4 EVALUATION OF HETEROPHORIA

A heterophoria only requires treatment if it is causing symptoms or if the binocular status is likely to deteriorate if it is not treated. A heterophoria that meets these conditions is called a *decompensated heterophoria*. If it is decompensated, the evaluation should identify which factors have caused it to become so. In general, it is a heterophoria that has been fully compensated but becomes decompensated that gives rise to symptoms. After identifying the factors that cause the heterophoria to become decompensated, the management will consist of removing or relieving as many of them as possible.

Some heterophoria can be a secondary effect of an active disease or pathological process or recent injury. This type will be called *pathological* heterophoria. It is usually incomitant, i.e. it varies with the direction of gaze. In some directions of gaze it may even break down into a strabismus and double vision occurs. As already explained (Ch. 2), some parts of the routine eye examination are particularly important in the detection of pathological deviations, and these assume more significance in the total evaluation when such a diagnosis is reached. These aspects are summarized in Table 15.1 and the detection of incomitant deviations is dealt with more fully in Chapter 17. At this stage, the emphasis is on comitant (non-pathological) heterophoria and, unless otherwise stated, the text in the next seven chapters assumes that there is no pathological element.

Factors affecting compensation

As most people have some degree of heterophoria, it is obviously important to decide which cases require treatment. That is to say, it is necessary to distinguish the compensated from the decompensated heterophoria. If the heterophoria is compensated, there is no need to evaluate it further. If it is decompensated, further evaluation is required to see which of the classifications describes the appearance presented with a particular patient, which may help to reveal the reason for the decompensation and the appropriate treatment.

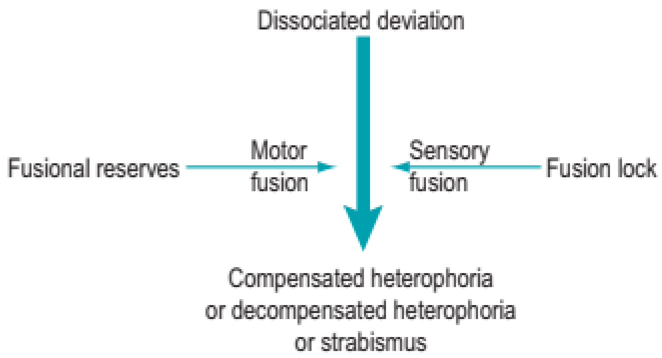

Figure 4.1 Factors influencing whether a person can overcome a dissociated deviation to cause it to be a compensated heterophoria, or whether it becomes decompensated or breaks down to a strabismus.

The factors that influence whether a heterophoria is compensated or not can be broadly classified under three headings: the size of the heterophoria, sensory fusion and motor fusion. These are illustrated schematically in Figure 4.1, which is derived from Figure 1.1. It is important to identify and to remove as many as possible of the decompensating factors. The factors listed in the next section may contribute to heterophoria becoming decompensated, particularly if there is a marked change in them. In the list, factors 1 (a–d), 2 and 3 are motor factors and 1 (e), 4 and 5 are sensory factors.

Stress on the visual system

(1) *Excessive use of vision under adverse circumstances.*

- **(a)** Work held too close to the eyes for long periods. A comfortable working distance depends on the amplitude of accommodation and therefore on the patient's age. As the amplitude decreases during the teenage years, stress on accommodation and convergence can occur if a proper working distance is not adopted. The near distance can also present stress in early presbyopia (Pickwell et al 1987a). Surprisingly, prolonged use of computer display screen equipment, which is typically further out than the usual reading distance, can cause a deterioration in the near point of convergence and near point of accommodation (Gur et al 1994).
- **(b)** A sudden increase in the amount of close work. This can occur with a change in the workplace, for example students nearing examination time or leaving school to start a clerical job.
- **(c)** Increased use of the pursuit reflexes, for example playing or watching ball-games or reading in the unsteady conditions on some public transport.
- **(d)** Tasks that dissociate accommodation and convergence. Several features of virtual reality displays can disrupt the normal relationship between convergence and accommodation (Wann et al 1995) and cause stress on the visual system (Mon-Williams et al 1993) associated with symptoms (Morse & Jiang 1999).

(e) Inappropriate illumination or contrast (Pickwell et al 1987b). Visual conditions in the home or workplace are sometimes inappropriate, involving too little or too much illumination or contrast or glare. Night driving conditions may produce long periods of looking into a dark field with very reduced fusion stimulus at a time when the patient is fatigued. Reduced illumination does not influence the degree of heterophoria (Kromeier et al 2001) but presumably reduces sensory fusion and perhaps also fusional reserves.

(2) *Accommodative anomalies*. Because of the relationship of accommodation and convergence, anomalies of accommodation can put stress on binocular vision. The additional accommodation required by an uncorrected hypermetrope to get clear vision or the high accommodative effort in incipient presbyopia are examples of this. Both of these conditions may show decompensated phoria until the appropriate refractive correction is given.

(3) *Imbalanced and/or low fusional reserves*. Where there is stress on the binocular vision, the fusional reserves are often found to be imbalanced and/or low. It is not known if this is a cause of the stress or the result of it, but the fusional reserves of individuals are known to vary from time to time. This is related to Sheard's and Percival's criteria, described below.

(4) *Refractive error*. Other refractive errors, such as astigmatism and anisometropia (and sometimes myopia), can make fusion more difficult due to image blur (Irving & Robertson 1996), particularly if it is unequal between the two eyes (Wood 1983), and contribute to decompensation of the phoria. However, in normal subjects binocularity is only slightly affected by blur, reduced contrast (Ukwade & Bedell 1993) and induced anisometropia from monovision contact lenses (Evans 2007).

(5) *Visual loss*. A visual impairment involving a portion of the visual field (e.g. in macular degeneration or glaucoma) will reduce the amount of matching binocular field from each eye and hence impair the sensory fusion lock. This will increase the likelihood of a heterophoria becoming decompensated. A distortion in the visual field can interfere with central fusion (Burian 1939) and this might produce symptoms, including diplopia (Steffen et al 1996).

Stress on the wellbeing of the patient

(1) *Poor general health*. A deterioration in the patient's health can result in decompensation of the phoria (Pickwell & Hampshire 1984). This is particularly true if other decompensating factors are also present.

(2) *Worry and anxiety*. It is helpful to know if there are major worries that might contribute to the binocular vision symptoms, even if the problems themselves are not visual. If the situation is temporary, as with a student's pre-examination stress, this may affect the type or the timing of treatment. For example, a student approaching examinations may be given prismatic spectacles to temporarily correct an anomaly that might usually be treated in the first instance with exercises.

(3) *Old age*. This can be important for decompensation of near phoria. Presbyopic patients can respond to eye exercises but frequently require 'top up' exercises (Wick 1977). In some cases, prism relief may be required.

(4) *Emotional and temperamental problems*. Psychological difficulties and personality problems are difficult to assess during a vision examination but they may be relevant factors. The treatment of psychological difficulties lies outside the scope of binocular vision treatment, although it may be necessary to take such difficulties into account. This is a useful reminder that we are not dealing just with eyes but with people.

(5) *Adverse effect of alcohol and pharmacological agents*. Alcohol decreases convergent and divergent fusional reserves (Watten & Lie 1996). Alcohol and some prescribed and abused drugs can cause patients to become relatively esophoric at distance and exophoric at near (Rosenfield 1997). Some drugs reduce the amplitude of accommodation and can therefore affect binocular vision indirectly.

In deciding if heterophoria is compensated, the results of all parts of the eye examination need to be considered, but some sections or tests are particularly important. Sometimes the routine eye examination may also suggest that supplementary tests should be carried out to help in the evaluation. The following parts of the routine or supplementary tests are particularly useful in assessing heterophoria:

(1) Symptoms
(2) Cover test
(3) Refraction
(4) Measurement of the degree of heterophoria
(5) Fusional reserves
(6) Partial dissociation tests
(7) Fixation disparity tests
(8) Suppression tests
(9) Stereoscopic tests
(10) Binocular acuity.

Diagnosis of decompensated heterophoria

Many optometric procedures, including the careful taking of symptoms, have been proposed as useful methods of diagnosing whether a heterophoria is decompensated. These will now be discussed and, at the end of this chapter, some research on which tests are the most useful will be reviewed.

Symptoms

Symptoms will usually be present in decompensated heterophoria (McKeon et al 1997). Less commonly, suppression develops to such an extent that

Table 4.1 Summary of symptoms of decompensated heterophoria

Symptom	*Generic description*
1. Blurred vision 2. Diplopia 3. Distorted vision	Visual perceptual distortions
4. Difficulty with stereopsis 5. Monocular comfort 6. Difficulty changing focus	Binocular factors
7. Headache 8. Aching eyes 9. Sore eyes 10. General irritation	Asthenopic factors

symptoms are not present. However, there is no set of symptoms that is pathognomic of heterophoria and the symptoms that are sometimes associated with decompensated heterophoria can also be caused by other problems. It can, however, be said that, in the absence of symptoms and of suppression, any heterophoria is compensated, at least at that point in time. When symptoms are present, the practitioner must decide if these are due to the heterophoria or to some other cause. It is only by considering the symptoms together with the other findings that the total picture enables the diagnosis of decompensated heterophoria. In general, the symptoms resulting from decompensated heterophoria can be associated with some particular use of the eyes for prolonged periods, and these symptoms are lessened or alleviated by resting the eyes. It follows that, in general, the symptoms will be less in the morning and increase during the day. In heterophoria, they are more frequently associated with near visual tasks.

Decompensated heterophoria can give rise to the symptoms detailed below, which are summarized in Table 4.1. The symptoms can be broadly classified into three categories: visual perceptual distortions (numbered in Table 4.1 and below as 1–3), binocular disturbances (4–6) and asthenopia (7–10).

(1) *Blurred vision*. Uncorrected refractive error may put a stress on the accommodation–convergence relationship, which results in decompensated heterophoria. Conversely, in other cases, where there is no refractive error, high degrees of phoria can induce excessive accommodative effort and blurred vision results. Some patients misinterpret small amounts of diplopia as blur.

(2) *Diplopia*. In heterophoria any diplopia is intermittent and is worse after prolonged use of the eyes for a particular task. The diplopia that accompanies a pathological deviation is usually more sudden in onset and is less often associated with any particular use of the eyes for lengthy periods.

(3) *Distorted vision*. In some cases of decompensated heterophoria (and in binocular instability) the precise binocular alignment may be rather variable. This can be seen during the fixation disparity test: even if the patient does not experience diplopia, there may be a variable fixation disparity with the visual axes showing a variable misalignment of several minutes of arc. This may cause the patient to perceive visual perceptual distortions (Gibson 1947, pp 139–175), such as letters or words moving, flickering, jumping. The patient may see shapes or patterns on the page and may skip or omit words or lines. This condition needs to be differentially diagnosed from Meares–Irlen syndrome (below).

(4) *Stereopsis problems*. Occasionally there are difficulties in depth perception reported by the patient, e.g. in ball games, pouring liquids into receptacles.

(5) *Monocular comfort*. Sometimes a patient notices that vision is more comfortable if one eye is closed or covered. This can also be due to photophobia but also seems to be associated with heterophoria problems. Patients, especially children, may adopt an abnormal head posture when they are reading (e.g. lay their head on the page) so that their nose is acting as an occluder to give monocular vision.

(6) *Difficulty changing focus*. Patients may report that distance vision is blurred immediately following prolonged periods of close work. This can also be a sign of a myopic shift.

(7) *Headache*. Rabbetts (2000, p 178) stated that hyperphoria is associated with occipital headaches and that horizontal heterophorias tend to give frontal headaches. These frontal headaches are said to occur in exophoria during concentrated vision but in esophoria at other times, possibly the day after concentrated work. A survey found that the commonest symptom in children consulting an optometric clinic was headache (8%) and for a quarter of these cases the headache was commonly associated with study or reading (Barnard & Edgar 1996). One study suggests that 10% of an unselected university student population report headaches associated with studying (Porcar & Martinez-Palomera 1997).

(8) *Aching eyes*. The patient says that the eyes hurt after a lot of close work, or that there is pain ‘behind the eyes’. In heterophoria, this is usually a dull pain and is therefore described by the patient as an ache, sometimes saying that the eyes ‘feel tired’. It usually follows a long period of intensive use of the eyes for reading, VDUs, television, cinema, etc.

(9) *Sore eyes*. The patient may describe a feeling of soreness.

(10) *General irritation*. The difficulty in maintaining comfortable single vision may result in the patient reporting a feeling of irritability or of nervous exhaustion.

Meares–Irlen syndrome

Meares–Irlen syndrome was originally called ‘scotopic sensitivity syndrome’ (Evans 2001a) and is also known as *visual stress*. This is believed to be a visual processing anomaly and is particularly prevalent in people with specific reading difficulties (dyslexia). Meares–Irlen syndrome is corrected with individually prescribed coloured filters and the hue and saturation of the required tint varies from one sufferer to another and often needs to be highly specific (Wilkins et al 1994). Patients may be screened for a benefit from colour with coloured overlays (e.g. Wilkins Intuitive Overlays) and, if there is a sustained benefit from overlays, are subsequently tested with the Wilkins Intuitive Colorimeter and precision tinted lenses (Evans 2001a). The condition is characterized by reports of asthenopia and visual perceptual distortions: sufferers typically perceive words appearing to move, shimmer or blur.

In some cases of Meares–Irlen syndrome (Case study 4.1), the situation is further complicated by a heterophoria that may be decompensating (Evans 2005b), or by binocular instability (Ch. 5) (Evans et al 1996a). This can make the differential diagnosis difficult, since it may not be clear whether the unstable visual perception from Meares–Irlen syndrome is causing the binocular vision anomaly or whether the binocular vision anomaly is a primary cause of the symptoms. The diagnostic criteria in Table 5.2 can be helpful in these cases. In some cases symptoms may only be completely alleviated by correction of any ocular motor anomaly in addition to coloured filters (Evans 2001a). A flow chart for the investigation of visual factors for people with (suspected) dyslexia is given in Appendix 4.

Migraine

Nearly 8% of the population suffers from migraine (Bates et al 1993) and a literature review (Harle & Evans 2004) revealed claims that migraine can be triggered by low convergent fusional reserves, decompensated near exophoria and hyperphoria. However, this review noted that the scientific evidence supporting these claims is weak. A recent study found that people with migraine have a slightly higher than usual prevalence of heterophoria, aligning prism and impaired stereoacuity (Harle & Evans 2006). Overall the data in this study and in another (Harle & Evans submitted) indicate that decompensated heterophoria is unlikely to be a cause of migraine in all but exceptional cases. Although correcting decompensated heterophoria did not decrease the prevalence of migraine, it was found to decrease the symptoms of pain and need for analgesia in some patients with migraine (Harle & Evans submitted). Common sense advice is for practitioners to ask patients whether there appears to be any association between migraine, or other headaches, and any particular visual tasks. It often helps if patients keep a diary of their headaches, including activities before the headache starts. If specific visual tasks trigger migraine, then attention should be paid to the refractive and binocular status at the relevant test distance(s).

A double-masked placebo-controlled trial revealed that some patients with migraine experience a visual trigger in the form of lights or patterned stimuli (including lines of text) and that this trigger can be treated with individually prescribed coloured filters in a condition (described as visual stress) that is related to the Meares–Irlen syndrome described above (Wilkins et al 2002). This subgroup of migraine patients is more prone to binocular vision anomalies (Evans et al 2002).

CASE STUDY 4.1 Ref. F4050

BACKGROUND: Boy, aged 8, with specific learning difficulties.

SYMPTOMS: After reading for 20 min: words 'jump around on the page', trouble following the line, and eyestrain. Skips or omits words or lines and light-sensitive. No headaches.

CLINICAL FINDINGS: *Normal:* ocular health, visual acuities, refractive error (low long-sightedness), accommodative function. Large decompensated exophoria at near.

MANAGEMENT: Given eye exercises for convergent fusional reserves.

FOLLOW-UP 2 MONTHS LATER: Exercises done but make eyes hurt and symptoms unchanged. Ocular motor status improved and exophoria now compensated. Tested with coloured overlays and showed consistent response, so issued coloured overlay.

FOLLOW-UP 3 MONTHS LATER FOR TESTING WITH INTUITIVE COLORIMETER: Overlay definitely helps: less 'hurting eyes' and less movement of text. Consistent response to testing with Intuitive Colorimeter and Precision Tints. Precision Tints prescribed.

FOLLOW-UP 9 MONTHS LATER: Precision Tints used voluntarily for reading, writing, etc. No symptoms as long as wears glasses. Refraction, ocular motor tests, ocular health and visual fields all normal. Colorimeter checked and new tint prescription found that further improved perception. This was prescribed.

FOLLOW-UP 24 MONTHS LATER: No symptoms as long as wears tints. Reading and spelling greatly improved. Refraction, ocular motor tests, ocular health, visual fields all normal. Colorimetry checked and no change to tint required. Advised yearly checks.

COMMENT: In this case correction of the ocular motor problem had no effect on symptoms, which originate from Meares–Irlen syndrome. The tint initially changed but now appears to have stabilized.

Cover test

The method of performing the cover test is described in Chapter 2. Here, we are concerned with evaluating the results. In heterophoria, three things should be noted during the cover test:

(1) *Direction of phoria*. The direction of the recovery movement will indicate how the eye was deviated under the cover before its removal, and hence the type of phoria. For distance fixation, most patients show little or no movement. For near fixation, the average patient becomes gradually more exophoric from the mid-20s and has about 6 Δ of *physiological exophoria* by the age of 65 years (Freier & Pickwell 1983). Obvious departures from this usual state may be decompensated, depending on other factors.

(2) *Magnitude of phoria*. The larger the amount of heterophoria present, the more likely it is to be decompensated. However, quite small departures from the normal degree are sometimes decompensated and sometimes high degrees are compensated.

(3) *Quality of recovery*. The speed and ease of recovery are a good guide to the degree of compensation. A quick, smooth recovery is likely to indicate compensated heterophoria, whereas a slow, hesitant or jerking recovery movement usually accompanies decompensation. A schema for grading the quality of cover test recovery movements in heterophoria is given in Table 2.1.

It will be seen that all three of the above aspects of the recovery movement to the cover test need to be considered in deciding if the heterophoria is compensated.

Refraction and visual acuity

Because of the accommodation–convergence relationship, there is an association between esophoria and uncorrected hypermetropia in young patients. When the patient is able to accommodate to compensate for the hypermetropia and thereby achieve clear vision, the extra accommodation brought into play will induce increased convergence. Usually this will show as esophoria and there will be an unusual stress on binocular vision, sometimes resulting in decompensation. This will be exaggerated in near vision when the amount of accommodation required may be a large proportion of the patient's total amplitude. In such cases, the degree of the heterophoria is usually less with the refractive correction, and the clinical signs of decompensation will be less apparent. In hypermetropic cases with exophoria, the correction may make the decompensation worse. This is not always the case: in some patients with low uncorrected hypermetropia correction of the refractive error may sharpen the retinal image, which, through aiding sensory fusion, improves the ability to compensate for an exophoria (Fig. 4.1).

In myopia, the link with exophoria is not so marked but the refractive correction usually assists the compensation. Sometimes the first sign of a refractive change towards myopia is decompensation of an exophoria, often at near.

The effect of the refractive correction on the heterophoria should always be noted. Correction of refractive errors may reduce blur and so improve sensory fusion (Carter 1963) even if these refractive errors are relatively small such as low astigmatism.

Although there are methods of binocular refraction that do not require the use of an occluder, such as the Humphriss immediate contrast method (Humphriss & Woodruff 1962), most refractive methods occlude each eye in turn. When both the monocular refractions have been completed, the occluder is removed and the eyes are free to resume binocular vision. In compensated heterophoria, this is done promptly and the binocular acuity is found to be slightly better than the best monocular acuity (Jenkins et al 1994). The patient will usually report a slight subjective improvement.

However, in decompensated heterophoria, the increase in binocular acuity over monocular is less than usual, unless an appropriate prism is prescribed. This effect occurs at distance (Jenkins et al 1994) and at near (Jenkins et al 1995).

The removal of the occluder may therefore be regarded as an important part of the assessment of compensation. The patient is asked to look at the best line of Snellen letters that was seen monocularly, the occluder is removed and the patient is asked if the line is better or worse. In most cases, it will be better, and the binocular acuity can be recorded. Where there are binocular vision problems, the patient may report that the appearance is not quite so good, or may hesitate and blink a few times before comfortable binocular vision is restored. In some cases diplopia may be reported, and the patient may have to make a convergent movement to look at a near object before binocular vision can be obtained. These reactions are subjective correlates of the objective observation of poor recovery during the cover tests and suggest decompensated heterophoria. Where binocular difficulties are suggested at this stage, particular attention to this aspect is indicated in the rest of the eye examination.

Measurement of the dissociated heterophoria

Indications for measuring the dissociated heterophoria

It has long been recognized that dissociation test results do not relate to symptoms (Percival 1928) except in the case of vertical heterophoria which, if consistently 1 Δ or more, often requires correction (Sheard 1931). High degrees of heterophoria can be compensated and low degrees decompensated (Yekta et al 1987). As early as 1954, Marton suggested that the size of prism to eliminate a fixation disparity might be more closely related to symptoms than the dissociated heterophoria (Yekta et al 1987). Tests that use this fixation disparity principle are described later in this chapter and are much better uses of clinical time than dissociation tests. However, dissociation tests are sometimes useful to monitor changes in the magnitude of a heterophoria over time, and are also valuable for detecting cyclovertical deviations that are difficult to see on cover testing.

In accommodative esophoria, a hypermetropic correction reduces the magnitude of the esophoria. Measurement in these cases may give an indication of the likely effect of wearing the glasses. If the heterophoria is reduced by the glasses, it is likely that it will become compensated by wearing the glasses without any other treatment. However, another test for compensation (e.g. Mallett unit) may give similar indications.

One occasion when it may be useful to carry out a dissociation test is to quantify the relationship between the dissociated heterophoria and the opposing fusional reserves (see below). One limitation of dissociation tests is that, with a large slightly paretic heterophoria, the eye may make a secondary movement of elevation in abducting or adducting. This is not likely to be a problem with a fixation disparity test.

Methods of assessing the dissociated heterophoria

Dissociation tests may be carried out at 6 m and at the reading distance. For example, this can be done by the Maddox rod (multiple groove) method. The Maddox rod consists of a series of very high power cylindrical elements that blur a spot of light into a streak. When placed before one eye, the Maddox rod produces this streak, which cannot be fused with the spot seen with the other eye at the same time. The eyes are therefore dissociated and take up the heterophoria position. The amount of the deviation can be noted by the patient subjectively as the separation of the spot and streak judged by a tangent scale (Thorington test) or by the power of the prism required to restore the streak to the central position where it appears to pass through the spot. Clear Maddox rods may be preferable to coloured ones, which might influence accommodation.

In another technique (von Graefe's), dissociation is achieved by using a prism that is too large to be fused whose axis is orthogonal to the direction of phoria that is to be measured. For example, to measure the horizontal phoria a 10 Δ base up or down would be placed before one eye, which would cause the object of regard to become vertically diplopic. Horizontal prisms would then be introduced and varied until the two diplopic images were vertically aligned; the magnitude of the horizontal prism to achieve this would equal the horizontal phoria.

For near vision, the same sorts of method may be used, or the phoria measurement may be made with a Maddox wing test. This employs a number of septa to dissociate one part of the field from that seen by the other eye. The measurement is read by the patient where an arrow seen by one eye points to a tangent scale seen by the other. A disadvantage of the Maddox wing test is the fixed distance that the test uses. More stable results are obtained if a smaller than usual print size is used (Pointer 2005).

When the heterophoria is measured it is not just the degree of phoria that needs to be assessed, but also the stability of the phoria should be noted (Ch. 5). For example, in the Maddox wing test the amplitude of movement can be recorded in addition to the median position of the arrow (e.g. recorded as 4 Δ XOP ± 2 Δ).

Most subjective methods of measuring heterophoria have limitations that make them unreliable in some patients. The degree and duration of dissociation and the stimulus to accommodation may vary, so that different techniques produce different results (Schroeder et al 1996). The 95% confidence limits of most tests is about 2–5 Δ (Schroeder et al 1996). A comparison of the interexaminer repeatability of dissociation tests (Rainey et al 1998) found that the Thorington test was the most reliable, with 98% confidence limits of ± 2.3 Δ and compared well with the reliability of the cover test (98% limits ± 3.3 Δ). Less repeatable results are obtained with a refractor head (phoropter) than with a trial frame (Casillas & Rosenfield 2006).

The measurement obtained with these methods should be taken, at best, only as another factor in helping to evaluate the heterophoria. Although dissociation tests are time-honoured procedures, it is doubtful if they are the best way of spending time in a routine eye examination.

Fusional reserves

The fusional reserves represent the amount of vergence that can be induced before fusion is compromised and blurred or double vision occurs. Fusional reserves are commonly measured with rotary or variable prism devices or, most commonly, with a prism bar (Fig. 4.2). The patient is asked to look at a target (see below) and the prism power is introduced and slowly increased until the patient reports that the print is blurring or doubling. The prism is then reduced until clear single vision is recovered. The prism power at which these occur is noted and recorded as the fusional reserve to 'blur point' (the relative convergence or divergence), to break point and to recovery point. This may be carried out with prism base-in (divergent reserves), with prism base-out (convergent reserves) or with vertical prism (vertical fusional reserves). Measurements are taken for distance and for near vision. In

Figure 4.2 Fusional reserves measured with a prism bar. The child is viewing a small detailed target at his usual reading distance. He has been instructed to report when the target goes blurred or double ('say when there are two pictures or two cards'). Base-out prisms are being introduced to measure the convergent fusional reserve.

young children and unreliable patients, the break and recovery points can often be checked by observing the eye movements.

Testing details

The testing of fusional reserves is strongly influenced by factors such as patient instructions, target design (Stein et al 1988) and speed of adjustment (Fowler et al 1988). Yet there seems to have been very little research on the test parameters that are most appropriate and very few text books discuss these factors.

Fowler et al (1988) recommended a rate of adjustment of 0.5 Δ/s for subjects with reading difficulties. Griffin & Grisham (1995, p 47) recommended 4 Δ/s, although they did not cite any published work. Ciuffreda & Tannen (1995, p 225) recommended 'slowly' for horizontal and 'very slowly' for vertical measurements.

Current models suggest that there are two components of vergence control: a *fast component* and a *slow component* (Schor 1979, Ciuffreda & Tannen 1995, pp 144–146). The fast component rapidly adjusts to changes in the stimulus and feeds into the slow component, which gradually adapts to the new situation. For example, if a 5 Δ base-out prism is held before one eye while a person views a target, most people will make a rapid vergence movement (fast component) to overcome the prism and then, after perhaps 10 s, manifest prism adaptation (slow component) so that their heterophoria adapts to the prism and returns to its normal value. This model explains the importance of the speed of adjustment during fusional reserve testing (Sethi & North 1987). If the prism is changed rapidly, then the test will primarily assess the fast component of vergence; if adjusted slowly, then the influence of the slow component is likely to predominate. Schor (1979) suggested that slow vergence adaptation takes over from the fast component after about 7 s, although there will be a gradual changing of predominance.

In the absence of research on the optimal rate of testing to detect symptomatic patients, it seems sensible to attempt to invoke significant degrees of fast and slow fusional vergence during testing. The fast component will respond to rapidly changing stimuli, faster than 1 Δ/s (Ciuffreda & Tannen 1995, p 147). The rate of adjustment should not be too much faster than this or the test may be over before the slow component has had time to adapt. Therefore, it is suggested that the test rate should be between 1 and 2 Δ/s.

Vergence adaptation will also have an impact on the order of testing, since the reserve that is measured second will be influenced by the act of vergence during the measurement of the first reserve (Rosenfield et al 1995). These authors made the sensible suggestion that it is better to measure the fusional reserve that opposes the heterophoria first. It would also seem sensible to allow 2–3 min between the measurement of opposing reserves.

There is a lack of research on the target design that is most appropriate to detect symptomatic patients. Small targets have been advocated for patients with reading difficulties (Eames 1934, Stein et al 1988), and a fairly small target helps the patient to identify blur and diplopia. The target should include detail to induce accommodation but should be resolvable by the eye with worst acuity. The author uses a row of four letters equivalent to 6/9 at the test distance, or a small detailed picture. If the worst eye cannot resolve these then a vertical black line is used, of a width that makes it readily resolvable by each eye.

One reason why fusional reserve test results can be quite variable is the influence of 'mental effort'. If patients try hard to fuse they do much better than if they just 'gaze lazily' at the target. Hence, verbal instructions to the patient are crucial, but have not been standardized. The purpose of the test is to detect the fusional reserve that the patient can comfortably use to overcome their heterophoria. So, it would not seem relevant to ask the patient to uncomfortably force their vergence. The wording that I have found most useful is to ask the patient to 'look at the target normally but continue to look at it throughout the test'. Some patients ask if they should 'really force the eyes' and are told to 'just look at the target normally'.

Terminology

There are many synonyms that have been used for fusional reserves, and some of these are listed in Table 4.2. No term is perfect, and Table 4.2 gives comments on alternative nomenclature. The phrase *fusional reserves* has been used in this book because it is felt to be a clear and commonly used term.

Table 4.2 Synonyms of the term 'fusional reserves' – reasons are given why each term is felt to be less appropriate than 'fusional reserves'

Term	*Criticism*
Fusional amplitude	Amplitudes are sometimes used to refer to the difference between positive and negative break or blur points, and at other times to refer to the difference between the phoria position and a fusional reserve. In this book, *fusional amplitude* describes the amplitude between corresponding convergent and divergent reserves
Fusional limits	In most patients, blur and break points do not represent a limit of everyday fusion so much as an amount of fusion that is 'held in reserve', so *reserve* may be more appropriate than *limit*
Relative vergences	Sometimes used to refer to the blur point only
Vergence reserves	Sensory fusion can be maintained for some 2° of disconjugate image movement, without any change in vergence angle (Ch. 12)
Prism vergences	The measurement can be made without varying the prism (e.g. with a synoptophore)
Binocular ductions	This term no longer seems to be in common use

Evaluation of results

A number of methods have been suggested for the evaluation of fusional reserves and these can be broadly classified into intersubject and intrasubject. Intersubject techniques are based on a comparison of the results with normative values. Fusional reserve data from a normal population are given in Appendix 10. Norms for monocular hand-held rotary prisms were given by Wesson & Amos (1985), who found that ocular dominance did not significantly influence the result. The small range of vertical fusional reserves probably explains why the visual system is so insensitive to vertical prismatic effect, which can be induced from incorrectly centred spectacle lenses.

Intrasubject methods compare an individual's fusional reserves with some other measure of that person's binocular function. An early intrasubject technique was that of Percival (1928), who proposed that, for comfort, the working fixation point should lie in the middle third of the total fusional amplitude obtained by adding the divergent to the convergent blur points. That is to say, the opposing fusional reserves should be balanced within the limits that one should not be less than half the other. It should be noted that Percival's criterion does not take account of the phoria. In contrast, Sheard (1930) related the heterophoria to its opposing blur point. Sheard's criterion is often stated thus: the opposing fusional reserve to the blur point should be at least twice the degree of the phoria. In fact, Sheard (1930, 1931) gave several possible criteria based on this principle, with the required amount of opposing reserve ranging from two to four times the phoria. Research evaluating these criteria is discussed at the end of this chapter. Percival's criterion seems to be appropriate for near vision only, since Appendix 10 shows that Percival's middle third rule does not apply to normal values for distance vision.

The recovery reading should be within 4–6 Δ of the break reading. Worse recovery than this can be a sign of decompensated heterophoria (Rowe 2004).

It should also be noted that the divergent reserve for distance is very small in comparison with other values, and that there is seldom any blur when measuring the divergent fusional reserve for distance vision. Perhaps the most significant aspect of this particular measurement is when it becomes excessively large, e.g. over 9 Δ, to break. This seems to indicate divergence excess (Ch. 8).

Vergence facility (prism flippers)

Fusional reserves measure the maximum vergence that can be exerted at a given distance. Prism flippers (see Fig. 2.5) are used to assess the vergence facility, or rate of change of vergence. Because the ability to converge is usually greater than the ability to diverge, the base-out prism is usually three or four times the base-in prism. The best flipper power to discriminate between symptomatic and asymptomatic subjects at near is 3 Δ base-in/12 Δ base-out (1.5 Δ in/6 Δ out each eye) and norms, based on 1 SD below the mean of an asymptomatic control group, are 12 cpm at distance and 15 cpm at near (Gall et al 1998a). It appears that the target does not need to include a suppression check, so 6/9 equivalent letters can be used with the lenses flipped when the target is clear and single (Gall et al 1998b). Test results appear to be very variable in presbyopes (Pellizzer & Siderov 1998).

Partial dissociation tests

Methods for measuring the degree of heterophoria require complete dissociation of the two eyes, e.g. the Maddox rod or the wing test. Another approach is to dissociate only part of the visual field by placing an impediment of a controlled extent in the way of binocular vision and to see what disturbance this causes. These methods leave part of the visual field common to both eyes, which provides a stimulus to fusion. The term used to describe this is *fusion lock*: it may be the central fixation area or it can be a peripheral fusion lock. Tests have been used in the past which provide a variable amount of dissociation, so that the amount which just causes a breakdown in binocular vision can be measured, but these tests are no longer in widespread use.

The dissociation is achieved by a septum (e.g. Turville infinity balance test), by a method of cross-polarization or by coloured filters. One approach combines a septum and polarization and has been called *parallel testing infinity balance* (Shapiro 1995, 1998). It is claimed that this can assess horizontal, vertical and cyclo deviations, although there do not appear to have been any controlled studies to date.

The principle underlying partial dissociation tests is that, owing to the slight degree of dissociation, in decompensated heterophoria a misalignment of the targets becomes apparent. However, these methods seem to have been largely replaced with fixation disparity approaches, which more closely replicate the conditions of everyday viewing and which are described below.

Fixation disparity tests

In normal binocular vision, the fovea of one eye corresponds with a small area centred on the fovea of the other eye: *Panum's area*. Similarly every other point on the retina of one eye corresponds with a small area in the other eye. This point-to-area correspondence means that if a deviation of one eye starts to occur, no diplopia will be seen until the eye has deviated enough to move the image out of Panum's area. Panum's areas are small and horizontally oval. Measurements of their size vary depending on the retinal eccentricity and on the spatial and temporal properties of the test stimulus; they should be thought of as a phenomenon of cortical processing rather than an entity of fixed size (Reading 1988, p 229).

Panum's areas allow the eyes to be deviated by a very small amount before any diplopia is noticed. This very small deviation from fixation without diplopia is called *fixation disparity*. It is very likely to occur when binocular vision is under stress; that is, in decompensated heterophoria (Charnwood 1950). Tests which detect fixation disparity are therefore very useful in assessing decompensation (Yekta & Pickwell 1986). The deviation can occur in one eye or in both eyes but because the magnitude is so small it cannot be seen with the cover test. Although fixation disparity has been detected objectively with special ophthalmoscopic methods (Pickwell & Stockley 1960), all clinical tests are subjective. Various instruments are available that can record eye movements, often by reflecting infra-red radiation from the limbus, but clinical versions of these instruments are unlikely to possess the accuracy required for reliably detecting fixation disparity.

The Mallett fixation disparity test

The Mallett fixation disparity test is a test designed to detect the fixation disparity that is most likely to occur when there is decompensated heterophoria. Apparatus is designed for use at distance (Mallett 1966) and also for near vision (Mallett 1964). There is a central fixation target, the word **OXO**, seen with both eyes, and two monocular markers (Nonius strips) in line with the **X**, one seen with each eye (Fig. 4.3). Dissociation of the monocular marks is obtained by cross-polarized filters. In fixation disparity, the images will be displaced slightly on the retina. Having no corresponding image in the same place on the other retina, the monocular markers will be given a visual direction associated with the retinal area

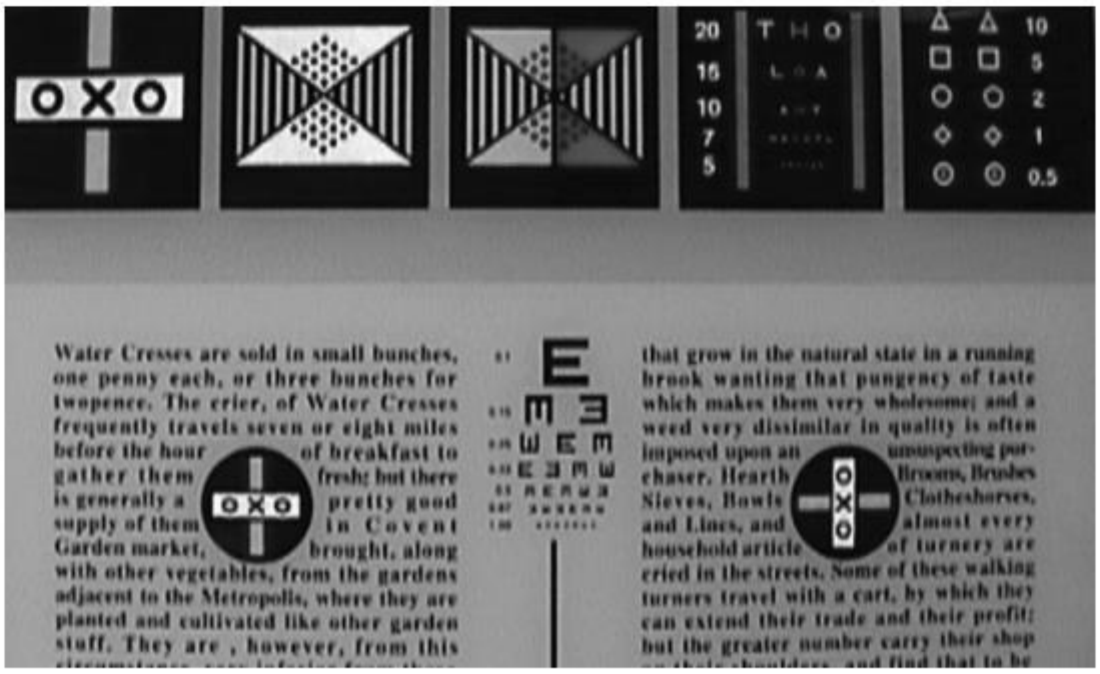

Figure 4.3 Mallett near vision unit. The tests, starting at the top left and working clockwise, are a 'large **OXO** test' for investigating sensory status in strabismus (Ch. 14); cross cylinder and balance chart; duochrome (bichromatic) test; quantitative test of foveal suppression; stereoacuity test; vertical fixation disparity test; and horizontal fixation disparity test. The fixation disparity tests are embedded in text to more closely simulate normal viewing conditions.

stimulated, while the binocular image **OXO** will be seen centrally. The monocular markers may therefore appear to the patient to be displaced from their alignment with the **X**. Throughout the test, the patient should be instructed to keep looking at the **X**. As well as the target with the vertical Nonius strips to detect horizontal fixation disparity, the unit has a similar target rotated through 90° to detect vertical fixation disparity.

A cyclophoria is indicated by the tilting of a Nonius strip. If this occurs in the presence of high astigmatism at an oblique axis, the test should be repeated with the target rotated so that the strips are at right angles to their original orientation. An opposite tilt confirms that the effect is due to astigmatic distortion, while a tilt in the same direction confirms that it is due to cyclophoria (Rabbetts 2000, p 183).

The Mallett units do not measure the degree of the fixation disparity, i.e. the amount by which the eye is actually deviated. This can, however, be estimated by the degree of the apparent misalignment compared with the letters **OXO**. What can be measured is the degree of prism relief required to neutralize the fixation disparity and restore the monocular markers to alignment with the **X**. This has been called the *associated heterophoria*, to distinguish it from the dissociated phoria which is revealed by methods which give complete dissociation such as the cover test, Maddox rod, etc. However, since the term heterophoria implies dissociation, the term associated heterophoria is in fact a contradiction. Therefore, the International Standards Organization (1995) has proposed replacing this term with *aligning prism*, and this term is used throughout this book. The angle of the actual fixation disparity is correlated with the magnitude of the aligning prism (Pickwell 1984a).

Occasionally, patients are encountered who have a *paradoxical fixation disparity*, typically eso-slip in exophoria. This may represent an overcompensation and can sometimes require base-in prism to remove the eso-slip, or convergence exercises. Other tests of compensation are required in these cases, as summarized at the end of this chapter.

There are a few people who, without polarization, perceive a misalignment of the two Nonius strips. This may be a true *alignment error*, which some people experience on Vernier tasks (Tomlinson 1969), or indicate an unreliable patient. If there is a genuine alignment error, then the position of the strips with the polarized filters in place should be compared to their position without the filters (Jaschinski et al 1999).

Mallett (1988a) stated that the aligning prism represents the extent of the *uncompensated* part of the heterophoria. Jenkins et al (1989) found that an aligning prism of 1 Δ or more in pre-presbyopes and 2 Δ or more in presbyopes was likely to be associated with symptoms. Fixation disparity, however, increases under the stress of working in inadequate illumination (Pickwell et al 1987b), working at too close a reading distance (Pickwell et al 1987a) and at the end of a day's close work (Yekta et al 1987). As it may be either physiological or the result of binocular stress, the presence of fixation disparity suggests decompensation of the heterophoria, which needs to be confirmed by the other methods discussed in this chapter.

The Mallett fixation disparity tests provide a considerable amount of information and, as with many subjective tests, the precise instructions given to the patient are very important. A suggested procedure, with appropriate patient questions and resultant diagnoses, is given in Figure 4.4, and research evaluating this is described below. This diagram applies to horizontal testing but a similar procedure can be used for vertical testing. Since an aligning prism of 1 Δ is abnormal in pre-presbyopes (Jenkins et al 1989), it is probably desirable to use smaller step sizes than this. So, at least with low prism powers, it is best to change the prism in 0.5 Δ steps.

In some cases, it is preferable to prescribe spherical lenses rather than prism relief. For example, in the case of an esophoric previously uncorrected hypermetrope the correction for the hypermetropia would be given. Sometimes the spherical correction can be modified (e.g. over-minused or under-plussed) to correct a decompensated heterophoria (Ch. 6). With the Mallett unit, the effect of spherical lenses can be investigated to determine the *aligning sphere*: the minimum spherical lens power with which the monocular markers are aligned.

A new version of the Mallett fixation disparity test uses one target with four Nonius strips (two horizontal and two vertical) to measure the horizontal and vertical aligning prism with the same target. Mallett & Radnan-Skibin (1994) showed that the results of this *dual fixation disparity test* are equivalent to those of the traditional unit. There have been attempts to copy the Mallett unit, one of which replaced the textual fusion lock with a red LED. It seems unlikely that such an instrument would give the same result as the genuine Mallett unit.

If one of the Nonius strips temporarily or constantly disappears, this does not necessarily indicate suppression. One eye's sight may be blocked by the trial frame, or this may be owing to retinal rivalry. If the patient is asked to blink several times, the line may reappear. If there is a suppression area, it may only be on one side of the fovea. Reversing the polarizing visor will interchange the Nonius strips and may prevent the strip being suppressed. The Mallett near unit also includes tests for quantifying suppression in the foveal area, near acuity and stereoscopic vision. These are important in assessing the decompensation (Mallett 1979a), and are discussed elsewhere in this chapter. The Mallett units are also very useful in prescribing prism and other modifications to the spectacle prescription (Ch. 6). These units have been designed and modified in the light of clinical experience and experimental findings and they provide very useful methods of assessing the compensation.

Other fixation disparity tests

Brownlee & Goss (1988) reviewed various fixation disparity tests and one that is popular in North America is the Sheedy Disparometer (Fig. 4.5). This differs from the Mallett unit in that there is no central binocular lock, just a parafoveal fusion lock that is raised in front of the plane of the Nonius markers (Jaschinski 2001). The result of using only a peripheral lock is that the degree of fixation disparities obtained will be greater and

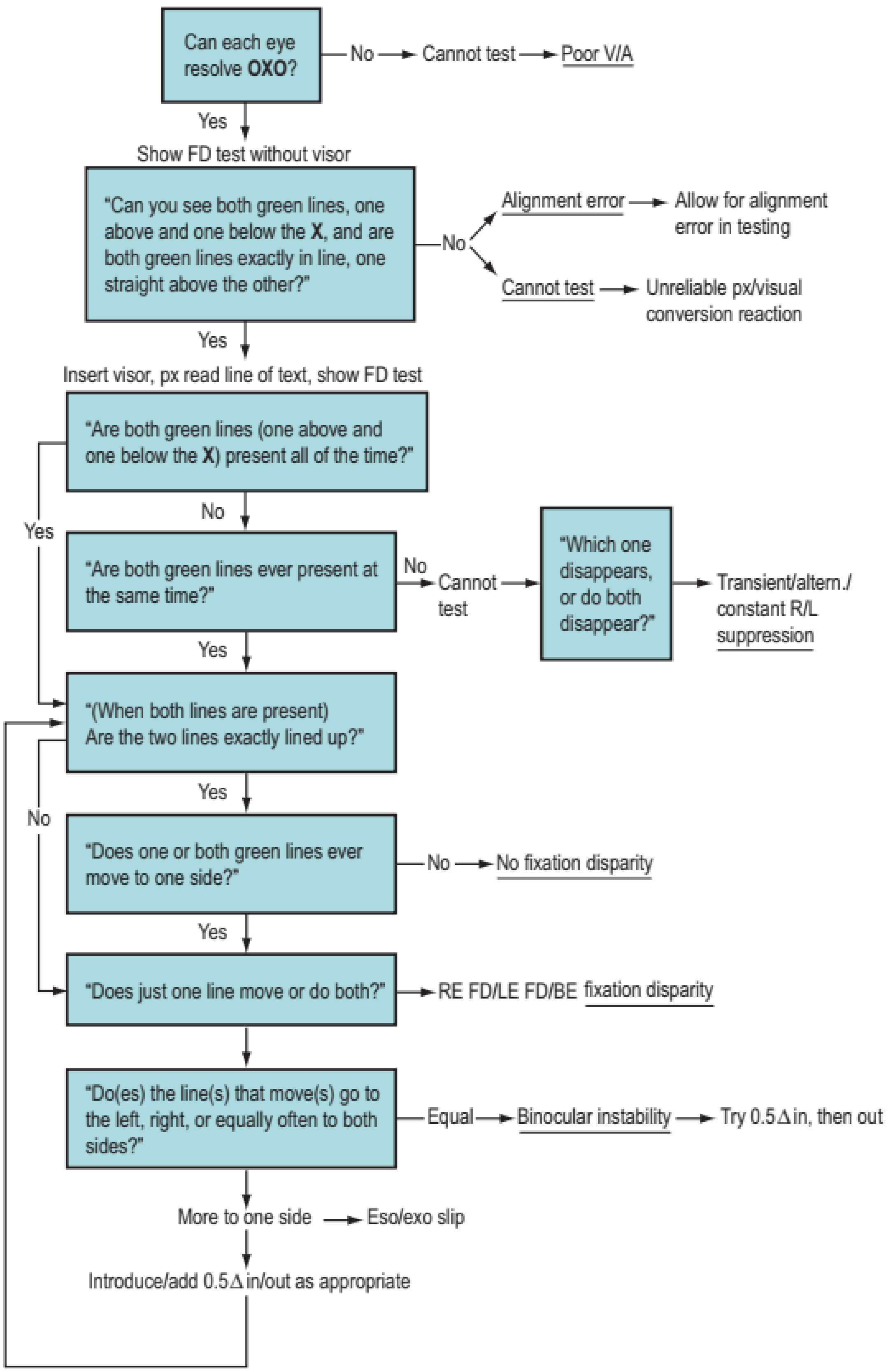

Figure 4.4 Flow chart illustrating the procedure, questions and diagnoses applying to the Mallett Fixation Disparity Unit. It should be stressed to patients, before and during testing, that they should keep looking at the central **X**. The chart applies to horizontal readings, although slight rephrasing of the questions allows it to be used for vertical readings. The actual questions to be asked are in quotation marks and the appropriate diagnoses are underlined. px, patient.

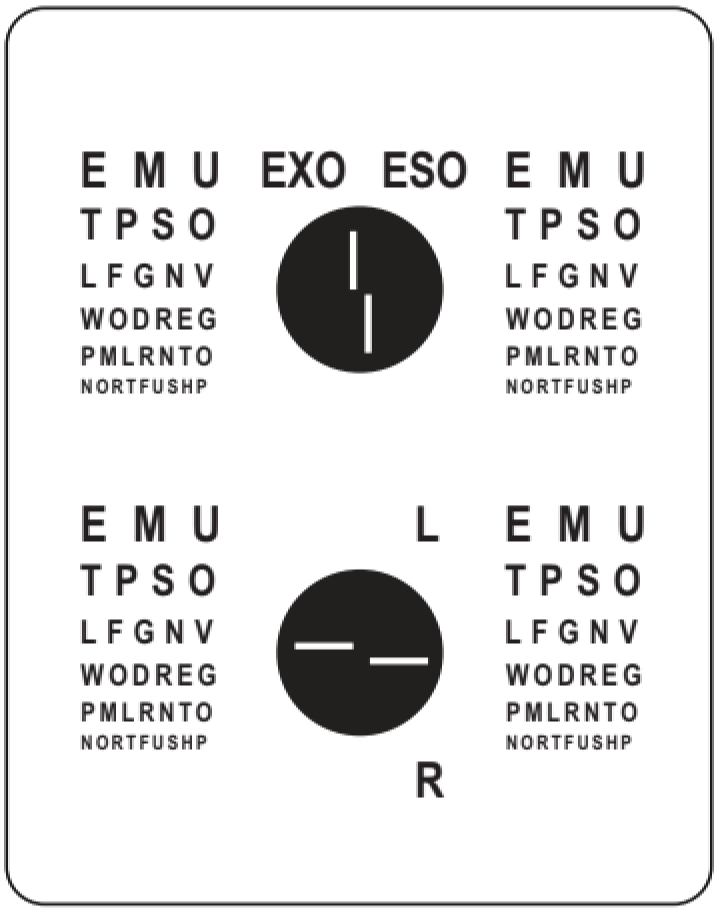

Figure 4.5 The Sheedy Disparometer – an example of a disparity test that has no central fixation lock. This apparatus allows the measurement of the actual disparity as well as the aligning prism.

more variable (Ukwade 2000) because Panum's areas are larger in the periphery. In the patient's everyday vision, a central fixation lock is almost always present and clinical assessment should explore whether the patient's heterophoria is compensated under normal circumstances. The importance of a good central and peripheral fusion lock is discussed further on p 81.

In some cases there will be foveal suppression, and in these patients the lock will be provided by the parafoveal regions and fixation disparity will be larger; hence the importance of knowing if there is suppression. Reading (1992) recommended that clinical tests should allow the monocular components of the fixation disparity to be determined: this is not possible with the Sheedy Disparometer.

All methods of detecting or measuring fixation disparity involve slightly abnormal circumstances that do not perfectly coincide with everyday vision. It is therefore important that immediately before investigating disparity the patient should undertake a few moments of binocular vision, such as reading a line of letters binocularly for distance or a few lines of print for near.

The Zeiss Polatest also provides a range of targets designed to analyse the compensation of the heterophoria. These include acuity and stereoscopic tests, and fixation disparity is detected and the aligning prism measured using more peripheral areas, so that the fixation disparity is greater than with tests using parafoveal locks (Brautaset & Jennings 2001). Both the distance and near Polatests, however, incorporate a very full range of targets, and the designers claim that this allows a greater degree of analysis of binocular vision (Haase 1962, Pickwell 1977a, 1979a). Nonetheless, it has been demonstrated that a fixation disparity that is detected with one of the key Polatest subtests (Zeigertest) does not indicate a fixation disparity under natural viewing conditions (Gerling et al 1998).

Advocates of the Polatest system recommend the prismatic full correction of distance heterophoria (Goersch 1979, Cagnolati 1991), which has been associated with a reduction in symptoms (Lie & Opheim 1985) and an improvement in high spatial frequency contrast sensitivity (Methling & Jaschinski 1996). However, the Polatest method may change a heterophoria into a strabismus requiring surgery (Lie & Opheim 1990) and has been criticized for a lack of supporting evidence (Brautaset & Jennings 2001) and as leading 'to excessive amount of prisms and unnecessary eye muscle surgery' (Lang 1994).

Further analysis of fixation disparity results

Since the degree of fixation disparity can be changed by prisms it is possible, with an instrument like the Sheedy Disparometer, to plot the degree of fixation disparity against the power of the prism (Ogle 1950). Fixation disparity (in minutes of arc) is plotted vertically (y-axis) against the prism power (in prism dioptres) horizontally (x-axis). Several types of curve have been found, of which type I is the most frequent and is illustrated in Figure 4.6A. It will be noticed that the middle part of this typical sigma-shaped curve has a flatter slope; fixation disparity changes less over the range of lower power prisms but with the higher powers of prism it rises steeply. Eventually, diplopia would occur at the limit of the fusional reserves.

It is suggested that, if the patient's normal fixation lies in the flatter part of the curve, it is likely that the heterophoria will be compensated (Sheedy & Saladin 1978). This is the case in Figure 4.6A, where a small amount of esophoric fixation disparity is present: where the curve cuts the y-axis. The aligning prism is also small: where the curve cuts the x-axis. In Figure 4.6B, the curve is placed further towards the right-hand (base-out) side of the figure. This illustrates a case of decompensated esophoria. The fixation disparity and the aligning prism is higher and the base-in prism part of the curve is closer to the y-axis. This means that the base-in fusional reserve must be less and the base-out relatively greater, which is to say that the fusional reserves are unbalanced. Figure 4.6C shows a similar plot, but for exophoria.

If a relieving prism were to be prescribed, it would bring the patient's fixation into the flatter part of the curve. For example, in the case illustrated in Figure 4.6C, for exophoria, 3 Δ base-in vergence would mean that the patient would be operating from the position of the dotted line rather than the actual y-axis. Here, the fixation disparity and aligning prism are less.

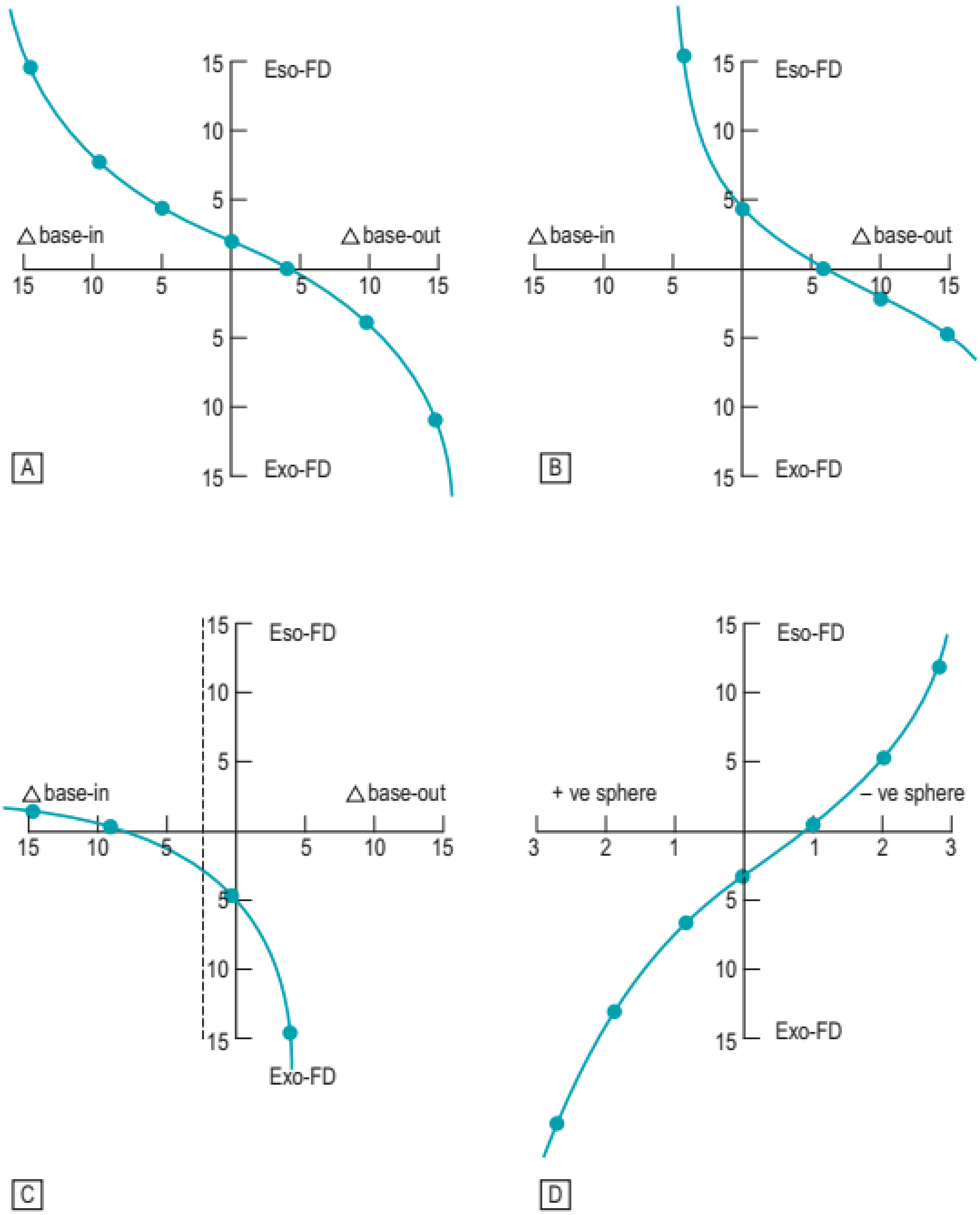

Figure 4.6 Fixation disparity curves: fixation disparity is plotted vertically in minutes of arc and, in the first three curves, the prism power before the eyes in prism dioptres is plotted horizontally. (A) Type I, the most usual curve. (B) Type II, curve in esophoria. (C) Type III, curve in exophoria. (D) Fixation disparity plotted against spherical lens power before both eyes (dioptres) for near vision. See also text.

Fixation disparity can also be changed by using positive or negative spheres to bring about changes in accommodation. This occurs because of the accommodation–convergence relationship. Figure 4.6D shows an example of plotting the changes in fixation disparity (y-axis) against the changes in spherical lens power.

One problem with the measurement of fixation disparity curves is that the variability of fixation disparity measures increases with larger fixation disparities (Cooper et al 1981). Wildsoet & Cameron (1985) showed that attempts by clinicians to classify fixation disparity curves into the different types were very unreliable and the Wesson Fixation Disparity Card produces different results from the Sheedy Disparometer (Goss & Patel 1995). The Wesson and Saladin Fixation Disparity Cards have also been shown to produce different results (Ngan et al 2005). Yekta et al (1989) found that the central slope of the forced vergence disparity curve was not significantly associated with symptoms but the aligning prism (as measured with the Mallett unit) was useful in detecting symptomatic binocular problems. This is probably why the fixation disparity curve is not commonly plotted in the UK, where the Mallett unit is usually used.

Is fixation disparity normal or abnormal?

There seem to be two schools of thought regarding fixation disparity. One, exemplified by Mallett (1988a), is supported by the findings that the cortical response is significantly greater when monocular receptive fields are superimposed very precisely (Suter et al 1993) and stereoacuity decreases as fixation disparity increases (Cole & Boisvert 1974, Ukwade et al 2003). It is therefore argued that any measurable fixation disparity is undesirable, is a sign of stress and of decompensated heterophoria, and should be corrected with changes to the workplace, spheres or prisms. The other viewpoint (Saladin 1995) is based on a model of the vergence system, which assumes that a small amount of fixation disparity may be physiological and could represent an error in the eyes' alignment, providing feedback to help control vergence (Schor 1979). There is clinical evidence to support both arguments: researchers in North America typically find that many asymptomatic subjects have a fixation disparity (Sheedy & Saladin 1978), yet similar studies in the UK find that a fixation disparity is uncommon in asymptomatic subjects (Jenkins et al 1989).

This controversy can probably be resolved by considering the degree of fusional lock that is present in different fixation disparity tests. Most research in the USA seems to have used the Sheedy Disparometer (Fig. 4.5), which does not have a central fusional lock. In contrast, research in the UK tends to use the Mallett unit, which does have a good foveal fusion lock and finds values of fixation disparity and aligning prism that are about half the typical values with the Sheedy Disparometer (Pickwell 1984a). For example, about a quarter of asymptomatic subjects with normal binocular vision demonstrate a vertical fixation disparity on the Sheedy Disparometer (Luu et al 2000). If a central fusional lock is added to the Sheedy Disparometer this has a significant effect on all fixation disparity parameters and causes a stabilization of the Nonius strips (Wildsoet & Cameron 1985), which agrees with objective data on the effect of a central fusional lock on fixation disparity (Pickwell & Stockley 1960, Howard et al 2000). Indeed, the presence of a foveal fusion lock makes subjective fixation disparity not only smaller (Ogle et al 1949) but also a more accurate indicator of the objective eye position (Brautaset & Jennings 2006a).

Even with the Mallett unit, experience shows that occasionally patients have small amounts of fixation disparity but there is no other reason to suspect decompensation. This is not surprising: it is unlikely that any single test will ever be able to infallibly diagnose decompensated heterophoria (Pickwell & Kurtz 1986). Nevertheless, research suggests that the aligning prism as measured with the Mallett unit may be the single best predictor of whether a phoria is associated with symptoms (Jenkins et al 1989, Yekta et al 1989). A small, double-masked randomized controlled trial showed that prisms prescribed with the Mallett unit were consistently preferred by patients to spectacles without prism (Payne et al 1974).

It is not just the presence of a foveal lock that influences the results of fixation disparity tests. As with most other binocular vision tests, different results will be obtained on various instruments that may seem to measure the same variable but in fact have slightly different designs (van Haeringen et al 1986). Other factors such as lighting levels and the precise instructions given to the patient will also be important. If, for example, a trial frame is used to assess the fixation disparity at the first appointment then similar equipment should be used at subsequent visits (Frantz & Scharre 1990).

To summarize on the significance of fixation disparity, the indications that decompensated heterophoria may be present are:

(1) *Fixation disparity* is of a degree greater than normal for the type of apparatus used
(2) *Aligning prism* is greater than normal for that instrument
(3) *Opposing fusional reserve is low* and the prism produces a sharp rise in the degree of fixation disparity, quickly leading to diplopia.

Foveal suppression tests

If binocular vision continues under stress, sometimes very small suppression areas may occur within the foveal region. Small parts of the central field of one eye are inhibited by the mismatch in the slightly displaced images, although the rest of the retina appears to function normally. If fixation disparity is not corrected, monocular acuities measured under binocular (haploscopic) conditions may be worse than the true monocular acuities measured when the other eye is occluded (Sucher 1991). Foveal suppression may act as a compensatory mechanism to prevent symptoms in a decompensated heterophoria. Foveal suppression may vary in different positions of gaze, and this variation may be associated with frequent headaches (Sucher 1994).

Foveal suppression areas can be detected by tests such as the 'binocular status' test on the Mallett near vision unit (Figs 4.3 & 4.7A). This is a Snellen-type letter chart where some letters are seen binocularly (the foveal lock) and some of the letters are cross-polarized to be seen monocularly. The test is calibrated for 35 cm (Mallett 1988a) although, using the approach described below (Tang & Evans 2007), the test can be used at

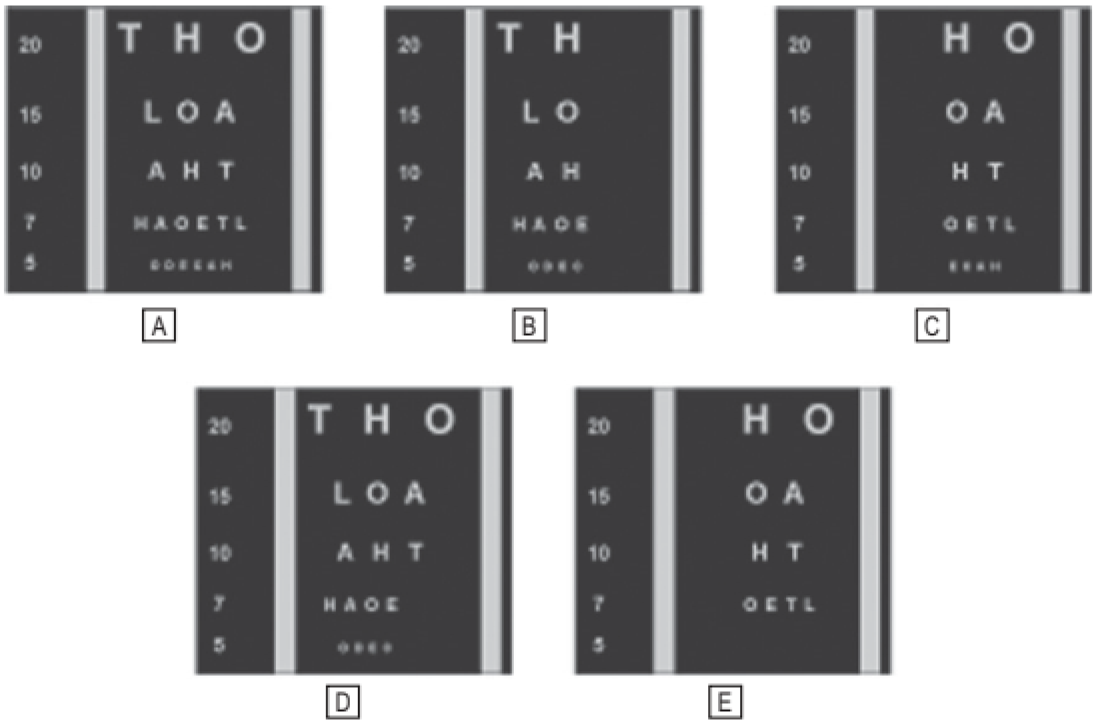

Figure 4.7 The use of the Mallett foveal suppression test. The numbers on the left-hand side of the test represent the acuity in minutes of arc (′). It is recommended that the patient is only shown the test while wearing the polarized filter, when (depending on the orientation of the polarizers) the right eye sees the image in (B) and the left eye the image in (C). If, for example, a patient reports seeing the letters illustrated in (D), then under binocular conditions the left eye has an acuity of 10′ compared with 5′ for the right eye. The poorer acuity in the left eye might result from a monocular factor (e.g. refractive error) or a binocular sensory adaptation (e.g. foveal suppression). If, while the polarized filter is still worn, the better eye (right in this example) is covered, the best acuity of the left eye under monocular conditions can be determined. In the example, the patient sees the letters illustrated in (E), so that the patient has one line of foveal suppression in the left eye and an acuity of 5′ in the right eye and 7′ in the left eye.

other viewing distances. If there is suppression, then some letters will not be read by the patient.

Figure 4.7 details a recommended method of using this test, and this approach was researched by Tang & Evans (2007). This method is based on an intrasubject comparison of the performance at the test under dichoptic but binocularly fused conditions and under monocular conditions. A key component of the test procedure is that the polarized visor is worn for both conditions and the patient should not be allowed to view the test without the visor in place. Tang & Evans (2007) produced the recommended method of use outlined in Table 4.3. These authors noted that there are limitations of this test, most notably the small number of optotypes on each line, and they found that abnormal results at the test do not invariably indicate the presence of binocular vision anomalies. However, they felt that the test could provide useful information when the results are taken in the context of other clinical tests.

Table 4.3 Recommended method of use of the Mallett foveal suppression (FS) test

Step	*Description*	*Patient instructions*
1	The polarizing visor is worn by the patient over any refractive correction that is usually worn at near. If the prescribing of a new, significantly different, refractive correction is being contemplated, the test can be repeated to investigate the effect of this proposed correction on FS	
2	The Mallett unit is held at the normal viewing distance and the patient is shown the FS test	
3	Have the patient read down the chart, continuing until none are seen or all responses are errors. Record the letters seen under dichoptic but binocularly fused conditions	'Please read the letters from the top to the lowest line you can read'
4	The left eye should then be occluded. The patient should not close their eye under the occluder. Have the patient read down the chart again. Record these *polarized* letters seen by the *right* eye	'Some letters may have changed now, but please read again from the top of the chart to the lowest line you can see'
5	This is then repeated while occluding the right eye. Record these *polarized* letters seen by the *left* eye	'Some letters may have changed now, but please read again from the top of the chart to the lowest line you can see'
6	Generally, the degree of FS is abnormal if the patient reads at least one line further under monocular conditions than under dichoptic conditions	

Source: with permission from Tang & Evans 2007

Stereoacuity tests

The value of stereoscopic tests, or stereotests, in routine examination is twofold. First, they help to establish that binocular vision is present and to assess its quality. When a heterophoria is decompensated or is associated with central suppression or amblyopia, the stereoscopic perception may be reduced (Rutstein et al 1994). The second use for stereoscopic tests is to help in assessing a patient's ability to undertake some visual task that requires a good degree of depth perception. For example, reduced stereoacuity in conjunction with poor visual acuity is associated with an increased risk of road accidents in older people (Gresset & Meyer 1994).

However, clinical methods of testing stereopsis (see Fig. 3.3) do not necessarily relate to everyday visual tasks. Indeed, they do not relate strongly to each other, as other factors influence performance in these tests (Simons 1981, Hall 1982). Clinical stereoscopic tests, therefore, need to be interpreted with caution in respect to their second function of assessing everyday depth perception.

Many clinical stereoacuity tests suffer from a ceiling effect, so that the hardest level of the test is passed easily by most of the population (Coutant & Westheimer 1993). Other factors that may limit the usefulness of stereotests, particularly for assessing subtle deficits in heterophoria, are a failure to take account of the time the subject takes to carry out the test (Larson & Faubert 1992) and poor psychophysical techniques.

Diagnostic prisms

Occasionally, prisms can be used to determine if symptoms are due to a heterophoria (Ansons & Davis 2001), especially if the symptoms are atypical and the results of tests of decompensation are inconclusive. Prisms can be prescribed as described in Chapter 6 and, if they alleviate symptoms, then the other management options considered in Chapter 6 can be considered.

The Skeffington model and behavioural optometry

Skeffington founded the Optometric Extension Program in 1928 and his teachings have been followed by a group of clinicians who are sometimes called *behavioural optometrists* (BOs). Although only a very small proportion of UK optometrists follow this discipline, the Skeffington model of binocular vision (Jennings 2000) is rather different from the conventional view and will be briefly described.

Skeffington stressed the interaction between vision, movement, orientation, language and information processing and viewed myopia as an adaptation to stress imposed by near work (Jennings 2000). BOs argue that many patients, despite having healthy eyes, good visual acuity, no refractive problems and no binocular problems according to conventional criteria (Jennings 2000), nonetheless have some form of visual disability that requires treatment with spectacles or vision therapy. BOs' vision therapy is often very different from conventional eye exercises for orthoptic problems. Training may be for pursuit or saccadic eye movements and might, for example, involve doing convergence exercises while a patient jumps on a trampoline. Some BOs prescribe reading glasses or multifocal glasses to a high proportion of children in the belief that this will prevent or control the progression of myopia. Another BO approach is to prescribe yoked prisms (e.g. 2 Δ base-down each eye). A few BOs practise syntonics, where patients view a coloured light source for prolonged periods of time in the belief that this may improve visual fields, academic performance and myopia (Kaplan 1983).

Jennings (2000) carried out a detailed and balanced review of BO. He concluded that 'The author finds much of the theory unconvincing and notes the lack of controlled clinical trials of behavioural management strategies'. The healthcare professions have gone through a quiet revolution in the last 50 years in their adoption of the *evidence-based approach*. This is necessary because patients and practitioners are subjective and are therefore prone to confounding factors, such as the placebo effect. So research to investigate treatments should use an objective design (e.g. a randomized controlled trial). Jennings's (2000) finding that BO lacks any randomized controlled trials must raise serious doubts about the validity of this approach. I would agree with Jennings's conclusion that 'It seems to me unlikely that present behavioural optometry can satisfy evidence-based scrutiny, indeed there must be concern that groups of optometrists following idiosyncratic management strategies within areas traditionally associated with other professions might hinder the credibility and development of optometry as a whole'.

One of the tenets of BO, that a reduction of near visual stress (e.g. with bifocals) will slow the rate of myopia progression, is not generally supported by the literature (p 103). There have also been criticisms of the overzealous use of 'vision therapy' to treat people with specific learning difficulties (reviewed by Evans 2001a) and for enhancing sporting performance (Hazel 1996, Wood & Abernethy 1997). Some elements of BO seem similar to another controversial approach, the Bates method of ocular treatment, which is practised by individuals who are not eyecare professionals (Cullen & Jacques 1960).

It is important that the controversy surrounding some vision therapies used within behavioural optometry does not cause validated eye exercises to be brought into disrepute. As noted in Chapter 10, eye exercises to treat decompensated heterophoria by training fusional reserves have been validated by randomized controlled trials.

Summary of the diagnosis of decompensated heterophoria

The evaluation of heterophoria occurs as the routine eye examination proceeds. It is not usually a process that has to be added on to the routine. The symptoms may cause the practitioner to suspect a decompensated heterophoria, which is one of the most common binocular anomalies. The cover test may further suggest this possibility, and the subjective aspect of binocular examination eventually confirms the diagnosis. There is no single test that will provide a conclusive diagnosis in all cases and a summary of the main factors to be considered is given in Table 4.4.

Several research studies have attempted to determine which tests are most useful in diagnosing decompensated heterophoria. Sheedy & Saladin (1978) studied a group of optometry students who, using rather vague criteria, were classified as symptomatic or asymptomatic. Looking only at the near muscle balance the researchers found that, overall, Sheard's criterion was the best predictor of symptoms. Percival's criterion was also useful

Table 4.4 Summary of main factors in assessing compensation of heterophoria

Factor	*Heterophoria likely to be compensated if:*	*Heterophoria likely to be decompensated if:*
Symptoms	None that are likely to be attributable to the phoria	Symptoms (Table 4.1)
Visual aspects of working conditions	No recent changes	Recent changes that may place vision under stress
Cover test	Quick, smooth recovery	Slow or hesitant recovery
Aligning prism on Mallett unit (Mallett criterion)	Less than 1 Δ for pre-presbyopes Less than 2 Δ for presbyopes	1 Δ or more for pre-presbyopes 2 Δ or more for presbyopes
Uncorrected refractive error	None significant	Significant uncorrected refractive error
Fusional reserve opposing phoria (Sheard's criterion)	Fusional reserve to blur at least twice the phoria	Fusional reserve to blur less than twice the phoria
Balanced fusional reserves (Percival's criterion)	Smallest fusional reserve more than half the largest	Smallest fusional reserve less than half the largest
Foveal suppression	Less than one line difference between haploscopic and monocular acuities	At least one line difference between haploscopic and monocular acuities
Stereoacuity	Good	Reduced
Binocular acuity	Better than monocular	Not as good as monocular

for esophores and the fixation disparity and type of fixation disparity curve were useful for exophores. However, Wildsoet & Cameron (1985) showed that the classification of fixation disparity curves into different types was unreliable. The fixation disparity instrument that Sheedy & Saladin used, the Sheedy Disparometer, does not have a foveal fusion lock.

Dalziel (1981) found that 83% of 100 patients who failed Sheard's criterion at near had symptoms, but only about half of those who failed had an aligning prism of 1 Δ or more on the near Mallett unit. A double-masked study by Worrell et al (1971) provided some support for using Sheard's criterion to prescribe prism for distance esophores and near presbyopic exophores, but not for other near exophores or near esophores. A recent randomized controlled trial did not support prescribing prisms based on Sheard's criterion (Scheiman et al 2005a). Another double-masked randomized controlled trial supported the prescribing of prisms based on the Mallett unit but found that there was little correlation between the prism indicated by the Mallett unit and by Sheard's criterion (Payne et al 1974). Indeed, these authors noted that 'based on our results, one would not expect to find a significant preference for prism prescribed according to Sheard's criterion'.

Jenkins and colleagues, using a modified Mallett unit, found that neither the measurement of the forced vergence disparity curve nor the dissociated heterophoria were useful tests (Yekta et al 1989). These researchers showed that the best predictor of symptoms was the aligning prism and that, if this was measured on an instrument with a good foveal lock, then it was not necessary to measure the angular fixation disparity (Jenkins et al 1989). This study, which looked at near vision symptoms and horizontal heterophorias in a large optometric clinic population, provided strong support for the use of the Mallett unit (Fig. 4.8). The study showed that, under the age of 40 years, 75% of patients with an aligning prism of 1 Δ or more on the Mallett unit had symptoms while only 22% of those without symptoms had such a result. For subjects aged 40 years and over similar results were obtained if the criterion of 2 Δ or over was used.

This work was supported by Pickwell and colleagues (1991), who found that the best cut-off in pre-presbyopes was 2 Δ or more, which was manifested in 30% of patients with near vision symptoms and only 1% of those without symptoms. For presbyopes, the best criterion was 3 Δ or more, which was present in 25% of those with near vision symptoms and only 6% of those without symptoms. This study also looked at the distance vision Mallett fixation disparity test results and symptoms but found no useful relationship. These authors speculated that this might be because of the rarity of distance vision problems (Pickwell et al 1991).

A recent study also found that the Mallett fixation disparity test was less useful for distance vision than for near (Karania & Evans 2006). This study

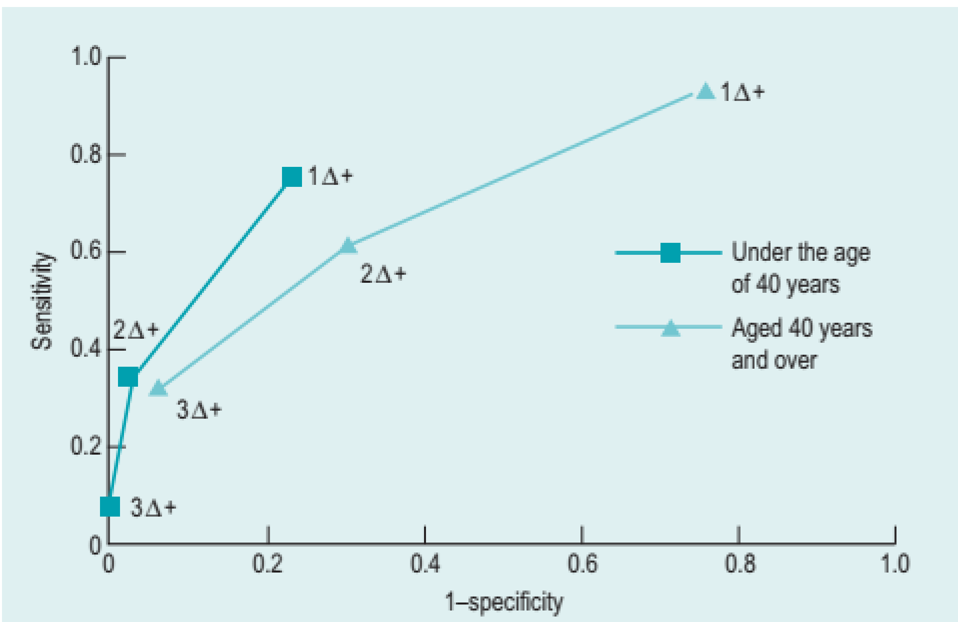

Figure 4.8 Receiver operator characteristic curve (ROC) of aligning prism for detecting decompensated heterophoria. Redrawn with permission of Blackwell Publishing Ltd from Jenkins et al 1989.

showed that the precise questions that are asked are important, and supported the test method detailed in Figure 4.4. In particular, these authors noted that it is important to enquire not just whether the Nonius strips are aligned but also whether they move. These authors also demonstrated that people with the highest degrees of aligning prism tend to be those with the most marked symptoms (Fig. 4.9).

The above research on the Mallett fixation disparity test has been centred on symptoms, which have been shown to be the main factor that optometrists consider when prescribing prisms (O'Leary & Evans 2003). On average, practitioners would consider prescribing a horizontal aligning prism if this was 1.5 Δ or more in the presence of symptoms but would never usually prescribe an aligning prism in the absence of symptoms (O'Leary & Evans 2003). This raises the question of whether there is ever an indication for prescribing prisms in heterophoria in the absence of symptoms, and this was investigated in a recent study (O'Leary & Evans 2006). These authors studied the relationship between the near Mallett test aligning prism and a dynamic test of visual performance (speed of reading). For near exophoria, an aligning prism of 2 Δ or more was manifested by 67% of participants who showed a significant improvement in visual performance and by only 21% of those who did not. The results were similar for pre-presbyopic and presbyopic exophores, but other types of heterophoria did not seem to show such an effect.

The studies described above concerning the Mallett aligning prism did not report fusional reserves, so that the diagnostic capabilities of the Mallett unit cannot be compared with Sheard's and Percival's criteria. It is

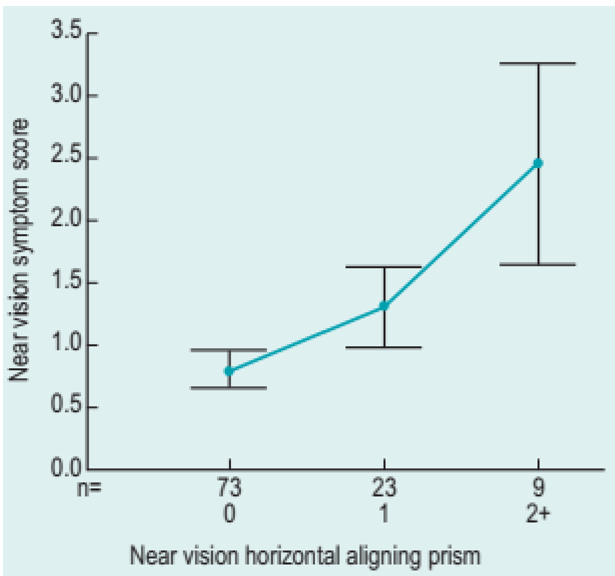

Figure 4.9 Graph of mean symptom score versus aligning prism (using the testing method in Fig. 4.4) at near. The error bars represent the standard error of the mean (SEM). The number of participants (shown above scale for horizontal axis) is small for higher degrees of aligning prism and this may explain why the SEM increases. Redrawn with permission of Blackwell Publishing Ltd from Karania & Evans 2006.

quite likely that improved sensitivity and specificity could be obtained by combining these three results, although there may not be a strong relationship between fixation disparity and fusional reserves (Pickwell & Stockley 1960). A flow chart summarizing the diagnosis of decompensated heterophoria is reproduced in Figure 4.10 and an algorithm for diagnosing decompensated heterophoria and binocular instability is suggested at the end of Chapter 5.

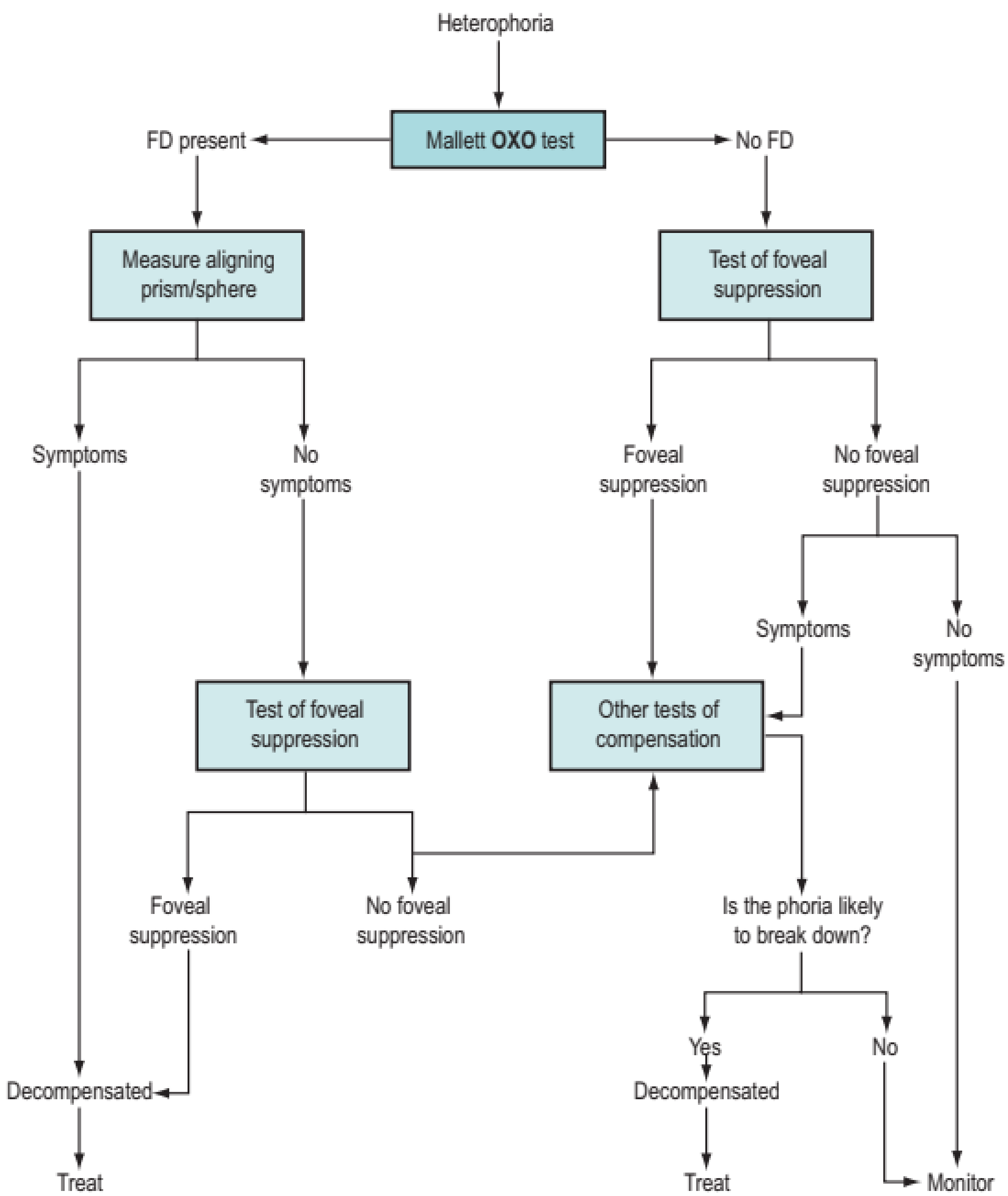

Figure 4.10 Flow chart summarizing the diagnosis of decompensated heterophoria. Symptoms are described in Table 4.1. 'Other tests of compensation' are listed in Table 4.4. Modified from Evans 2001b.

Clinical Key Points

- Heterophoria requires treatment (is decompensated) if it is causing symptoms or if is likely to deteriorate if left untreated
- A heterophoria can decompensate if there are changes in the working environment, the visual system or systemic factors
- Symptoms can be non-specific and a battery of tests is required to diagnose decompensated heterophoria, including cover test, aligning prism, fusional reserves and foveal suppression or stereoacuity
- The aligning prism should be assessed with fixation disparity tests that have a good foveal and peripheral fusion lock (e.g. Mallett unit)