2 DETECTING BINOCULAR VISION ANOMALIES IN PRIMARY EYECARE PRACTICE

Introduction

The routine for examining the eyes and vision of every patient in primary eyecare should have two objectives: to detect the presence of anomalies and/or to indicate when further investigative tests are required. In some cases the patient will indicate by the presenting symptoms or history that a binocular anomaly is likely to be the cause of the trouble. With other patients, binocular vision anomalies will be discovered during the examination, although these were not obvious to the patient.

When all the results of the eye examination are considered together they may fit into a recognizable pattern, which is called the diagnosis. On the basis of this conclusion, a decision can be reached on what to do for the patient: the management of the case. This process can be summarized as follows:

Investigation + Evaluation = Diagnosis → Management.

This formula represents the general principle of clinical procedure; the results of the examination are evaluated to reach a diagnosis. Then experience may suggest the best way of dealing with the particular condition that has been diagnosed. Management options for primary eyecare practitioners include further investigation, refractive or prismatic correction, treatment (e.g. eye exercises or patching) or referral for medical attention.

An outline of the routine procedures is illustrated in Figure 2.1. The type of investigation of the binocular functions will depend on whether a strabismus or heterophoria has been found. Whereas a routine examination will have broader objectives, the description in this chapter emphasizes particularly the binocular vision aspects. This chapter does not describe all the clinical procedures that are routinely used to investigate heterophoria and strabismus; most of these are described in later chapters on these subjects. However, certain tests, such as the cover test, are fundamental to the investigation of binocular function and are best described at this stage.

Tests should be explained to patients as they are carried out, so that patients understand the general aspects of a routine eye examination. It is

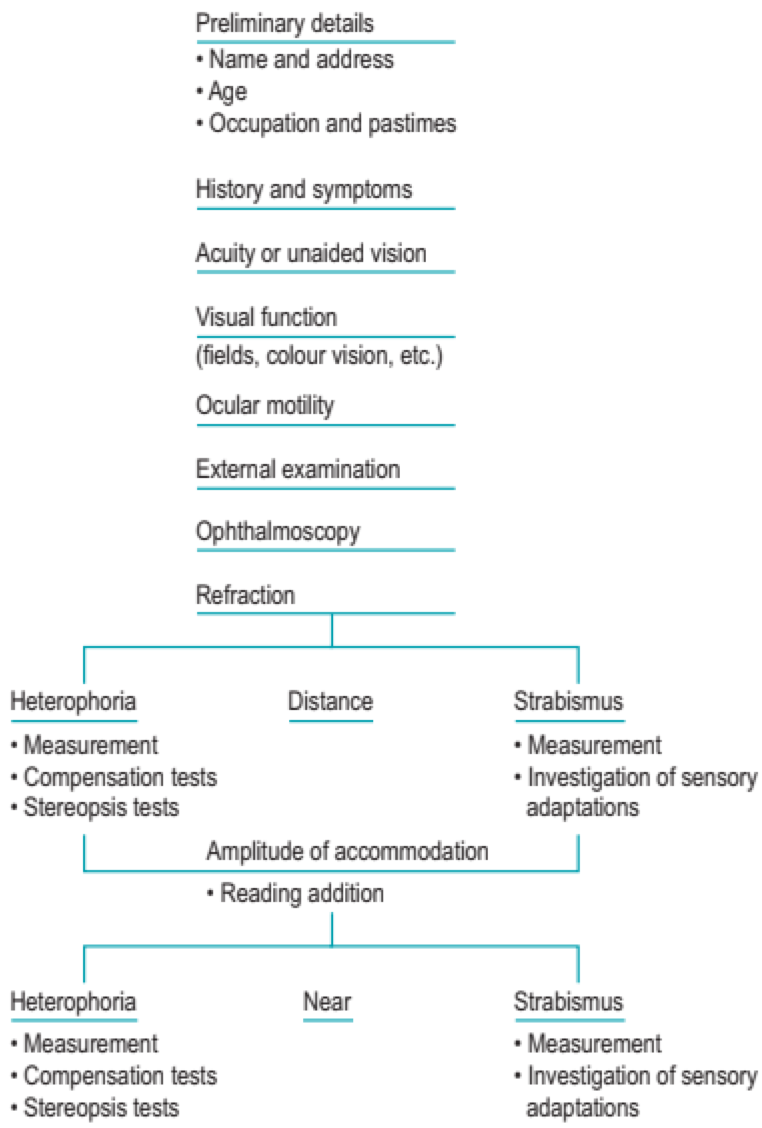

Figure 2.1 Summary of routine eye and vision examination.

best to leave a detailed explanation of the results until the end of the eye examination, when a full picture should have emerged.

Should binocular vision tests create natural or artificial viewing conditions?

There are often several different tests that can be used, for example to measure the magnitude of heterophoria at a given distance. The various tests will be likely to create differing conditions and will therefore produce different results. In particular, tests that create less natural viewing conditions and dissociate the eyes to a greater degree tend to produce higher estimates of the deviation. This raises the question of whether it is better to know the deviation that occurs under natural viewing conditions or the 'full' deviation that occurs under artificial viewing conditions.

If the purpose of a binocular vision test is to detect what is happening with that person's visual system under everyday conditions, then the binocular vision test should mimic everyday visual conditions. For example, the practitioner may wish to know whether symptoms that a patient has reported when working on the computer are attributable to a binocular vision anomaly. The most relevant tests are those that mimic the viewing conditions when the patient works on the computer, and include a cover test and Mallett fixation disparity test at the appropriate distance (Ch. 4).

If, on the other hand, the purpose of a binocular vision test is to reveal information about the aetiology of a binocular vision anomaly, then it may be helpful to fully dissociate the patient to discover the nature of the binocular vision anomaly. For example, in a patient who is complaining of vertical diplopia when reading it may be necessary to perform a double Maddox Rod Test to fully investigate the characteristics of the vertical diplopia (p 286).

Refractive correction during binocular vision tests

A fairly common question from students and practitioners is 'What refractive correction (if any) should be worn when carrying out binocular vision tests?' The answer to this question depends on what the clinician wishes to know. If the clinician wishes to know whether symptoms in everyday life are related to a binocular vision anomaly, then the binocular vision tests should be carried out while the patient wears the optical correction, if any, that they would use most often for that task in everyday life. Conversely, if the clinician wishes to determine what effect a proposed refractive correction will have on a patient's binocular vision status then they should carry out the tests while the patient wears the proposed refractive correction. It will sometimes be appropriate to test patients under both conditions.

Preliminary details

These will include such information as the name and address. More important, clinically, is the age of the patient. This must be noted in relation to the age of onset of any strabismus, as it is likely to influence the extent of the sensory adaptations and the prognosis.

The patient's occupation and pastimes should also be noted, so that the visual conditions of work and recreational activities are understood. Some patients have a greater need for stereopsis and others use their eyes in conditions that put a greater stress on binocular vision. Changes in the work place can also help in understanding the cause of the patient's problem.

History and symptoms

Symptoms

Many patients will attend for examination at regular intervals, although they are not complaining of symptoms. This can result in the early detection of any anomalies. Symptoms often occur at an advanced stage in the progression of a condition. In children, binocular anomalies can occur without any serious symptoms, as a result of sensory adaptations. The onset of a strabismus at an early age is seldom accompanied by symptoms. However, a high percentage of patients will attend for examination because they are having symptoms that they associate with the eyes and vision, or come for a check because they have a history of binocular vision problems. Patients often underestimate the role of symptoms: the most powerful single factor in determining whether optometrists prescribe interventions are the symptoms that the patient reports (O'Leary & Evans 2003).

Headache is a common symptom. It may be caused by a very large variety of problems, many of which have nothing to do with the eyes or vision. It is important to determine if any headache is associated with the use of the eyes. It is common for decompensated heterophoria to cause some headache that occurs after prolonged use of the eyes, often under adverse visual conditions. This type of headache is more likely to be in the frontal region of the head. Usually, headache due to binocular vision problems is less intense or absent in the morning after a night's sleep and gets worse as the day wears on.

Diplopia is a less usual symptom in long-standing strabismus, as sensory adaptations occur. Its presence therefore indicates a deviation of recent onset, although about two-thirds of cases of acquired strabismus from brain damage (usually stroke or trauma) do not report diplopia (Fowler et al 1996). Deviations of recent onset may have a pathological cause and careful attention is therefore given to the tests for comitancy. The patient may sometimes report that the double vision is greater in one direction of gaze. The patient should also be asked if the doubling is constant or intermittent; whether it is horizontal, vertical or both (diagonal); and if it is associated with any particular use of the eyes. Incomitant deviations are more likely to have a vertical component. Double vision in heterophoria indicates that it is intermittently breaking down into a strabismus. This may be because the factors causing the decompensation have reached a serious state and sometimes it is an early indication of an active pathological cause. In the latter case, the onset of intermittent diplopia is likely to be more sudden and dramatic.

Blurred vision is a common symptom in heterophoria. It can be associated with accommodative difficulties such as undercorrected presbyopia or hypermetropia. In these cases, the blurred vision is more likely to be noticed by the patient during close work. Patients may also report general tiredness or soreness of the eyes or lids. The significance of blurred vision should not be underestimated: having blurred vision more than once or twice a month has a detectable and significant impact on functional status and wellbeing (Lee et al 1997).

Poor stereopsis occurs with some binocular vision problems in which the patient reports difficulty in judging distances. Patients often do not notice this symptom because of the many monocular clues to depth perception (Rabbetts 2000, p 191). The symptom of monocular occlusion is a relatively common sign of a binocular anomaly and may be described as closing one eye when reading or adopting an unusual head posture so that the nose occludes the view of one eye (e.g. reading or writing with the head on the page).

Asthenopia is a term used to describe any symptoms associated with the use of the eyes, typically eyestrain and headache. Asthenopic symptoms can result from either internal (binocular and accommodative disorders) or external (e.g. dry eye) factors (Sheedy et al 2003a). Literally, the term asthenopia means weakness or debility of the eyes or vision, so the term may be best confined to describing symptoms arising from a visual or ocular anomaly rather than from purely extrinsic (e.g. environmental) factors. Symptoms of eyestrain, tired eyes, irritation, redness, blurred vision and double vision associated with the use of display screen equipment have been collectively referred to as computer vision syndrome, which has been largely attributed to dry eye (Blehm et al 2005).

Specific reading difficulty (dyslexia) may be reported as a symptom and this occurs in about 5% of children (Yule 1988). People with dyslexia are particularly likely to suffer from binocular instability (Ch. 5) although, in most cases, this is unlikely to be a major cause of the dyslexia (Evans et al 1994). If patients with reading difficulties report asthenopia then this can be the result of binocular or accommodative anomalies or might be a sign of Meares–Irlen syndrome, which can be treated with coloured filters (p 63–64).

Dizziness and vertigo may occur in incomitant heterophoria (Ch. 17). Vertigo can also be caused by variations to the blood supply to the brain, middle ear defects or alterations in magnification from spectacle changes, particularly astigmatic changes (Rabbetts 2000, p 179).

Monocular eye closure (eyelid squinting) is used by patients with refractive error to improve acuity and in other cases to reduce illumination, particularly glare from the superior visual field (Sheedy et al 2003b). It is a common symptom in sunlight and in strabismus, particularly intermittent exotropia; and occurs to reduce photophobia rather than to avoid diplopia (Wiggins & von Noorden 1990). Monocular eye closure under normal lighting conditions can occur to avoid diplopia or other visual symptoms associated with binocular vision anomalies.

History

When strabismus is reported or detected, it is important to discover how long it has been present and if it is constant or intermittent. If there is a hereditary factor or an aetiology relating to orbital trauma during birth delivery, it is unlikely that strabismus will respond to non-surgical treatment alone. It may be necessary to investigate the presence of history or symptoms which suggest other trauma or pathological conditions which contribute to the cause of the strabismus (Ch. 17). In particular, questions should be asked about the possibility of birth trauma (e.g. were forceps used?). Parents should be asked whether the birth was on time: prematurity is associated with a five-fold increased risk of esotropia (Robaei et al 2006a). If postnatal trauma is suspected the practitioner should always be mindful of the possibility of non-accidental injury (child abuse). An estimated 40% of cases of physically abused children exhibit ocular complications and any serious or suspicious injuries should be reported to the general medical practitioner (Barnard 1995a).

Another important part of the history is to gain an understanding of any previous treatment. This may have included spectacles, occlusion, eye exercises or surgery. In each case, it is necessary to discover the type of treatment given and the effect on the symptoms and the binocular condition. Generally, if a particular treatment has been tried and proved to be unsuccessful it is not worth trying again.

The patient's general health may also be significant in binocular vision anomalies. Poor general health may contribute to heterophoria becoming decompensated and will make treatment more difficult.

Other general conditions should be identified, particularly those that are associated with binocular anomalies. For example, there is a high (29%) risk of strabismus in children with Down's syndrome and this risk is present whatever the refractive error (Cregg et al 2003).

Family history

The family history may be important. The highest familial association is for hypermetropic accommodative esotropia, where 26% of first-degree relatives are affected, compared with 15% in infantile esotropia, 12% in anisometropic esotropia and 4% in exotropia (Ziakas et al 2002).

Acuity or unaided vision

The unaided vision of each eye or the corrected acuity with the patient's present refractive correction is usually measured with a standard letter chart. For young children, other kinds of apparatus may be more appropriate (Ch. 3). If the patient does not wear a refractive correction all the time, it is useful to record the vision with and without the correction and to note any obvious effect on the binocular vision. It is important to record the acuities early in the examination, as this often gives a clue to what may be expected in subsequent investigation. For example, an eye with reduced acuity is more likely to be the deviated eye in strabismus. When visual acuity is carefully measured in children aged 6–11 years, 95% of cases are repeatable to within ± 1.5 lines of a letter chart (Manny et al 2003).

In amblyopia, other details may be inferred from the way in which the patient reads the chart. Difficulty in reading the middle letters of a line in the correct order may suggest eccentric fixation with the small accompanying scotoma (Ch. 13).

Patients with low vision, for example in age-related maculopathy, may be particularly prone to symptomatic binocular vision anomalies and need careful evaluation of their binocular status (Rundstrom & Eperjesi 1995).

In older people, binocular vision anomalies may increase the risk of falls (Evans & Rowlands 2004).

Reduced vision can result from a *visual conversion reaction* (psychogenic visual loss, functional visual loss). In about one-third of cases (Lim et al 2005), this only affects one eye and might be misdiagnosed as amblyopia. It can occur at any age and may be associated with psychosocial events, primarily social in children and trauma in adults (Lim et al 2005). One-fifth of cases have migraine, facial pain or coexisting organic pathology (e.g. macular disease).

Ocular motor investigation

The term *motor* refers to that which imparts motion, so that *ocular motor* is used to describe the neurological, muscular and associated structures and functions involved in movements of part or all of one or both eyes. Strictly speaking, the term *oculomotor* refers only to the functioning of the third cranial nerve. Confusingly, some authors use *oculomotor* variously as a synonym of *ocular motor*, to describe saccadic eye movements or to describe saccadic and pursuit eye movements.

A basic investigation of ocular motor function will normally include:

(1) *Cover test:* which will indicate whether any deviation is strabismus or heterophoria, the degree of deviation and some indication of compensation in heterophoria
(2) *Motility test:* which investigates any restrictions of eye movements and comitancy
(3) *Near triad:* convergence, accommodation and pupillary miosis occur during near vision and are called the near triad. Another associated motor reflex is the movement of the eyelids during eye movements.

Cover test

This is largely an objective test relying on the critical observation of the practitioner. It is the only way to distinguish between heterophoria and strabismus, unless there is a very marked deviation. The cover test requires considerable skill, but this can be acquired by practice. Essentially it consists of covering and uncovering each eye in turn while the other eye fixates a letter on a distance chart or a suitable near fixation target. The basic cover/uncover test will be described first, and then various modifications will be discussed.

As one eye is covered, the practitioner watches the other: any movement indicates that it was deviated (strabismic) and had to move to take up fixation. As the cover is removed, the practitioner watches the eye that has been covered: any movement of this eye indicates that it was deviated under the cover and recovers when the cover is removed and it is free to take up fixation. In the absence of strabismus, this shows heterophoria.

The test should be carried out for distance vision using a letter on the Snellen chart from the line above the visual acuity threshold of the eye with lowest acuity, so that precise accommodation is required. It is repeated for near vision at the patient's usual working distance. If the visual acuity is worse than about 6/36 at the relevant distance then a spot light should be used for fixation. If it is known from previous eye examinations that a patient has a permanent or intermittent strabismus in one eye then the non-strabismic eye should be covered first. It is important that the covered eye is fully occluded, particularly from bright lights in the periphery, which can stimulate abnormal movements in some patients. Translucent occluders are available that allow the practitioner to observe the approximate position of the eye behind the occluder without allowing the patient any form of vision. In performing the cover test, the eye is usually covered only for 1–2 seconds, so that the response to momentary dissociation is observed; although longer occlusion (up to 10 seconds) will be more likely to reveal the full deviation (Barnard & Thomson 1995).

The cover test should not be repeated unnecessarily, since the deviation increases with repeated covering and can break down into a strabismus. In cases where it is suspected that the heterophoria may be breaking down into a heterotropia the cover test should be performed as the first step before the visual acuity is assessed. The practitioner will have to estimate the appropriate target and repeat the cover test if the target proves to be too small when the visual acuity is later assessed. The effect of repeated and longer dissociation can be observed by the alternating cover test method (below) and by holding the occluder in place for longer.

Cover test in strabismus

This is illustrated in Figure 2.2, which shows the movements in right convergent strabismus (esotropia), and in Figure 2.3, which shows right divergent strabismus (exotropia) with right hypertropia. The cover test will also help in investigating the other aspects of strabismus:

(1) *Constancy.* An intermittent strabismus may be present sometimes and binocular vision recovered at other times. Often this type of strabismus is not present until the cover test is performed but the momentary dissociation is sufficient to make the strabismus manifest.

(2) *Direction of deviation.* Indicated by the direction of the movement; for example, in convergent strabismus the deviated eye will be seen to move outwards to take up fixation when the other eye is covered.

(3) *Eye preference.* In alternating strabismus, covering one eye will transfer the strabismus to the other eye, which will continue to fixate when the cover is removed. In such cases, a preference for fixation with one eye may be found; although fixation can be maintained with either eye: if the patient blinks or changes fixation momentarily the fixation always reverts to the preferred eye. In other cases, the patient may be able to maintain fixation with either eye at will.

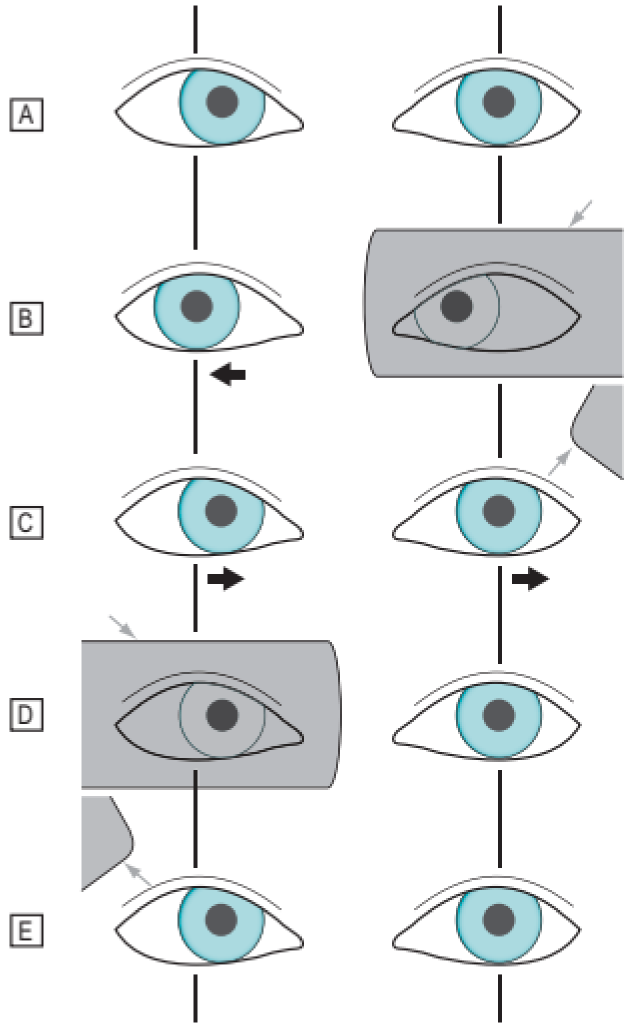

Figure 2.2 Cover test in right convergent strabismus (movement of the eye is signified by the broad arrow, movement of the cover by the thin arrow). (A) Deviated right eye. (B) Left eye covered: both eyes move to the right so that the right eye takes up fixation. (C) Left eye uncovered, both eyes move to the left so that the left eye again takes up fixation. (D) Right eye covered, no movement of either eye. (E) Cover removed, no movement. Note that both eyes move together in accordance with Hering's law.

(4) *Degree of deviation.* With practice, the angle of the strabismus can be estimated from the amount of the movement. This is the preferred method of assessing the deviation and can be made easier by comparing the movement during the cover test to a version movement of known magnitude. For example, the angle of $1\,\Delta$ is equivalent to a distance of 6 cm at 6 m and the width of a line of letters on most Snellen charts for acuities from 6/18 to 6/6 is 12 cm. Hence, if the patient looks from a letter at one end of the line to one on the other end, the resulting saccadic eye movement would be equivalent to a cover test movement of $2\,\Delta$.

Cover test in heterophoria

This is illustrated with respect to esophoria in Figure 2.4. The eyes are straight until they are dissociated by covering one. Then the covered eye

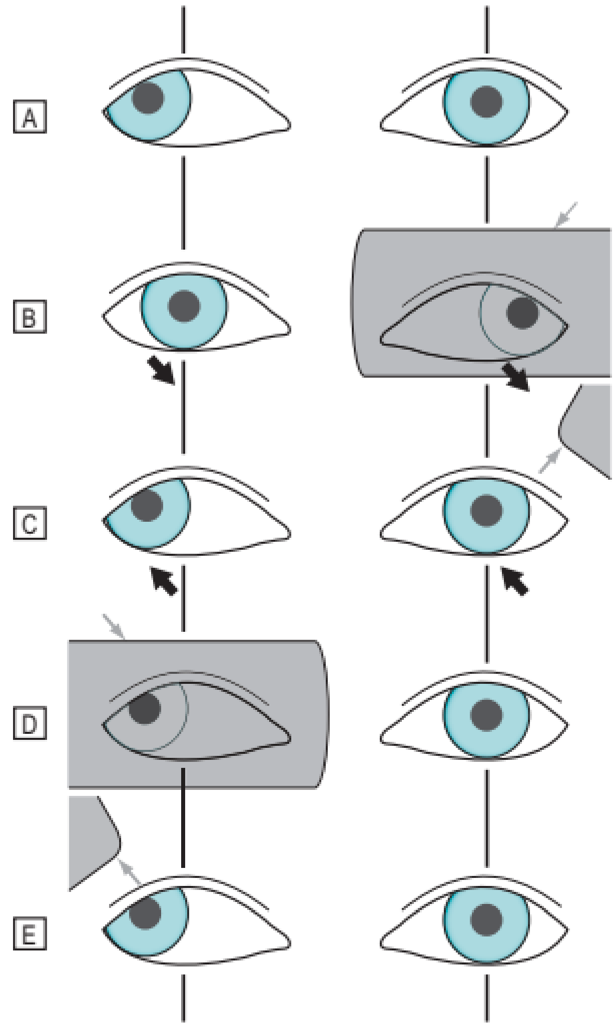

Figure 2.3 Cover test in right divergent strabismus with right hypertropia (movement of the eye is signified by the broad arrow, movement of the cover by the thin arrow). (A) Right eye deviated out and up. (B) Left eye covered: both eyes move left and downwards so that the right eye takes up fixation. (C) Left eye uncovered: both eyes move right and upwards so that the left eye again takes up fixation. (D, E) No movement of either eye as the strabismic right eye is covered and uncovered.

deviates into the heterophoric position behind the cover. It will be seen to make a recovery movement when the cover is removed. In the most simple cases (Fig. 2.4A–C) the eye that is not covered will continue to fixate without making any movements either when the other is covered or when the cover is removed. However, it should be noted that this is not in accordance with Hering's law of equal eye movements (see Glossary).

Movements of both eyes may be seen on the removal of the cover in some cases (Fig. 2.4D–F). This is particularly noticeable in large degrees of heterophoria. When the cover is removed, both eyes are seen to make a versional movement of about half the total phoria deviation; that is, they both move in the same direction, to the left or to the right. This versional movement is relatively quick and is followed by a slower change of vergence of about the same magnitude. For the eye that has been covered, the second part of the recovery will be in the same direction as the versional

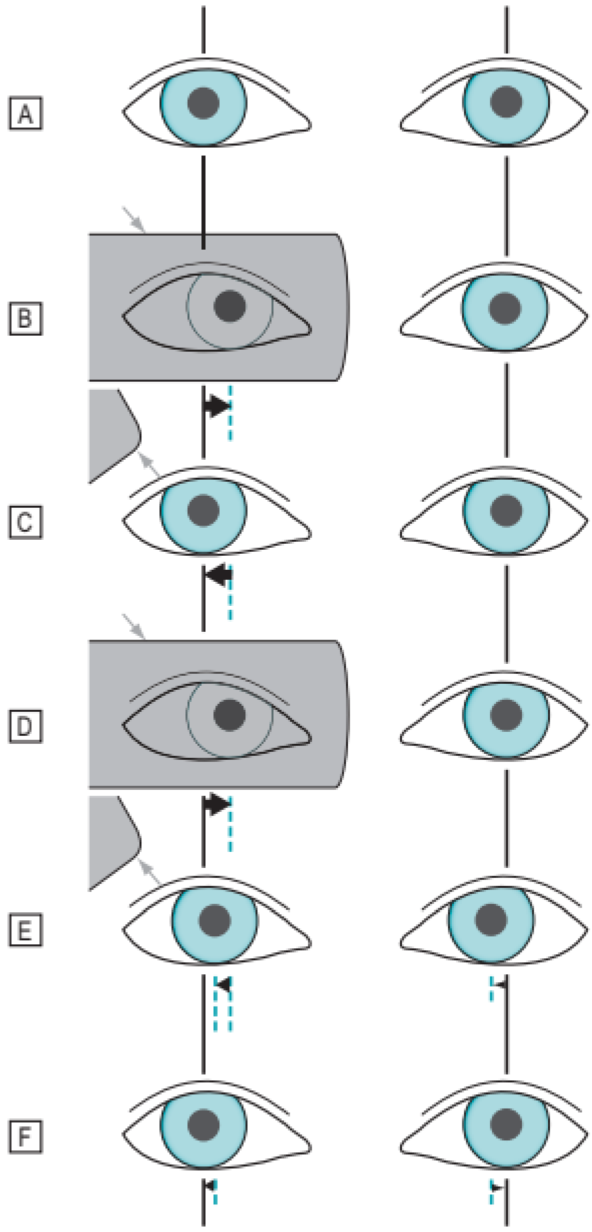

Figure 2.4 The cover test in esophoria (movement of the eye is signified by the solid arrow, movement of the cover by the dotted arrow). (A–C) From the 'straight' active position, the right eye moves inwards when dissociated by covering (B). It moves smoothly outwards to resume fixation with the other eye when the cover is removed (C). Note that the left (uncovered) eye does not move during the simple pattern of movements. (D–F) The 'versional pattern': the right eye moves inwards under the cover, as in the simple pattern (D); on removing the cover, both eyes move to the right by the same amount (about half the degree of the esophoria (E); both eyes then diverge to the straight position (F).

movement. For the non-covered eye, the second movement will be a return to its fixation position. That is to say, the eye that is not covered will be seen to make an apparently irrelevant movement outwards (for esophoria) and back again to its fixation position. In the cases that show this pattern of movements, it will be noted that Hering's law does apply.

In heterophoria, the cover test movements are usually the same whether the left or the right eye is covered. In some cases, however, this is not so.

Table 2.1 A grading system that can be used to gauge cover test recovery in heterophoria

Grade	*Description*
1	Rapid and smooth
2	Slightly slow/jerky
3	Definitely slow/jerky but not breaking down
4	Slow/jerky and breaks down with repeat covering, or only recovers after a blink
5	Breaks down readily after one to three covers

Source: reproduced wih permission from Evans 2005a.

In uncorrected anisometropes, the movement can be larger in one eye if a change in accommodation is required to keep the fixation target in focus when one eye is covered but not when the other is covered. Another cause of asymmetry of eye movements during cover testing is incomitancy.

In some patients, the versional pattern of movements may show when one eye is covered but the simple pattern if the cover is applied to the other eye. These patients have marked ocular motor dominance. The versional pattern is seen on removing the cover from the dominant eye: fixation is quickly transferred to the dominant eye by the versional movement and the recovery from the heterophoric position occurs in the non-dominant eye. These patients often have slight amblyopia with a small central suppression area in the non-dominant eye and are considered by some to be a variant of microtropia (below).

The cover test helps in the investigation of heterophoria by giving information about:

(1) *Direction of deviation:* esophoria, exophoria, hyperphoria or cyclophoria
(2) *Degree of deviation:* estimated from the amount of movement seen on removing the cover
(3) *Compensation:* assessed by observing the speed and smoothness of the recovery movement. A smooth quick recovery movement usually indicates compensated heterophoria, but if it is decompensated, the recovery is likely to be slow and hesitant. A schema for grading the quality of cover test recovery movements in heterophoria is given in Table 2.1.

Cover test in microtropia

Strabismus with inconspicuously small angles exist, and have been described by a number of terms and as having various characteristics (Ch. 16). Microtropia may not be detected with the cover test because of abnormal retinal correspondence and eccentric fixation that both coincide in degree with the angle of the strabismus. In microtropia, therefore, the strabismic eye is often not seen to move to take up fixation when the dominant eye is covered as it would in other strabismus. However, in some cases of microtropia, the angle of the deviation may increase when one eye is covered. There may be an apparent 'phoria movement' when the cover is removed. This movement may be particularly noticeable if the cover is held in place for a longer time or if the alternating cover test (below) is used. It may be assumed that, in the active or habitual position, the eyes are held straighter under the influence of peripheral fusion. This condition was called 'monofixational phoria' (Parks & Eustis 1961; Ch. 16).

Other cover test observations

Failure of an eye to take up fixation sometimes occurs in both strabismus and heterophoria. The experienced practitioner may see that an eye is deviated. The eye will move to take up fixation if the patient is asked to 'look very hard at' the fixation target or is asked to look at a point a little higher than but close to the original fixation point; say 2–3 mm for near vision. The eye can then be seen to make a horizontal movement as well as the necessary very small vertical one. Alternatively, the head can be moved by 1–2 cm or during near fixation the fixation target can be moved by this amount. The patient will then make a pursuit movement with, if they have failed to take up fixation, a refixation movement superimposed upon it.

Latent nystagmus may also be revealed by the cover test. It shows an oscillation of one or both eyes when one is covered (Ch. 18).

The cover test described above is the basic method, sometimes called the *cover/uncover test*. There are several modifications to the cover test which will give further useful information in some cases.

Alternating cover test

When the cover/uncover test has been carried out as described above, it is sometimes useful to transfer the cover from one eye to the other and back several times. The degree of the deviation usually increases, making it easier to see.

Where no obvious strabismus is seen, the eyes should be observed to see if any recovery movement takes place when the cover is finally removed after the alternating cover test. This may give some indication of the degree of compensation, as poorly compensated heterophoria does not recover so readily or as smoothly after the alternating cover test and may break down into a strabismus. If, as the cover is removed, the eye that is being uncovered does not appear to take up fixation, then the cover should be reintroduced in front of the other eye. This is to see if the repeated covering has induced a strabismus, in which case the recently uncovered eye will be seen to move to take up fixation when the other eye is covered.

Prism measurement

Measurement of the deviation can be carried out by placing a relieving prism before an eye to neutralize the cover test movement. This can be done using single prisms from a trial case or more conveniently by the use of a prism bar. The lowest power of prism that neutralizes the movement is taken as a measure of the deviation. This can be done in heterophoria or in strabismus but, for larger deviations, potential inaccuracies associated with the use of prisms should be borne in mind (Firth & Whittle 1994, 1995).

In the case of a strabismus, the habitual angle is measured by the *simultaneous prism cover test*, which should be carried out after the cover/uncover test and before the alternating cover test so as to avoid increasing the angle by dissociation. The cover/uncover test will have revealed the strabismic eye and the likely size of deviation. The practitioner simultaneously approaches the fixating eye with the cover and the strabismic eye with the prism estimated to neutralize the deviation. If no movement is observed then the size of the habitual deviation has been correctly estimated. If a movement is seen then the test is repeated with the new estimate of the required prism.

Once the habitual angle has been measured in this way, then the total angle can be measured by neutralizing the movement during the alternating cover test without removing the prism bar between movements of the cover.

It will also be noticed that, when the correct relieving prism is in place, the corneal reflections of a fixation light appear symmetrically placed in the two eyes. Before applying the cover, therefore, an estimate of angle can be made by increasing the prism power until the corneal reflections appear to be symmetrically placed. This is called the Krimsky test (Krimsky 1943) but is not as accurate as the cover test.

Subjective cover test ('phi' test)

If there is a deviation, either heterophoria or strabismus, the patient will observe an apparent jump of the fixation point when the cover is transferred from one eye to the other. This apparent jump is known as 'phi' movement. In convergent deviations, the jump will appear to be against the movement of the cover; that is, if the cover is moved from the right eye *to the left*, the fixation point will appear to the patient to move to the *right*. A 'with' movement occurs in divergent deviations (see Appendix 1). Prisms can be introduced to eliminate this movement and provide a subjective measure of the deviation. Since the phi test involves repeated covering (usually an alternating cover test) the angle of deviation is likely to increase beyond that usually measured with the cover/uncover test.

Value and accuracy of the cover test

Although this section describing the cover test is quite lengthy, it will be appreciated that the cover test is the most important binocular vision test. It is a comparatively quick procedure and a very great deal of useful information can be found in a few moments. Because it is so valuable as a diagnostic procedure and takes so little time, it should be incorporated in all routine eye examinations. The time taken to acquire the necessary skill in observation is well worth while.

Rainey et al (1998) noted that 99% of observers could detect eye movements of less than 2 Δ. These authors examined the inter-examiner repeatability of variations of the alternate cover test. The 95% confidence limits were 3.3 Δ when the eye movements were estimated, 3.6 Δ when measured with prisms and 2.5 Δ for the subjective cover test. Minimal training is required for the efficient detection of small eye movements (Fogt et al 2000).

Rabbetts (2000, p 170) advised that the practitioner should watch the limbus and noted that, because the lateral vertical borders of the limbus are most easily seen between the patient's eyelids, it is easier to detect horizontal than vertical movements of the eyes. He therefore suggested that other methods should be used to double-check for vertical imbalances. The examiner should also watch for any eyelid movements, since a slight vertical movement of the eyelashes may help in detecting vertical deviations. For young or uncooperative patients, there are alternative methods of assessing ocular alignment; these are discussed in Chapter 3.

Motility test (ocular movements)

An examination of the binocular vision needs to explore the ability of the patient to move the eyes into all parts of the motor field. This is usually carried out by asking the patient to look at a pen torch light, which is moved in the motor field while the patient is asked to follow it with the eyes and keep the head still. The pen light should be kept at an approximately constant distance from the patient's head (about 50 cm). It is easier to detect any incomitant deviations if the light is not moved too fast: typically the light is moved from the centre to the periphery in about 3–5 s. Spectacles are not usually worn, unless there is a very marked accommodative strabismus (e.g. high hypermetropia with a marked convergent strabismus when the spectacles are removed).

The motility test is usually done binocularly and if there is any suspicion of abnormality it is repeated monocularly. The binocular motor field is restricted by the patient's brow and nose to eye movements of about 25° from the primary position. It can be useful, however, to move the light into the monocular fixation area, as this is similar to carrying out a cover test in peripheral directions of gaze. Latent deviations and incomitancies can sometimes be detected by doing this. If there is any doubt, an actual cover test can be carried out in the peripheral gaze position. The cover will eliminate peripheral fusion when this is done. A quick useful routine is as follows, and a recording sheet for the results is given in Appendix 8:

(1) *Fixation* is checked first, in each eye, by asking the patient to fixate the pen torch with the eyes in the primary position while the other eye is occluded. Each eye is observed to see that steady fixation is maintained, with no wandering. The position of the pen torch reflection in the cornea is also noted with respect to the pupil. It should be symmetrical between the two eyes; usually slightly nasal if the angle lambda is normal (see Fig. 3.2). Any asymmetry may indicate eccentric fixation (Ch. 13).

(2) *Pursuit eye movements* should be smooth with no jerks as the light is moved horizontally. Both eyes should follow the light evenly across the binocular motor field and out into the area of monocular fixation, first one way and then the other. The lid apertures should not vary appreciably as this is carried out. In crossed alternating fixation, a jump of both eyes can be seen as the patient changes fixation to the other eye on moving from one half of the motor field to the other (Ch. 3).

(3) *Vertical movement of the eyes and lids* are checked by moving the pen torch slowly about 25 cm above the horizontal, and then 25 cm below. Both eyes should follow the movement with corresponding lid movements. This may detect an A- or V-syndrome (Ch. 17).

(4) *Comitancy* is next examined. This is done by moving the light across the upper part of the motor field to the right and then to the left. This includes the area of binocular fixation and the monocular part of the field. The patient is asked to say if any doubling occurs in the binocular area and the practitioner observes any underaction or overshooting of one eye compared with the other. Incomitancy may be detected either by the subjective diplopia or by the practitioner's observation. The process is repeated across the lower part of the motor field (Ch. 17). Alternatively, some authorities recommend that a 'star' technique is used where the pen torch is moved in the horizontal (at eye level), vertical (looking for gaze palsies) and four oblique positions (Mallett 1988a).

(5) *Cover testing in peripheral gaze* will help identify areas of overaction or underaction (see Appendix 8). It is important to watch the pupil reflexes to ensure that both eyes can see the target in all positions, and to ensure that the cover fully occludes the eye.

(6) *Reports of diplopia*. Patients should be asked about any diplopia they report during the test (see Appendix 8). The position of gaze where there is maximum diplopia will usually identify the primary problem and the image that is furthest out originates from the underacting eye (Ch. 17). It is again essential to watch reflections of the light so as to be certain that the patient is fixating with both eyes. Reports of diplopia are in some cases inconsistent with the other clinical findings. Some patients appear to suppress the diplopic image in certain directions of gaze; others seem to be inconsistent and easily confused in describing their diplopia.

(7) *Monocular motility* can be useful in some cases. In mechanical (restrictive) incomitancies there will be a restriction of monocular motility but this is not usual in neurogenic incomitancies.

(8) *Saccadic movements* can be checked by asking the patient to change fixation from the pen torch held at the right of the field to the practitioner's finger held in the left of the field, pause and back to the pen torch. These movements should be smooth, quick and accurate.

It is clear that the motility test provides a great deal of information, and the interpretation of the test results can be rather difficult for inexperienced practitioners. Initially, it can be simpler to carry out the test three times, first looking solely at the corneal reflections of the pen torch, second carrying out cover tests in peripheral positions of gaze and third asking the patient about diplopia (see Appendix 8).

The motility test is the only objective routine clinical test for incomitant eye movements but there are a number of subjective methods that can be used. These are particularly useful in recently acquired deviations where suppression is unlikely, and are described in Ch. 17.

Tests of saccadic eye movements

Objective instruments for assessing saccadic eye movements (e.g. by measuring the reflection of light from the limbus) are discussed further in Chapter 18. Some clinical tests exist that, it is claimed, can assess saccadic eye movements in a simulated reading task. An early example of this type of test was the New York State Optometric Association King–Devick Test. This used randomly spaced numbers in horizontal rows and it is argued that good saccadic eye movement control is required to perform well at this task. However, many other skills are also required to perform this test, so it is unlikely that the test has a high sensitivity or specificity for diagnosing saccadic dysfunction. To control for some confounding variables, the Developmental Eye Movement (DEM) test was developed, which has vertical rows of numbers as a control condition (Taylor-Kulp & Schmidt 1997). However, although it is an improvement this test is still likely to be influenced by many confounding variables such as digit recognition, attention (Coulter & Shallo-Hoffmann 2000), sequencing and intelligence. The test has been shown to have poor repeatability (Rouse et al 2004a).

In any event, the need for the routine clinical assessment of saccadic eye movements is rather questionable. Saccadic eye movements are the fundamental method of using the visual system to analyse or search any visual scene. For example, saccadic eye movements are used when walking down a street, driving a car, playing a ball sport or watching television. It seems intuitively unlikely that saccadic dysfunction is a common clinical finding and I am unaware of any well controlled studies that have demonstrated this. It has been argued that saccadic dysfunction is a feature of specific reading difficulties (dyslexia) but the scientific evidence for this is rather weak (Evans 2001a). Similarly, the evidence for a beneficial effect of saccadic training programs is equivocal at best (Evans 2001a).

There are some rare pathological conditions that affect saccadic eye movements and these are discussed in Chapter 18.

Near triad

The third aspect of the motor investigation is concerned with the near triad (associated reflexes): convergence, accommodation and pupil reflexes. These constitute three synkinetic actions which normally come into play together during near vision. The oculomotor (third cranial) nerve serves all of these, and disturbances of one may be accompanied by the others (see Ch. 17 for pathological causes of recent onset).

Convergence

There are two aspects of convergence movements. The first is concerned with pursuit (ramp) convergence: following an object brought slowly closer to the eyes by converging to retain a foveal image in both eyes. The second convergence movement concerns changing fixation from one object to another at a different distance: a re-fixation task for which there is the added stimulus of physiological diplopia. This second convergence movement is jump (step) convergence. The investigation of convergence can include both pursuit and jump convergence.

Near point of convergence (pursuit convergence) A suitable target is brought slowly towards the eyes from a distance of about 50 cm and on the median line until the patient reports that it doubles and/or the practitioner sees that one eye has ceased to converge. It may be instructive to note if the patient reports or demonstrates excessive discomfort during the test (Adler 2001). The target should be detailed (accommodative), of a size that is resolvable by each eye, and the patient should wear reading glasses where appropriate. 85% of children aged 5–11 years have a near point of convergence of 6 cm or less (Hayes et al 1998). Another study found that stricter norms are appropriate for younger children: 5 cm or less for children aged 0–7 years (Chen et al 2000).

With most older patients, the near point of convergence will be closer to the eyes than the near point of accommodation, and the target will be seen to blur before it doubles. The convergence should still be investigated even if the target is blurred.

Jump convergence test The patient is asked to fixate a small object placed at about 50 cm from the eyes and then to change fixation to a second object introduced at 15 cm. The patient's eyes should be seen to converge promptly and smoothly from the more distant object to the nearer one. Version movement of both eyes, hesitant or slow convergence, or no movement are all abnormal (Pickwell & Hampshire 1981a). A quantitative measurement can be obtained by repeating the test while gradually bringing the near target closer to the patient. The closest distance to which the patient can 'jump converge' is recorded.

The assessment of convergence by clinical tests needs to indicate if it will be adequate to cope with the needs of the patient in near vision. This can be decided by considering both convergence tests together; a near point of convergence less than 8–10 cm and good jump convergence are taken as adequate. A fuller discussion of convergence anomalies is given in Chapter 8 and other tests of vergence function are described in more detail elsewhere in this book, including fusional reserve testing (p 69) and vergence facility (p 72).

Accommodation

The amplitude of accommodation is a measure of the closest point at which the eyes can focus; it is the range from the far point to the near point in dioptres. Because it is measured from the far point, the measurement needs to be taken with the distance correction in place. It is therefore assessed after the refraction part of the routine examination.

The usual clinical method is to ask the patient to look at small print on a card that is moved slowly towards the eye until the patient reports that clear vision cannot be maintained. When a just noticeable blur occurs the card is moved in further to confirm that it becomes worse and is then moved back until it clears. The midpoint between the first blur and first clear positions is the near point (Reading 1988). The card is mounted on a near-point rule so that the dioptral distance can be read from the rule. In the case of a young patient with a near point close to the eyes, a negative sphere (-4.00 DS) is held before the eyes so that the accommodative range is moved to the middle of the rule (DS = dioptres of spherical power). The value of this sphere is then added to the reading. This is a subjective method and its accuracy depends on the patient's ability to distinguish a blur point, the depth of focus and other variables, but it is a standard clinical procedure. The repeatability (95% confidence limits) is ± 1.4 D, so a deterioration of less than 1.5 D is unlikely to be significant (Rosenfield & Cohen 1996). Accuracy can be improved by using smaller text as the target approaches, although this method will reveal conventional norms to be an overestimate (Aitchison et al 1994).

A subject that rarely receives the attention it deserves is the speed at which the target is moved when testing the amplitude of accommodation. Evans et al (1994) moved the target at 0.50 diopters per second (D/s) but Evans et al (1996a) used 1 D/s, which seems more practical in a clinical setting. This means that the target will move slower when it is nearer the patient. Patient instructions are also important (Stark & Atchison 1994) and it is best to ask patients to carefully look at the target. Literate patients can read text and pre-literate patients can describe a detailed picture: when they make errors then the end-point has been passed.

The expected amplitudes of accommodation (Table 2.2) for a given age can be calculated from the Hofstetter formulae (Reading 1988):

$$\text{Minimum amplitude (D)} = 15.0 - (0.25 \times \text{age in years})$$

$$\text{Probable amplitude (D)} = 18.5 - (0.3 \times \text{age in years}).$$

The values in Table 2.2 generally seem to be appropriate for European races living in temperate climates. It is accepted that there is a racial variation or differences caused by geographical area of upbringing (Duke-Elder 1970) that give a lower amplitude. Otherwise, an amplitude lower than the value in Table 2.2 is suspicious, indicating accommodative insufficiency. Accommodative insufficiency can result from some medications, such as antihistamines (Wright 1998) and alcohol abuse (Campbell et al 2001), but accommodation is only minimally reduced in patients undergoing heroin detoxification (Firth et al 2004). Abnormalities of accommodation related to binocular vision are considered in later chapters.

The amplitude of accommodation can also be measured monocularly using negative lenses. This will give a different result to the push-up method because the cue of proximity will be lacking.

Table 2.2 Expected minimum accommodative amplitudes for various ages, given in dioptres and centimetres

Age (years)	*Minimum (D)*	*Minimum (cm)*
4	14.00	7.00
6	13.50	7.50
8	13.00	7.75
10	12.50	8.00
12	12.00	8.25
14	11.50	8.75
20	10.00	10.00
30	7.50	13.25
40	5.00	20.00
50	2.50	40.00

Jump accommodation can be investigated using flippers, and this assesses the accommodative facility, or rate of change of accommodation (Fig. 2.5). This form of accommodative facility testing has been criticized because it is prone to a number of confounding variables (Kedzia et al 1999) but the test may be useful for children who report difficulties changing focus in class between the board and a book, or pre-presbyopic adults with similar symptoms (although such symptoms sometimes result from the onset of myopia). Typically, flippers with ±2.00 lenses are used at 40 cm, and Zellers et al (1984) found that the normal response for this test was 7.7 cycles per minute (cpm) with a standard deviation (SD) of 5 cpm. One cycle is a change from plus to minus and back to plus (i.e. two 'flips'). Since 68% of a normal population lie within 1 SD of the mean, then patients whose accommodative facility is 2.5 cpm or less are in the bottom 16% of performance at this test. Eperjesi (2000) recommended using the vertical **OXO** target on the near Mallett unit for this test, since it allows a check on suppression. Binocular vision problems are more likely to influence binocular than monocular accommodative facility, although there are many exceptions to this rule (Garcia et al 2000).

A very useful test for assessing accommodative accuracy is MEM (monocular estimate method) retinoscopy, which assesses accommodative lag (Cooper 1987). The patient binocularly fixates a detailed target on the retinoscope and is asked to keep this clear. Retinoscopy is carried out along the horizontal meridian and lenses are very briefly held in front of each eye to neutralize the retinoscope reflex. Each lens should only be present monocularly and for a split second so as not to disrupt the status of the patient's accommodative and binocular response. The accommodative lag is usually about +0.50 D; values greater than +1.00 D may represent accommodative insufficiency (see Appendix 10). If a negative lens is required to neutralize the reflex this suggests that accommodative spasm is occurring. This test may give useful additional information when there

Figure 2.5 'Flippers', as used to test or train accommodative or vergence facility. The patient is wearing polarized glasses and views the vertical fixation disparity target of the near Mallett unit to monitor for suppression.

is a low amplitude of accommodation, and with uncooperative patients. A slightly different approach (Nott retinoscopy) involves the fixation target being held in a constant position and the retinoscope being moved to and fro to obtain reversal. Typically, this reveals a slightly lower degree of accommodative lag (Cacho et al 1999).

Pupil reflexes

Anomalies of pupil reflexes may help in the diagnosis of binocular difficulties due to neural disturbances. It is necessary therefore to check the pupil reflexes to light, and in near vision. The direct light reflex is checked by shining a light into one eye and observing the pupil constriction. At the same time, the consensual reflex is checked by observing the constriction of the pupil of the other eye. This is repeated by shining the light into the other eye. The near-vision pupil reflex is checked by asking the patient to look at a distant object and then at one about 25 cm from the eyes: the pupil constriction accompanying the accommodation and convergence is observed.

A 'swinging flashlight' test should be carried out to detect any relative afferent pupillary defect (RAPD); this has been described as the single most important test in eye examination (Kosmorsky & Diskin 1991). Each pupil is stimulated by a bright pen torch light which is swung to alternately illuminate each eye, pausing for just 1–2 s for an eye to equilibrate with the light stimulus (Bremner 2000). If an eye has a RAPD then, when stimulated in this way, its pupil will dilate instead of constricting. This is because when the abnormal eye is stimulated the consensual reflex from the other eye will outweigh the direct response from the abnormal eye. The presence of a RAPD in the absence of gross ocular disease indicates a neurological lesion in the afferent visual system (Spalton et al 1984, p 19.15). A cataract will not produce a RAPD but a major retinal lesion or neurological lesion of the afferent visual pathway will. Dense amblyopia may also produce a RAPD.

When checking the pupil reflexes, abnormalities in size, irregularities in shape or inequalities between the right and left pupils should be noted.

Sensory investigation

Stereoacuity

Stereoacuity tests (see Fig. 3.3) can be classified as random dot and contoured, which are sometimes described as measuring *global* and *local* stereoacuity respectively (Saladin 2005). It has been argued that constant strabismus is always associated with markedly reduced random dot stereoacuity but not necessarily with greatly reduced contoured stereoacuity. However, one study suggests that patients who have fusion but lack stereoacuity, as may occur following patching in infancy, can do surprisingly well on random dot tests (Charman & Jennings 1995). Monocular cues have been shown to influence results in the following tests: Titmus circles (Cooper & Warshowsky 1977), Frisby (Cooper & Feldman 1979), random dot E (Cooper 1979) and TNO (Cooper 1979). The Lang II stereotest is not a reliable method of screening for strabismus or amblyopia (Ohlsson et al 2002a). Indeed, a large study of 12–13-year-old children suggests that none of the commonly used stereotests (Titmus, Frisby, Lang II, TNO, Randot) are suitable for screening for amblyopia or strabismus (Ohlsson et al 2001).

Clinical stereotests do not fully describe patients' ability to use stereopsis in everyday life, where monocular cues may be integrated with binocular cues (Harwerth et al 1998). Patients who perform poorly on clinical tests may still have stereo-perception for dynamic (moving) scenes in real life (Rouse et al 1989). Also, clinical stereotests suffer from a ceiling effect: the most difficult stimuli are easily attainable for most people (Heron et al 1985). Nonetheless, stereotests can provide useful information when the results are considered together with the results of other clinical tests.

The development of stereoacuity in young children is discussed in Chapter 3. Stereoacuity declines in advancing years because of alterations in early stages of visual processing (Schneck et al 2000). Impaired stereoacuity is correlated with a history of falls in older people (Lord & Dayhew 2001), indicating a need for binocular vision anomalies to be detected in this age group. Multifocal spectacles impair depth perception and edge-contrast sensitivity at critical distances for detecting obstacles in the environment and may contribute to the risk of falls when negotiating stairs and in unfamiliar settings outside the home (Lord et al 2002). Compared with other tests, the TNO test seems to underestimate stereoacuity in older people (Garnham & Sloper 2006) and it is best to use other tests with this age group.

Other sensory investigation

The Mallett foveal suppression (binocular status) test can sometimes detect a range of problems, including reduced visual acuity, foveal suppression in heterophoria, and strabismus. The test is described on page 82.

External and ophthalmoscopic examinations

During the early part of the examination, general observation of the patient can take place. With respect to binocular vision it is appropriate to notice:

(1) Compensatory head postures that may be adopted in incomitant deviations: a head-tilt, a rotation of the face to the left or right, or the face turned up or down
(2) Any obvious strabismus
(3) *Exophthalmos:* protrusion of one or both eyes
(4) *Epicanthus:* a fold of skin across the inner angle of the lids seen in some European children, and frequently in oriental races, which may give the appearance of a convergent strabismus; the cover test should confirm whether a strabismus is actually present
(5) Anatomical asymmetries, malformations or signs of injury
(6) *Ptosis or other anomalies of the lid openings:* patients may attempt to compensate for ptosis by using their frontalis muscle; this can be prevented by asking the patient to close their eyes when the practitioner presses against the frontal bone – pressure is maintained when the eyes are opened and significant frontal muscle activity is thus prevented
(7) Scleral signs of previous strabismus operations, which may show as a scar or a local reddening.

It is essential that a fundus examination is carried out to discover any signs of active pathology before proceeding to treat a functional deviation. An assessment of the visual fields is also advisable in patients who are old enough, as it will help to detect certain pathological abnormalities.

Retinoscopy and subjective refraction

In very many binocular vision anomalies, the correction of the refractive error is important in the treatment. For example, in many heterophoria cases no other treatment is required, and in accommodative strabismus it can be the principal treatment. Exact and full determination of the refractive error is often essential. The role of the refractive correction in particular anomalies is described in later chapters, and it is not the function of this book to give details of different methods of refraction. However, it is emphasized that great care must be taken to ensure that each eye is given the correction that will provide a sharp retinal image. This correction should be balanced between the two eyes in the sense that it is equally clear without either eye accommodating. This can be done objectively by passing the retinoscope light quickly from one eye to the other to ensure that, at the conclusion of the retinoscopic examination, both eyes are neutralized simultaneously. In heterophoria where there is binocular fixation, this is best done by asking the patient to fixate the retinoscope once the monocular error has been neutralized with distance fixation (Barrett 1945, Hodd 1951). Balancing can be carried out subjectively by several methods (Rabbetts 2000, pp 106–109): Humphriss fogging, polarized duochrome, Turville infinity balance or septum, or by an equalizing technique using alternate occlusion.

The indications for cycloplegic refraction are listed in Box 2.1. The use of atropine has been largely replaced by the safer cyclopentolate, and indeed tropicamide is adequate for most healthy, non-strabismic infants (Twelker & Mutti 2001). Ideally, cycloplegic refractions should be carried out in the late afternoon so that the binocularly stressful period of increased AC/A ratio occurs while the child is asleep (Jennings 1996). Additionally, photophobia caused by the cycloplegia will be less of a problem towards dusk. The child will need to be excused any homework.

In strabismus or amblyopia, retinoscopy is more important, as an accurate subjective test may not be possible on the amblyopic eye. Extra care must be taken to ensure that refraction is on the visual axis. In divergent or larger-angle convergent strabismus, the practitioner can move round in line with

Box 2.1 Indications for cycloplegic refraction

Symptom of ‘turning eye’
Other suspicious symptom (e.g. young child closing or covering one eye)
Esotropia
Significant esophoria
Low accommodation
Unstable objective or subjective refraction
Large discrepancy between objective and subjective results
Significant anisometropia in young child
Spasm of the near triad

the visual axis. The correct position can be judged by centring the reflection in the cornea of the retinoscope light. In the case of cycloplegic refraction, the patient can be asked to look at the retinoscope and the other eye is then occluded.

It is important to discover the full extent of anisometropia, usually with cycloplegic refraction. As the degree of anisometropia increases, so the risk of amblyopia and impaired binocularity increases (Rutstein & Corliss 1999).

Measurement and assessment of deviation

In heterophoria, the first requirement is to assess if it is compensated when any appropriate correction is in place. If the heterophoria was not compensated before the refractive correction was found but it is now better compensated, the correction is indicated as a part of the management of the heterophoria and in alleviating the symptoms. Assessing the degree of compensation with and without the spectacles is discussed in Chapter 4. The assessment should be made for distance or for near vision, according to when decompensation occurs. The measurement of the degree of heterophoria and investigation of stereopsis may be required as part of the assessment (Chs 3 and 4).

In strabismus, the angle of deviation is measured for distance and for near vision with the refractive correction in place so that its effect on the angle can be determined. The measurement can be made with the cover test, as described above. In the case of long-standing strabismus, binocular sensory adaptations may have developed to alleviate diplopia and confusion. The extent and nature of these adaptations will need to be determined. Sensory adaptations and their investigation is covered in the chapters on strabismus, but a routine is summarized here.

(1) Retinal correspondence can be investigated with Bagolini striate lenses or with a polarized test (e.g. the special Mallett large **OXO** test). The depth of abnormal retinal correspondence can be assessed with a filter bar before the deviated eye until diplopia or suppression occurs.
(2) Suppression can be investigated by the ease with which the patient gets diplopia and the depth of suppression determined with a filter bar in front of the undeviated eye until diplopia occurs.
(3) In esotropia, physiological diplopia may be elicited at a distance where the visual axes cross; this can indicate a good prognosis.

AC/A ratio

The AC/A ratio is the amount of convergence that occurs reflexly in response to a change of accommodation of 1 D. It can be measured in several ways but the most usual method is the *gradient test*. The degree of heterophoria for near vision is measured using a dissociation test with an accommodative target (e.g. Maddox wing test), with any habitually worn refractive correction in place. It is then measured with binocular positive additions to change the accommodation. The change in convergence per dioptre of accommodation is assessed. For example, if the heterophoria measurement with the prescription is 6 Δ esophoria, with an addition of +2.00 DS is 4 Δ exophoria, the vergence is changing by 5 Δ per dioptre of accommodation, i.e. an AC/A ratio of 5. The AC/A ratio may be different at distance and near (Rosenfield & Ciuffreda 1991, Spiritus 1994), but is little affected by the length of period of dissociation (Rosenfield et al 2000) or by previous adaptation to prisms (Rainey 2000). The effect of age on the ratio (Tait 1951) is slight, suggesting that the effort to produce a unit change in accommodation remains fairly constant with age (Ciuffreda et al 1997).

Another method of measuring the AC/A ratio is the *heterophoria comparison method*, in which the distance heterophoria is compared with the near heterophoria. The total change in convergence from distance to near is divided by the dioptric change. The total change in convergence needs to take into account the interpupillary distance and the heterophorias. The dioptric change, for example, is approximately 3 D from 6 m to 0.3 m. The formula is given in Appendix 10 (for derivation, see Jennings 2001a).

The heterophoria comparison method usually gives a higher value of the AC/A ratio, since the awareness of the proximity of the near target will increase the convergence at near (proximal convergence). In the gradient method there is no change in the proximal cue. It has been argued that the heterophoria method gives a better approximation to the true value (Jennings 2001a), although the phoria method is confounded by changes in tonic vergence (Bobier & McRae 1996) and may be less accurate (Ansons & Davis 2001). The gradient method is more relevant for predicting the effect of a refractive correction on the deviation at a given distance.

The dominant eye

Eyecare practitioners often refer to ‘the dominant eye’, for example when prescribing spectacles or prisms. However, there are many different methods of assessing ocular dominance (Fig. 2.6) and, for most people, the eye that is dominant will vary depending on the task. For example, the eye with best acuity is not necessarily the same as the sighting dominant eye (Pointer 2001). An exception to this is unilateral strabismus when the dominant eye will be the non-strabismic eye. With normal subjects, ocular dominance will even vary at different points in the visual field (Fahle 1987).

The significance of Figure 2.6 is that, when practitioners have to ask the question ‘Which is the dominant eye?’, they should choose a test to assess ocular dominance that is relevant to the question. For example, if the practitioner wishes to prescribe a prism just in front of one eye (the ‘non-dominant’ eye), the most appropriate test for determining which eye requires the prism is the test that is used to determine the prism (e.g. Mallett fixation disparity test). If a contact lens practitioner is prescribing monovision

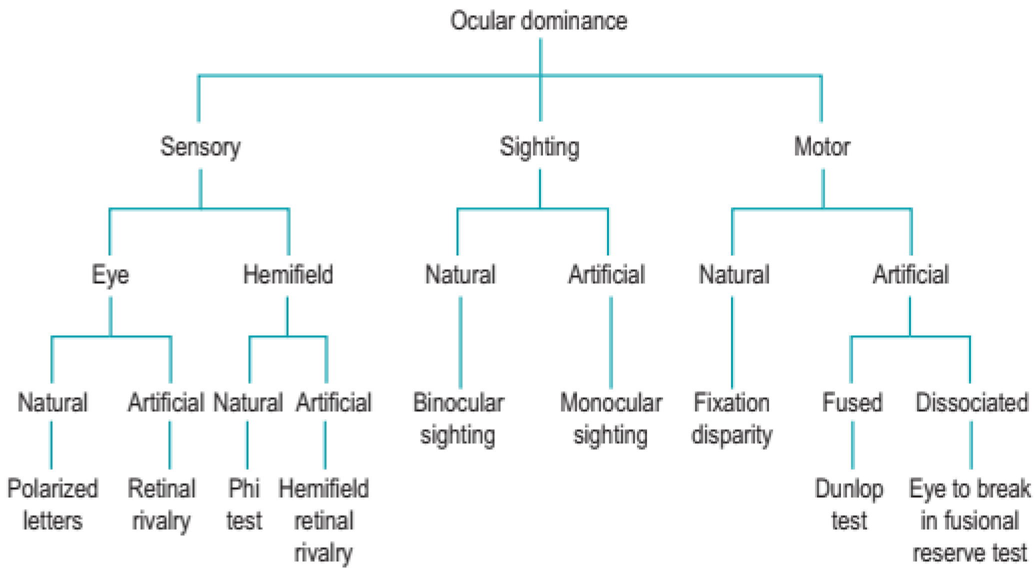

Figure 2.6 Classification of tests of ocular dominance. (Reproduced with permission from Evans 2001a.)

then the best method to determine which eye is preferred for distance is to simulate the monovision situation while the patient fixates in the distance and to see whether the patient is more comfortable when the left or right eye is blurred with a near vision lens (Evans 2007).

Clinical Key Points

- For all patients with two eyes, a thorough eye examination must always include an assessment of binocular function
- An assessment of binocular function is best carried out as a part of a complete eye examination. A careful assessment of ocular health and refractive status is an important part of the investigation of binocular vision anomalies
- The act of measuring binocular coordination usually influences the binocular status
- The orthoptic tests that best predict the binocular status during everyday visual function are those that most closely mimic everyday visual function
- The best time to explain a test is as you do it. The best time to explain a result is when you have finished all your tests and have the complete picture