testing, 396
- P**
- P pathway. *See* Parvocellular pathway
- PALs. *See* Progressive addition lenses
- Paper, pencil, and miscellaneous tasks
 accommodative therapy with, 218–219
 advantages of, 143
 classification of, 140
 disadvantages of, 143
 fusional vergence therapy with,
 182–186, 182f–183f, 185f–186f
 instrumentation for, 140, 140t,
 141–142, 142f
 ocular motility procedures for, 222–230,
 223f–225f
 types of, 140t, 142f
- Papilledema, 261–262
- Parallax
 children and, 152
 definition of, 152
 feedback from, 152
- Paralysis of accommodation
 description of, 337–338
 prevalence of, 338
- Parametric adjustment, 370
- Parents
 letters to, 686–688, 690–691
 questionnaire for, 606–609, 607f–609f
- Parietal lesions, 374, 375t
- Parkinson disease, 375, 375t, 376t
- Parvocellular (P) pathway, 599
- Passive therapy, 131–134, 132t, 202
 for amblyopia, 481–483, 482f
 atropine, 131–132, 132t, 482–483
 occlusion, 89, 101, 131–132, 132t, 308,
 481–482, 482f
- Pathologic diplopia, 296–297
- Patient instructions, for home-based vision
 therapy
 Ann Arbor letter tracking, 703
 beads and string, 699–700
 colored circle cards for convergence,
 700–701
 Eccentric Circles at 10–15 feet, 697–698
 Eccentric Circles for convergence,
 696–697
 Eccentric Circles for divergence,
 695–696
 first- or second-degree targets at 10–15
 feet, 701–702
 Hart chart for saccadic therapy, 702–703
 monocular loose lens rock, 704
 red lens and penlight technique to
 eliminate suppression, 694
 tranaglyph slides, 698–699
 TV trainer, 694–695
 visual tracing, 703–704
- Patients. *See also* Children
 age and intelligence of, 103–104, 361
 change created by, 114
 compliance of, 377, 479
 counseling for, 415, 503–504
 feedback provided to, 145
 financial issues of, 106
 frustration of, 144
 history of, 494–495, 601
 individual v. multiple per session, 679
 level of, 144, 154–155
 localization cues for, 148–149
 motivation of, 106, 377, 479
 positive reinforcement for, 144
 prognosis determination for, 104–106
 SILO response elicited from, 148
 vision therapy issues and, 674–678, 675t
- Pattern glare, 600
- PAVE Program. *See* Perceptual Accuracy/
 Visual Efficiency Program
- Payment, 682–684, 691–692
- Pencil push-up treatment (PPT)
 effectiveness of, 244–246
 technique for, 244
- Pendular nystagmus, 492–493, 493f, 492t
- Penlight, 157
 red/green glasses used with, 203, 694
 in vertical prism dissociation, 204
- Perceptual Accuracy/Visual Efficiency (PAVE)
 Program, 371
- Percival's criterion, 99–100
- Peripheral fusion, 164–165
- Peripheral tranaglyph targets, 161f–162f, 163
- Peripheral vestibular nystagmus, 502–503
- Personality testing, 602
- Per-visit payment method, 683
- PFV. *See* Positive fusional vergence
- Phakic intraocular (IOL) lens, 656
- Pharmacologic treatment
 with atropine, 131–132, 132t, 482–483,
 618–619, 636–637
 of convergence excess, 278
 of myopia, 636–637
 of nystagmus, 513
- Phasic vergence training, 155
 in accommodative infacility vision
 training program, 362t
 in basic esophoria vision training
 program, 324
 in basic exophoria vision training
 program, 333
 CAVT Random Dot Stereograms and,
 175
 in fusional vergence dysfunction vision
 training program, 312
 with tranaglyphs, 165, 165t, 166f
- Phenobarbital, 376t
- Phenothiazides, 342t
- Phenytoin, 376t
- Phoria
 accommodative problems and, 133–134
 associated and dissociated combinations
 of, 418, 418t
 cyclovertical, 83, 86f, 87
 definition of, 389
 dissociated, 49, 50f
 fixation disparity associated with, 431f,
 432, 435
 insignificant, in case analysis, 83, 87, 86f
 lateral associated, 432
 predictors of, 460t
 significant, in case analysis, 76–83,
 77f–79f, 83f
 vertical associated, 130–131, 395–396,
 395f–396f, 406, 434–435
 as x-intercept, 431–432, 431f–432f, 438
- Phoria size and direction assessment, 3t,
 5–11, 5f, 8t, 56, 100, 395, 414
 AC/A ratio technique for, 9–10, 39–40
 CA/C ratio technique for, 10–11
 cover test for, 5–7, 5f, 6t, 36–37, 63, 118
 instrumentation for, 433–434, 443t
 modified Thorington test for, 3, 3t, 7–8,
 8t, 38–40, 63
 von Graefe test for, 3, 3t, 7, 8t, 37–39, 63
- Phoropter
 setup, in fixation disparity analysis, 434
 testing outside, 8, 434
- Phospholine iodide. *See* Echthiophate
 iodide
- Photostimulation, 512

- Photorefractive keratectomy (PRK), 656, 661–662, 669–670
- Physiologic diplopia
Brock string for, 142
vectogram for, 148–149
- Physiologic nystagmus, 500t, 502
- Pierce saccade test, 27
- Pilocarpine, 280, 625
- Pirenzepine, 636
- Placebo effects, 336, 337
- Plane of accommodation, 152–153, 152f–153f, 179, 180, 180f, 182, 182f
- Plane of regard, 152, 153
- Plane of vergence, 152–153, 154f, 180, 180f, 182, 182f
- Plastic period, of amblyopia, 473
- Pleoptics, 512–513
- Plus lenses
accommodative insufficiency treated with, 337, 343–344
amblyopia treated with, 481–482
BAF test with, 58, 327
basic esophoria treated with, 320, 320t
bifocal, 97, 126, 287
convergence excess treated with, 280–281, 281, 281t
CUC treated with, 550, 556–557
MAF test with, 61
at near and calculated AC/A ratio, 126–127, 127t
NRA test with, 327
nystagmus treated with, 504–506
plane of accommodation influenced by, 153f
prescribing of, 95–97, 95t–97t, 320
retinal images magnified by, 147
single vision, 287
- Polachrome illuminated trainer, 149–150, 150f, 164, 166, 166f, 171
- Polaroid bar reader, 199
- Polaroid target, 17, 22, 23f, 122
- Polaroids
accommodative therapy with, 209–212, 210f, 211t
advantages of, 141
categorization of, 138
disadvantages of, 141
fusional vergence therapy with, 160–176, 161f–163f, 164t–165t, 166f, 167t, 168f–171f, 174f, 175t
instrumentation, 140–141, 140t
recommended procedures for, 164t
types of, 140t
- Positive fusional vergence (PFV)
accommodative excess and, 350
in accommodative therapy, 155
analysis of, 57–59
BAF testing, 58, 237, 311, 327
fused cross-cylinder testing, 60
MEM retinoscopy testing, 58–59, 240–241, 339\$\$
NPC, 58–59
NRA testing, 58, 240, 311, 327
smooth vergence testing, 57
step vergence testing, 57
vergence facility testing of, 57
basic esophoria and, 309, 323
basic exophoria and, 309, 330
in binocular vision therapy, 155
convergence excess and, 282t
convergence insufficiency and, 240–241
divergence excess and, 292, 298
fusional vergence dysfunction and, 312–313
normalization of, 312, 329t, 380
ocular motor dysfunction and, 380
refractive error and, 94, 292
- Positive reinforcement, 144
- Positive relative accommodation (PRA), 49, 50f, 56, 60–62, 73t
discontinuation of, 14
tests, 3, 3t, 14–15, 19t, 42–43
for accommodative insufficiency, 340–341
for CUC, 555
with minus lenses, 319
for NFV, 59–60, 279, 319, 548
- PPT. *See* Pencil push-up treatment
- PRA. *See* Positive relative accommodation
- Prednisolone/sulfacetamide (Blephamide) SOP, 564
- Pre-Lasik monovision trial, 663–664
- Presbyopia
accommodative insufficiency v., 338
convergence insufficiency associated with, 255–257
- Primary care optometry
accommodative disorders assessment, 121–124, 121t, 123t, 124
of binocular vision disorders, 112–120, 113t–114t, 124
common vision problems analyzed in, 124
definition of, 112, 113t–114t
diagnosis, 112–117, 115f, 117f
of eye movement disorders, 112–134, 113t–114t
model for establishment of vision therapy in
fees, 679, 681, 684
home v. in-office therapy, 679–680
individual v. multiple patients per session, 679
insurance coverage for vision therapy, 683–684
office space, 681
payment, 682–684, 691–693
revenue and expenses, 682, 682t
therapists v. optometrists, 678–679
vision therapy schedule, 680–681
nonstrabismic binocular vision disorder assessment, 118–120, 124
treatment modalities, guidelines, and prognosis in, 125–134, 125t, 127t, 129t, 132t
- PRIO instrument, 555, 555f
- Prism, 120
ABI and, 578, 582–584
accommodation-vergence interactions treated with, 467
accommodative dysfunction treated with, 134, 336
accommodative therapy with, 212–218, 213f, 215f, 217f–218f
advantages of, 141
amblyopia treated with, 481
bar, 140t
basic esophoria treated with, 320
basic exophoria treated with, 328
BIM, 167–168, 329
BOP, 168, 320
in case analysis, 57–59, 62
categorization of, 140–141
complications of refractive surgery and, 669
conjugate, 507
convergence excess treated with, 281
convergence insufficiency treated with, 243–244, 582–584
CUC treated with, 550, 559–560
cyclovertical heterophoria treated with
clinical management of vertical heterophoria and, 401t
patient counseling, 415
prescription criteria for, 401t, 402–406, 405f, 407f
prism adaptation, 406–408
diopter, 161
disadvantages of, 141
dissociation evaluation, 393, 395f
divergence excess treated with, 295
for divergence insufficiency, 236–237, 262
dove, 425
effectiveness of, 97–101, 103t, 104, 129, 129t
explanation of proposed treatment using, 677
fixation disparity analysis and, 99, 429–430
flip, 140t, 165, 165t, 176, 404, 405f, 461
fusional vergence dysfunction treated with, 312
fusional vergence therapy with, 176
horizontal, 236, 281, 295
basic esophoria treated with, 320
basic exophoria treated with, 329
description of, 97–100, 103t, 128–130
in fixation disparity analysis, 393, 405–406
latent hyperopia treated with, 407–410
lateral correction design, 439–442, 440f–441f
loose, 140t, 165, 165t, 176, 221
Maddox double, 392, 393f
nystagmus treated with, 506–507
occlusion, 507–508
ocular motility procedures with, 221
plane of vergence influenced by, 152–153, 154f
prescription considerations of, 130
resistance to, 669
Risley, 436
treatment with, 97–101, 103t, 131–132, 132t, 320
TV trainer and, 202
vergence ranges of, 402–404
vertical prism, 100–101, 130–131, 243, 281, 295
adaptation to, 406
basic esophoria treated with, 320
basic exophoria treated with, 329
correction design, 442–443
dissociation, 204
vision therapy and, 101
- PRK. *See* Photorefractive keratectomy
- Progressive addition lenses (PALs), 558, 558f
- Proportional-controller-based negative feedback systems, 618
- Proximal vergence, 456, 467
- Pseudoconvergence insufficiency, 241–242, 257–258, 339, 349
- Pseudomyopia. *See* Accommodative excess
- Psychoeducational testing, for reading dysfunction
achievement testing and, 602
basic components of, 600–602, 601t
cognitive testing and, 601–602
comprehensive history and, 601
emotional or personality testing, 602
importance of, 600
previous, 604t
- Pull-away method, of accommodative amplitude assessment, 45
- Pupil size, 556
- Pursuit dysfunction, 368
functional v. medically significant, 376
pathological causes of, 376, 376t
saccadic v., 376

- Pursuit eye movements, 63, 196, 197f
 activities influenced by, 372–373
 expected values for, 32, 31t
 in fixation stability evaluation, 25t,
 30–31, 31t, 47–48
 medications influencing, 376
 neurologic pathways of, 374
 ocular motor dysfunction and, 376,
 376t, 375t
 slow pursuit gain and, 376, 376t
 testing format for, 25t, 30–31, 31t,
 47–48
- Push-up amplitude test, 19–20, 18t–19t,
 121–122, 121t
- Q**
- Questionnaires. *See* Symptom and quality of
 life questionnaires
- Quoit vectogram, 148–150, 148f, 150f,
 152f, 166f
- R**
- Radial keratotomy (RK), 530
- Random Dot Stereograms, 175, 206, 231
- Random dot stereopsis, in Computer
 Orthoptics VTS3 Liquid Crystal
 System, 174f, 175
- Randot stereotest, 16–18, 16f–17f
- Rate of refractive change
 ametropia progression and, 626–628,
 627f–628f
 in hyperopia, 626, 627f
 lenses influencing, 626
 in myopia, 626, 627f
- Readalyzer, 25t, 26, 29–30, 602
- Reading
 accommodative infacility influencing,
 597–598
 colored filters and, 598–600
 comprehension of, 596t
 convergence excess and, 664
 dynamic, 231
 eye movement and, 368–369, 372–373,
 381–383, 597–598
 glasses and, 341, 598–600
 higher cognitive processes in, 369
 improvement of, 609–612
 learning to read v. reading to learn and,
 595, 596t
 saccades in, 368, 372–373
 signs and symptoms of problems with,
 597t
 visual basis of, 596t
- Reading dysfunction
 comanagement of problems related to,
 594, 613
 definition of, 594
 dyslexia v., 593, 594–595
 psychoeducational testing in diagnosis
 of, 600–602, 601t, 603t
 remediation strategies for, 600
 risk factors for, 605t
 symptoms of, 596t
 therapy for, 609–613
 vision problems' relationship with,
 595–596, 596t–597t
- Recent-onset vertical diplopia, 399
- Red/green bar reader, 199, 200f, 217, 217f
- Red/green glasses, 13, 17, 157, 160, 171,
 209
 in BAF therapy, 217
 penlight used with, 203, 694
- Red/green targets. *See* Anaglyphs
- Red-red rock
 description and setup of, 209–210, 210f
 endpoint of, 210
 equipment needed for, 209
 objectives of, 209
- Refractive amblyopia. *See* Amblyopia
- Refractive correction
 for amblyopia, 470–480
 case study of, 479
 for CUC, 549–550
 for cyclovertical heterophoria, 400–401
 full, 131, 132t, 481–482
 for nystagmus, 504
- Refractive error. *See also* Binocular vision–
 based model, for refractive error
 management
 accommodative dysfunction and, 335
 amblyopia and, 471, 474–475
 aniseikonia and, 519
 basic esophoria and, 318
 basic exophoria and, 326
 convergence excess and, 278
 convergence insufficiency and, 239
 CUC and, 550–551
 determination of, 2, 117–118
 diagnostic testing of, 2, 117–118
 distribution of, 619, 619f
 divergence insufficiency and, 260
 fusional vergence dysfunction and, 310
 guidelines for, 125t
 hypersensitivity to, 578
 low, 94
 NPC and, 326
 nystagmus with, 495
 ocular motor dysfunction and, 371
 PFV and, 94, 292
 significant degrees of, 92–93, 92t, 125,
 125t
 type of, 93
- Refractive modification, 638
- Refractive state (RS)
 anterior chamber depth related to, 620,
 621f
 axial length related to, 620, 621f–622f
 at birth, 616
 changes in, from visually driven
 emmetropization mechanism,
 649, 649t
 corneal curvature related to, 621, 621f
 genetic basis of, 618–619
 lens power unrelated to, 621, 621f
 rates of change of, 626–628, 627f
 refractive error distribution and
 components of, 619, 619f
 suppression influencing, 618
- Refractive surgery, 486. *See also*
 Complications, of refractive
 surgery
 LASIK, 655–660, 662–663
 optometrist's role in, 666–669, 666t
 phakic IOL lens, 656
 popularity of, 655, 672
 surface ablation techniques
 epi-LASIK, 656
 Lasek, 656
 PRK, 656, 661, 669
- Regard, plane of, 152
- Relative accommodation, 462
- Relative distance magnification, 121
- Relative stimulus strength, 157
- Relative vergence, 456, 461
- Remy separator, 140t, 142f. *See also*
 Modified Remy separator
- Response CA/C, 11
- Retinoscopy, 93, 117–118
- book, 372
 cycloplegic, 495
- MEM, 3t, 3, 18, 47, 55, 73t, 121, 121t,
 123t, 128
 for accommodative insufficiency, 339
 accommodative response assessed
 by, 18t, 19t, 23–24, 24f, 121,
 121t, 495, 555, 555f
 accommodative system tested by,
 61, 122
 cards used for, 23, 24f
 issues of, 122
 NFV tested by, 58, 279, 327, 548
 for nystagmus, 497
 PFV tested by, 58–59, 240–241, 339
- Nott, 18
 static, 2
- Retraction, 503t
- Revenue, 682, 682t
- Reverse geometry contact lenses, 638–639,
 648–649
- RGP contact lenses. *See* Rigid gas-permeable
 contact lenses
- Rheostat, 203
- Rigid gas-permeable (RGP) contact lenses,
 504, 637, 648
- Risley prisms, 436
- RK. *See* Radial keratotomy
- Room illumination, 157
- Rotating cylinder cyclovergence therapy,
 424–425
- Rotating pegboard, 225, 225f
- Rotator-type instruments
 automatic rotator, 225, 226f
 description and setup of, 225, 225f–226f
 equipment needed for, 225, 225f–226f
 objectives of, 225
 rotating pegboard, 225, 226f
- RS. *See* Refractive state
- S**
- Saccades, 63, 196
 accuracy disorders of, 375, 375t
 challenges of testing formats for, 26–27
 direct observation, 27, 26t–27t
 in fixation stability evaluation, 25t–27t,
 25–31, 28f–29f
 from gross to fine, 156
 hypometric, 375, 375t
 inappropriate, 375, 375t
 initiation disorders of, 375, 375t
 main sequence of, 372
 neurologic pathways of, 374
 objective eye movement recording,
 29–30, 28f–29f
 peak velocity of, 372
 Pierce test for, 27
 in reading, 382, 372–373
 testing recommendations for, 30, 47,
 56, 63
 velocity disorders of, 374, 375t
 vergence procedures integrated with,
 315, 324, 332
 visual-verbal, 27
- Saccadic dysfunction, 368, 373–374, 374t
 functional v. medically significant, 376
 pathologic causes of, 374–376, 375t
 pursuit v., 376
 vision therapy for, 218–219, 702–703
- Saccadomania, 375
- Scotopic sensitivity syndrome, 598
- Secondary vertical deviations, 419
- Second-degree targets. *See* Flat fusion targets
- Sensitive period, of amblyopia, 473
- Sensory cyclofusion, 391
- Sensory fusion deficiency. *See* Fusional
 vergence dysfunction

- Sensory fusion disruption syndrome, 573, 579, 588–590, 590t
- Sensory motor therapy, 420
- Sensory status assessment, 3t, 4–5
 - general considerations in, 15
 - stereopsis evaluation in, 16–17, 16f–17f
 - suppression evaluation in, 15–16
- Septums
 - advantages of, 141
 - classification of, 140
 - definition of, 141
 - disadvantages of, 141
 - fusional vergence therapy with, 187f–191f, 176–181, 177f–181f
 - instrumentation, 138, 140t, 141, 142f
 - in modified Remy separator, 180–181, 181f
 - types of, 140t, 142f
- Sheard's criterion, 49–50, 98–99, 101
- SIL0 response. *See* Small in, large out response
- Simulated divergence excess, 292–294
- Single Maddox rod, 392, 393f
- Single vision prescriptions, 287
- Sixth nerve palsy, 261–262, 269, 370
- Size constancy, 146
- Slab-off prism, 402, 410
- Sliding vergence. *See* tonic vergence
- Slit lamp evaluation, 498
- Slope, of forced vergence fixation disparity curves, 430f, 430, 437–441, 437f, 438f, 440f–441f
- Slow pursuit gain, 376, 376t
- Small axis power alterations, 530
- Small in, large out (SIL0) response
 - clinical relevance of, 147–148
 - feedback from, 145–148, 147f
 - geometric explanation for, 147, 146f
 - lenses and, 147
 - from patients, 147–148
 - size constancy and, 146
 - SOLI response v., 146
 - in variable tranaglyph procedures, 164, 164t
 - vergence and, 146–148, 157f
- Small out, large in (SOLI) response, 146–147, 164
- Smooth vergence
 - in convergence excess therapy, 312–313
 - in convergence insufficiency therapy, 247
 - testing of, 3–4, 3t, 8t, 11, 40–42, 55, 57
 - amplitude v. facility and, 11
 - of NFV, 59
 - of PFV, 57
 - step vergence v., 11
- Smooth vertical vergence therapy, 422, 423f
- Snellen fractions, 687
- Soft contact lenses, 637
- SOLI response. *See* Small out, large in response
- Space eikonometer
 - accuracy of, 525
 - anisikonia and 525–528, 526f–527f
 - availability of, 525
 - examination difficulties with
 - heterophoria, 527, 527f
 - monocular suppression, 527, 527f
 - image size determination and, 527
 - settings of, 526–527
 - target of, 525–526, 526f, 527f
- Spasm of accommodation, 280, 349, 664
- Spasm of convergence, 280
- Spasm of the near reflex, 349, 353
- Spasmus nutans, 502
- Sphere modification, of forced vergence fixation disparity, 443–444, 443f–446f
- Sports/Action cards, 178f, 177
- Square wave jerk, 375, 375t
- Standard dynamic reading, 231
- Static aniseikonia, 517, 519, 529
- Static retinoscopy, 2
- Step vergence testing, 3–4, 3t, 8t, 41, 55
 - of NFV, 59
 - of PFV, 57
 - smooth vergence v., 11
- Step vergence training. *See* Phasic vergence training
- Step-Jump Vergence program, 174
- Stereograms, 175, 188f, 206
- Stereopsis evaluation, 3t, 4, 16–17, 16f–17f, 164–165, 173, 174f, 498
- Stereoscopes
 - Bernell-O-Scope, 139f, 187f
 - Brewster, 140t, 143
 - accommodative and convergence demands
 - determined with, 188–189
 - convergence demand, 189
 - description and setup of, 187–188, 187f–188f
 - endpoint of, 190
 - equipment needed for, 187
 - objectives of, 186
 - therapy procedures for, 190
 - cheiroscope, 140t, 420
 - diagnostic procedure for, 190, 191f
 - interpretation and, 191–192, 191f
 - Keystone Correct-Eye-Scope, 190, 191f
 - in red-red rock therapy procedure, 210f
 - therapy procedures for, 192, 192f
 - circumstances requiring, 143
 - classification of, 140
 - in cyclovergence therapy, 425, 425f
 - cyclovertical heterophoria treated with, 420
 - in divergence excess vision therapy, 298
 - double mirror, 138, 139f
 - fusional vergence therapy with, 186–194, 187f–188f, 190f–194f
 - haploscope, 140t
 - instrumentation, 138, 139f, 140t, 143
 - stereograms for, 187, 188f
 - tromboning and, 143, 190
 - Wheatstone, 140t, 143
 - Bernell Variable Prismatic Stereoscope, 192f, 193, 193f, 420
 - description and setup of, 193, 193f
 - endpoint of, 194
 - equipment needed for, 193
 - objectives of, 193
 - therapy procedures for, 193, 194f
- Stimulus CA/C, 11
- Strabismus, 460t
 - constant, 16, 17, 319
 - cover test in absence of, 5, 5f, 118
 - decompensation of, as refractive surgery complication, 661
 - intermittent, 319
 - management of, 131
 - Strabismus surgery, 294, 485
 - Stress vertical vergence therapy, 423
- Stroke. *See* Cerebrovascular accident
- “Successful Treatment” determination, 89–92, 90f–91f
- Sulfonamides, 280
- Superimposition targets, 206, 205f–206f, 298, 301, 701–702
- Suppression. *See also* Antisuppression therapy
 - anisometropic amblyopia and, 475–476
 - assessment of
 - nystagmus and, 498
 - other tests for, 16
 - scotoma size in, 15
 - Worth four-dot test for, 15–16
 - cheiroscope tracings and, 192
 - environment preventing, 156–157
 - feedback from, 145
 - isoametropic amblyopia and, 475
 - IXT and, 643
 - lack of symptoms and, 106–107
 - monocular, 527
 - precipitation of, 141
 - RS influenced by, 618
 - space eikonometer and, 527, 527f
 - therapy, amblyopia treated with, 483–485, 485f
 - treatment for, 154, 483–485, 485f, 694
- Supranuclear control centers, 374
- Supraverge test, 56, 62
- Surface ablation techniques, 655–656
- Surgery. *See also* Refractive surgery
 - accommodative dysfunction and, 336
 - for amblyopia, 485–486
 - for basic esophoria, 324
 - for basic exophoria, 333
 - for convergence excess, 285
 - convergence insufficiency and, 251
 - for CUC, 551
 - for cyclovertical heterophoria, 425–426, 425
 - for divergence excess, 276, 294, 303
 - divergence insufficiency and, 266
 - effectiveness of, 107
 - fusional vergence dysfunction and, 309, 316
 - for nystagmus, 513–514
 - for ocular motor dysfunction, 385
 - strabismus, 294, 485
- Sustained processing system, 599
- Sustained retinal blur, 625
- Symbol tracking
 - description and setup of, 222–223, 223f–224f
 - endpoint of, 224
 - equipment needed for, 222
 - objectives of, 222
- Sympathetic paralysis, 280
- Symptom and quality of life questionnaires
 - CISS, 90–92, 90f, 112, 115, 115f
 - COVID-QOL, 91–92, 91f, 239
 - VQS, 116f–117f
- Symptomatic cyclophoria, 400–401
- Synthetic Optics targets, 17, 17f
- Syphilis, 280
- Systematic reviews, 102, 102f
- Systemic toxicity, 482, 636

T

- Television trainer. *See* TV trainer
- Testing. *See* Diagnostic testing
- Thallium, 376t
- Therapists, optometrists v., 678–680
- Third nerve paresis, 370
- Three-component model of vision, 594, 594t
- Three-dot card, 140t, 198t
- Three-step test, 392, 393t, 397
- Tinnitus, 505t
- Tonic vergence, 63, 113t, 155, 318, 326, 455f, 460t, 468
 - in accommodation-vergence interactions, 453–456, 457f
 - proximal, 456, 467–468
- Tonometry, 498
- Track and Read program, 228–231
- Training conditions, natural v. artificial, 140, 157

- Tranaglyphs, 140t, 149, 151f, 423f
 important factors in working with, 167
 nonvariable, 170–171, 171f
 description and setup of, 170, 171f
 equipment needed for, 170
 objectives of, 169–170
 therapy procedures with, 171
 patient instructions for, 698–699
 projection of, 323, 330
 variable
 description and setup of, 161–164, 161f–163f
 equipment needed for, 160
 objectives of, 160
 SILO response and, 164, 164t
 targets of, 161f–162f, 163–164
 therapy procedures using, 165–168, 165t, 166f, 167t
 vectograms v., 168
- Tranquilizers, 376, 376t
- Transient system deficit theory, 599–600
- Transilluminator, 157
- Translation, 529
- Traumatic brain injury (TBI), 571, 574
- Treatment. *See also* specific treatment
 “Successful Treatment” determination, 89–92, 90f–91f
 rewards of, 108
 sequences of, 92
- Tromboning, 143, 190
- True divergence excess, 292–294
- Turville testing, 131, 395, 396f
 for aniseikonia, 522–524, 523f
 tasks based on, 140t
- TV trainer
 in antisuppression therapy, 201–202, 201
 description and setup of, 201–202, 202f
 endpoint of, 202
 equipment needed for, 201
 lenses and, 202
 objectives of, 201
 patient instructions for, 694–695
 prism and, 202
 task difficulty changed with, 202
 working distance of, 202
- Typhoid, 343, 360t
- U**
- Ultraviolet (UV) protection, 558
- Unequal accommodation, 338
- Unilateral cover test, 36
- Unilateral high myopia, 475
- UV protection. *See* Ultraviolet protection
- V**
- Variable prismatic stereoscope. *See* Bernell Variable Prismatic Stereoscope
- Variable tranaglyphs
 description and setup of, 161–165, 161f–163f
 equipment needed for, 160
 objectives of, 160
 SILO response and, 164, 164t
 targets of, 161f–162f, 161–162
 therapy procedures using
 BAF, 166
 phasic, 165–166, 165t, 165f
 vergence at working distance, 167–168, 167t
- Variable vectogram, 168, 168f
- VDT. *See* Video display terminal
- Vectograms, 140t, 423f
 Bernell No. 9, 22, 23f
 for physiologic diplopia, 148–149
 Quoit, 148–150, 148f–150f, 152f, 166f
 tranaglyphs v., 168
 variable, 168, 168f
- Vectographic slide, 2, 54, 131, 395, 396f, 432f
- Velocity disorders, of saccades, 374, 375t
- VEP acuity threshold. *See* Visual evoked potential acuity threshold
- VER. *See* Visually evoked response
- Vergence, 197f. *See also* Fusional vergence
 accommodation interactions with, 344, 354, 361, 430
 analysis approaches to, 451–452, 452f
 binocular vergence, 456–460, 457f–459f, 460t
 clinical testing and, 460–467, 464f–467f
 dual interactive model of, 616–617, 617f
 key concepts of, 452–453, 454f
 lens therapy and, 467
 myopia and, 632
 prism therapy for, 467
 relative fusional vergence and, 461
 tests of, 63, 460
 theoretical, 453, 454f
 tonic vergence, 453, 454f
 accommodative, 461
 adaptation of, 463
 ancillary testing of, 120
 Computer Vergences program, 175, 175t, 206, 231
 multiple choice program, 172–174, 174f
 phasic training for, 155, 165, 165t, 166f, 313, 322, 331t
 plane of, 152–153, 153f–154f, 178, 179f, 182, 182f
 prism ranges of, 402–404
 procedures for
 increasing and decreasing demands of, 167, 167t
 saccades and versions integrated with, 315, 324, 332
 proximal, 456, 467
 relative, 456, 461
 SILO response associated with, 145–147, 147f
 smooth
 in convergence excess therapy, 281–282
 in convergence insufficiency therapy, 247
 testing of, 3, 3t, 8t, 11, 40–42, 55, 57, 59
 step, 3–5, 3t, 8t, 41, 55, 57, 59
 tonic, 63, 113t, 155, 318, 453, 460t
 vertical reserves of, 404
- Vergence facility testing, 3, 3t, 8t, 11–12, 40–42, 119
 amplitude v. facility and, 12
 of NFV, 59
 of PFV, 57–59
 prism, 4f
- Vergence range testing, 119
- Vergence therapy
 endpoint of, 168
 fusional, 154
 anaglyphs, Polaroids, and liquid crystal filters, 160–175, 161f–163f, 164t–165t, 166f, 167t, 168f, 705f, 174f, 175t
 lenses, prisms, and mirrors, 176
 paper, pencil, and miscellaneous tasks, 182–186, 182f–183f, 185f–186f 192–196, 192f–193f, 196f
 septums and apertures, 187f–191f, 176–181, 177f–181f
 stereoscope, 186–195, 187f–188f, 191f–194f
 with voluntary convergence procedures, 194–197, 195f, 197f–198f
- horizontal, 417–420, 418t, 508–509
 phasic, 155
 in accommodative infacility vision training program, 362t
 in basic esophoria vision training program, 324
 in basic exophoria vision training program, 333
 CAVT Random Dot Stereograms and, 175
 in fusional vergence dysfunction vision training program, 312
 with tranaglyphs, 165, 165t, 166f
 procedures for increasing and decreasing demands of, 167, 167t
 vertical, 417–418, 418t, 420–424, 423f
 at working distance, variable tranaglyphs and, 167–168, 167t
- Versions, vergence procedures integrated with, 315, 324, 332
- Vertical associated phoria, 130–131
 fixation disparity curves and, 406, 434
 forced vergence fixation disparity curves and, 435
 vertical fixation disparity analysis of, 395–396, 395f–396f
- Vertical deviations, 389
 ABI and, 582–583
 assessment of, 392–393, 394f–395f
 secondary, 419
 well-compensated, 421
- Vertical diplopia
 recent-onset, 399
 sector occlusion and counseling treatment for, 416
- Vertical fixation disparity analysis
 cyclofixation disparity, 396
 forced vergence disparity curves and, 9, 496, 406
 vertical associated phoria, 395–397, 395f
 VFV analysis and, 62
- Vertical fusion, 62, 95, 391
- Vertical fusional vergence (VFV) analysis, 62, 95
- Vertical heterophoria, 57, 64, 124
 clinical management of, 401t
 Maddox rod evaluation of, 392, 393f
 prism dissociation evaluation of, 392, 393f
- Vertical line counting, 510–511, 511f
- Vertical prism, 100–101, 130–131, 243, 281, 295
 adaptation to, 406
 basic esophoria treated with, 320
 basic exophoria treated with, 329
 correction design, 442–443
 dissociation, 204
- Vertical vergence reserves, 404
- Vertical vergence therapy, 420–423
 case study of, 421–422
 cyclovertical heterophoria treated with, 417–418, 418t
 horizontal vergence therapy v., 417–418, 418t
 jump, 422
 smooth, 422, 423f
 stress, 423
- Vertigo, 505t
- Vestibular nystagmus, 498–499
 central v. peripheral, 502
 characteristics of, 500t

- Vestibular system, in oculomotor movement, 498
- Vestibulo-ocular reflex (VOR), 499
- VFS. *See* Vision Function Scale
- VFV analysis. *See* Vertical fusional vergence analysis
- Video display terminal (VDT), 547, 555
- Visagraph II, 25t, 26, 29–30, 29f, 56, 372, 373f, 602
- Vision deprivation, 471
- Vision disorders. *See also* specific disorder classification system of
- accommodative, 56, 64–65, 65t, 70–71
 - alternative system of, 64, 65t
 - binocular, 56–57, 65–70, 65t, 73t, 103t, 113t–114t, 124, 129t, 292–293
 - case analysis and, 57–59, 64–65, 65t
 - Duane's, 64, 124, 309, 335
 - ocular motor, 57, 63, 65t, 72, 73t
 - vertical, 57, 62, 65t, 70
 - identification of, 62, 65t
 - prevention of, 52, 55
- Vision Function Scale (VFS), 115
- Vision Quality Scale (VQS), 116f–117f
- Vision shaping treatment (VST), 638
- Vision therapy. *See also* specific treatment method
- ABI and
- advice for, 580
 - case study of, 580–581
 - cognitive and perceptual problems, 579
 - excyclotorsion, 580
 - prognosis of, 578–579, 579t, 585t, 590t, 590, 590t
 - sensory fusion disruption syndrome, 580
 - visual field loss, 580
- for accommodative dysfunction, 335–336
- for accommodative excess, 354–360, 354t, 355t–356t
- for accommodative infacility, 361–364, 361t–363t
- for accommodative insufficiency, 343, 344t–346t
- for amblyopia, 485
- for basic esophoria
- indications for, 320
 - objectives of, 321t
 - specific program for, 321–324, 321t–323t
- for basic exophoria, 307–309
- length of, 329
 - objectives of, 329t
 - specific program for, 329–333, 331t–332t
- for children, 103, 148
- for complications of refractive surgery, 670–671
- for convergence excess, 281, 282t, 283t–284t
- for convergence insufficiency, 236–237, 243–251, 670–671
- child requiring, 674–676
 - feedback cues used in, 246t
 - objectives of, 246t
 - office-based, 253–259, 246t, 248t–250t
 - specific program for, 253–259, 246t, 248t–250t
- for CUC, 550, 560–562
- for cyclovertical heterophoria, 417–425, 423f, 425f
- antisuppression, 418
 - horizontal vergence, 417–420, 418t
 - vertical vergence, 417, 418t, 421–423
- design v. implementation of, 158
- for divergence excess, 275–277
- Aperture Rule in, 298, 301f
 - cheirosopic tracings in, 302
 - length of, 296–297
 - objectives of, 297t
 - specific program for, 296–303, 297t, 299t–301t, 301f
 - stereoscopes in, 302
 - strategies for, 295–296
- for divergence insufficiency, 263
- guidelines for, 263
 - indications for, 263
 - objectives of, 263t
 - office-based, 264t–265t
 - specific program for, 263–266, 263t–265t
- effectiveness of, 101–103, 102f, 277, 309
- evaluation for, 682
- for fixation disparity, 432, 444, 446f
 - for fusional vergence dysfunction, 154, 307–308
 - length of, 311
 - objectives of, 313t, 315
 - specific program for, 312–316, 314t–315t
- general principles and guidelines for, 144–152, 147f–152f
- instrumentation
- afterimages, 140, 140t, 143, 230
 - anaglyphs, 140–141, 140t
 - apertures, 140, 139f, 140t, 141
 - basic, 684
 - categorization of, 138–139, 140t
 - computer software, 684
 - electrophysiologic techniques, 140, 143
 - entopic phenomena, 140
 - for forced vergence fixation disparity curves
 - generation, 433–434, 433t
 - lenses, 140–142, 140t
 - for paper, pencil, and miscellaneous tasks, 140, 140t, 141–142, 142f
 - for phoria measurement, 433–434, 434t
 - Polaroids, 140–141, 140t
 - septums, 140, 140t, 141, 142f
 - stereoscopes, 140, 139f, 140t, 143
- for learning-related vision disorders, 606
- lenses prescribed before, 328
 - as medical care, 683
 - misconceptions about, 678
 - necessity of, 103–107
- for nystagmus
- biofeedback, 508–513, 511f–513f
 - categorization of, 508
 - fusion enhancement, 508–509
- for ocular motor dysfunction, 156
- computers in, 377–378
 - effectiveness of, 105, 370–372
 - objectives of, 377t
 - prognosis of, 369–371
 - specific program for, 370–372, 377–378, 378t–380t
 - office policy for, 691–692
- patient and practice management issues in
- case presentation, 674–677, 675t
 - communicating findings, 678
 - insurance coverage, 683–684
 - model for establishment of vision therapy in primary care practice, 678–684, 682t, 691–692
 - planning and monitoring, sphere modification in, 444, 446f
 - prism and, 101
 - procedures, categorization of, 138–144, 139f, 140t, 142f
 - saccadic, 221–222, 702–703
 - time course of, 107
 - variety in, 143
- Visual acuity, 495–497, 496f, 631, 687
- Visual efficiency disorders, 604–605, 606–613, 687–688
- Visual evoked potential (VEP) acuity threshold, 495
- Visual field defects, 375, 375t, 579
- Visual field testing, 498
- Visual growth mechanism, 618
- Visual system, deterioration of, 52, 55
- Visual tracing, 140t
- description and setup of, 224, 224f
 - endpoint of, 225
 - equipment needed for, 224
 - objectives of, 224
 - patient instructions for, 703–704
- Visually driven ocular growth, 625
- Visually evoked response (VER), 477
- Vitamin B1, 280
- Voluntary convergence procedures
- Barrel card, 140t, 197, 198f
 - Brock string, 194–197, 195f–197f
 - fusional vergence therapy with, 193–197, 195f, 197f–198f
- Voluntary nystagmus, 500t, 503
- Von Graefe test
- accommodation control for, 7
 - phoria assessed with, 3, 3t, 7, 8t, 37–39, 63
- Von Noorden amblyopia classification, 472, 472t
- VOR. *See* Vestibulo-ocular reflex
- VQS. *See* Vision Quality Scale
- VST. *See* Vision shaping treatment

W

- Wallenberg syndrome, 375, 375t
- Wechsler intelligence tests, 601
- Welch Allyn retinoscope, 23
- Well-compensated vertical deviations, 421
- Wesson cards, 54, 396f, 432f, 435f
- Wheatstone stereoscopes, 140t, 143
- Bernell Variable Prismatic Stereoscope, 192f, 193, 193f, 420
 - description and setup of, 193, 193f
 - endpoint of, 194
 - equipment needed for, 193
 - objectives of, 193
 - therapy procedures for, 193, 194f
- Whole line dynamic reading, 231
- Woolf card, 432f
- Workstation evaluation, 554, 570
- Worth four-dot test, 3t, 4, 15–16, 44
- Written correspondence
- insurance letters, 683–684, 688–690
 - letters to parents, 686–688, 690–691
 - reports, 102, 102f, 678

Z

- Zone of singular binocular vision, 463