CHAPTER 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 three objectives: to detect the presence of anomalies, indicate when further investigative tests are required, and to determine the management. In some cases, the presenting symptoms or history indicate 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 recognisable pattern, which is called the diagnosis. It is unhelpful that various diagnostic criteria apply to some binocular vision and accommodative anomalies (Cacho-Martinez, Garcia-Munoz, & Ruiz-Cantero, 2010); the issue of diagnostic uncertainty is returned to on p. 13. Based on the diagnosis, a decision can be reached on what to do for the patient: the management of the case. This process can be summarised as follows:

$$\text{Investigation} + \text{Evaluation} \rightarrow \text{Diagnosis} \rightarrow \text{Management}$$

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 Fig. 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 emphasises the binocular vision aspects. This chapter does not describe all the clinical procedures that routinely are used to investigate heterophoria and strabismus; most of these are described in later chapters. 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 best to leave a detailed explanation of the results until the end of the eye examination, when a full picture emerges.

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 create differing conditions and will therefore produce different results. Tests which 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.

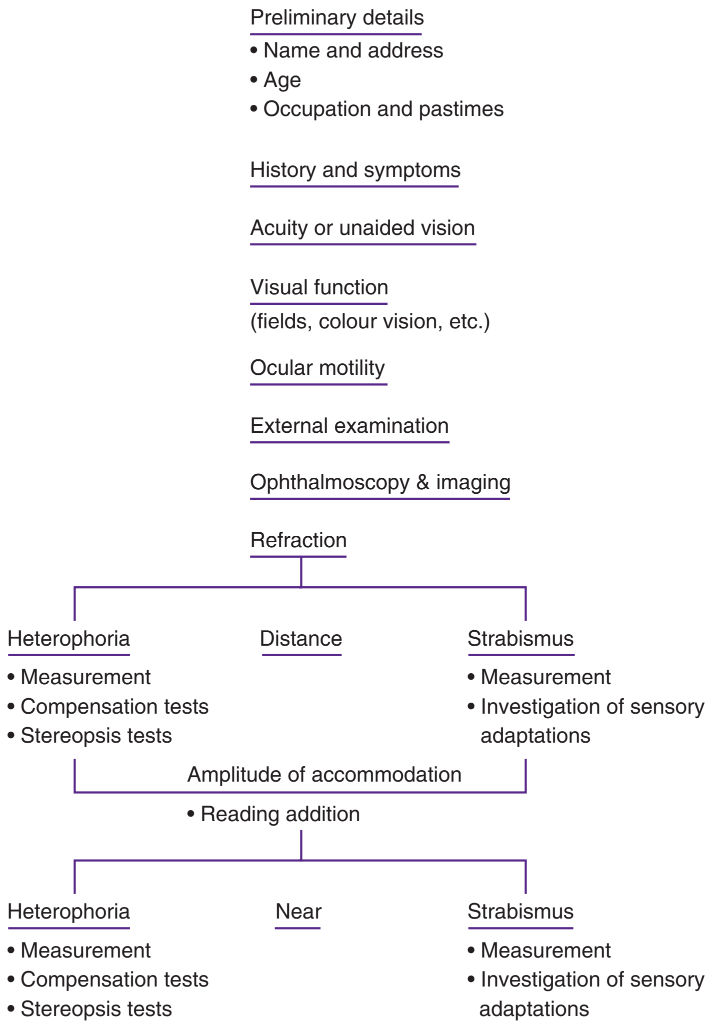

Fig. 2.1 Summary of routine eye and vision examination.

If the purpose of a binocular vision test is to detect what is happening with that person's visual system under everyday conditions, 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 gaming on their smartphone are attributable to a binocular vision anomaly. The most relevant tests are those that mimic the viewing conditions when they view the smartphone and include a cover test and Mallett fixation disparity test at the appropriate distance (pp. 74–79). It is best to carry out the most naturalistic tests (e.g., fixation disparity) before more dissociative tests (Brautaset & Jennings, 1999).

If, on the other hand, the purpose of a binocular vision test is to reveal information about the aetiology of a binocular vision anomaly, it may be helpful to fully dissociate the patient. 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. 133).

REFRACTIVE CORRECTION DURING BINOCULAR VISION TESTS

A 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. To discover whether symptoms in everyday life are related to a binocular vision anomaly, the binocular vision tests should be carried out with the patient wearing 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, they should carry out the tests with the patient wearing the proposed refractive correction. It will sometimes be appropriate to test patients under both conditions.

DIAGNOSTIC UNCERTAINTY: EFFECTS OF TEST REPEATABILITY, DIAGNOSTIC STABILITY, REGRESSION TO THE MEAN

The diagnostic process was described at the beginning of this chapter, and it was noted that disagreement over diagnostic criteria leads to uncertainty over diagnosis. Several other confounding factors influence diagnosis, and these will now be briefly considered. Fundamental properties of any clinical test are its repeatability (variation in measurements by the same person under the same conditions) and reproducibility (variation in measurements by different clinicians). There has been relatively little research on the reproducibility of many tests for diagnosing binocular vision anomalies.

Even if a clinical test perfectly measures the clinical status, it is possible that this status changes in an individual on different occasions. For example, fatigue may cause the angle of deviation to increase and/or a heterophoria to break down to a strabismus. Physical and mental activities can also influence test results (Vera, Jiménez, García, & Cárdenas, 2017), as can the instructions given to the patient (Karania & Evans, 2006a, 2006b).

The two factors just described will contribute to random errors on repeated measurements, which in turn lead to an effect described as **regression to the mean**. This statistical effect means that when a clinical measurement is repeated, individuals with extreme values (e.g., poor performance) at the first measurement are likely to change towards the population mean at the second reading. Regression to the mean occurs even when the person tested receives no treatment (Yu & Chen, 2014). This has consequences for researchers (Barnett, van der Pols, & Dobson, 2005) and clinicians (Morton & Torgerson, 2003). If a binocular vision anomaly is diagnosed from one measurement and then treatment is instigated, some patients may appear to have improved on treatment solely because of this statistical effect. One approach that will minimise this error is sequential testing (Morton & Torgerson, 2003). For example, in a prevalence survey, Stidwill (1997) made a diagnosis of decompensated heterophoria only when the Mallett fixation disparity test detected an aligning prism on at least two separate occasions. As a rule, repeat testing is recommended before a binocular vision anomaly is diagnosed. In exceptional cases, this may not be required; for example, if a patient reports intermittent diplopia and is found to have a very large exophoria that breaks down rapidly on the cover-uncover test.

The importance of repeat testing was highlighted in research (Adler, Scally, & Barrett, 2013) measuring the amplitude of accommodation (pp. 30—32), a test which is prone to many measurement errors (Burns, Allen, Edgar, & Evans, 2020). Adler and colleagues found, of 26 children who 'failed' the test at the first visit, with no treatment 58% passed at a second visit and 81% passed at a third visit. This highlights not only the importance of repeat testing to confirm a diagnosis, but also the problems inherent in converting a continuous variable (amplitude of accommodation) into a binary, pass/fail, variable (see Preface).

Randomised controlled trials (RCTs) will control for regression to the mean, but will nonetheless lead to an overestimation of treatment effects (Yudkin & Stratton, 1996). It is therefore preferable to use the mean of several measurements as the basis for selection in RCTs, and this approach has been used in a trial of vision therapy (Evans, Evans, Jordahl-Moroz, & Nabee, 1998).

Preliminary Details

Preliminary details will include such information as the name and address. More important clinically, however, 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 the visual demands 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 workplace can also help understand the cause of the patient's problem.

Symptoms and History

SYMPTOMS

General Comments About 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 anomalies as symptoms often occur at an advanced stage in the progression of a condition. In children, binocular anomalies can occur without any serious symptoms, due to sensory adaptations. The onset of a strabismus at an early age is seldom accompanied by symptoms. Older patients may attend because of symptoms which 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).

The eyes are just one organ in a complex organism and visual symptoms should not be considered in isolation. As discussed on p. 18, psychogenic factors can be the source of many visual symptoms and can indeed cause some ocular motor anomalies (see Case Study 2.1 on p. 35). Practitioners should be sensitive to anything that is causing anxiety, such as family problems, bullying at school or in the workplace, and health worries. Anxious people do not always appear anxious and sometimes, a gentle enquiry about whether there is anything causing the patient anxiety or stress can be revealing.

Headache

Headache is a common symptom. It may be caused by a very large variety of problems, many of which are unrelated to the eyes or vision. It is important to determine if any headache is associated with the use of eyes. Decompensated heterophoria can cause headache which occurs after prolonged use of the eyes, often under adverse visual conditions. Some authors have observed that the headache is most likely to be frontal (Pickwell, 1984a), but others say headache from asthenopia can be of any type (Duke-Elder & Abrams, 1970). 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. Refractive error is a risk factor for headache in children (Hendricks, De Brabander, van Der Horst, Hendrikse, & Knottnerus, 2007) and adults (Akinci et al., 2008). Appendix 11 is a headache diary that can be given to patients to help them identify whether there are any visual triggers.

An unusual source of headache that may present to the eyecare practitioner is trochlear headache, from inflammation to one of the structures in the trochlear region, related to trochleodynia and trochleitis (Tran, McClelland, & Lee, 2019). The condition can be misdiagnosed as migraine or tension-type headache, with which it can coexist. Referral is required for medical investigation and management.

It has long been claimed that migraine can be a symptom of heterophoria (Worth, 1905) and this is discussed further on p. 64. On average, patients with migraine have a slightly higher than usual prevalence of heterophoria, fixation disparity, and reduced stereopsis (Harle & Evans, 2006). There is no good evidence that these anomalies are a common cause of migraine.

Palinopsia, the persistence or recurrence of visual images after the stimulus has been removed, is an uncommon symptom which may need careful questioning to differentiate from diplopia. There are two types (Gersztenkorn & Lee, 2015). **Illusory palinopsia** describes after-images that are unformed, indistinct, or of low resolution and are affected by ambient light. This represents a dysfunction in visual perception resulting from migraine, drugs, or head trauma. In contrast, **hallucinatory palinopsia** describes after-images that are not usually affected by environmental conditions of light or motion and are long-lasting, isochromatic, and of high resolution. This category represents a dysfunction in visual memory and is caused by posterior cortical lesions or seizures (Gersztenkorn & Lee, 2015).

Diplopia

Diplopia is uncommon in long-standing strabismus, as sensory adaptations occur. Its presence therefore suggests 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, Wade, Richardson, & Stein, 1996). Deviations of recent onset may have a pathological cause. 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 visual tasks or directions of gaze. 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. A simple questionnaire has been developed for quantifying diplopia (Holmes, Liebermann, Hatt, Smith, & Leske, 2013).

Blurred Vision

Blurred vision is a common symptom in heterophoria. It can be associated with accommodative difficulties such as undercorrected presbyopia or hypermetropia. In these cases, blurred vision is more likely to be noticed by the patient during close work. 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 well-being (Lee, Spritzer, & Hays, 1997).

Poor Stereopsis

Poor stereopsis occurs with some binocular vision problems in which the patients report difficulty in judging distances. Patients often do not notice this symptom because of the many monocular clues to depth perception (Rabbetts, 2007).

Asthenopia

Asthenopia describes any symptoms associated with the use of the eyes, typically eyestrain and headache, including general tiredness or soreness of the eyes or lids. Asthenopic symptoms may be unrelated to the eyes and vision (Ip, Robaei, Rochtchina, & Mitchell, 2006), or can result from either internal (binocular and accommodative factors) or external (e.g., dry eye) factors (Sheedy, Hayes, & Engle, 2003). In this research, one of the conditions triggering internal asthenopia is induced astigmatism and Sheedy and colleagues assumed the mechanism was stressed accommodation and convergence from 'accommodative uncertainty and fluctuation'. An alternative hypothesis might be the direct effect of blur.

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. Asthenopic symptoms associated with the use of digital displays (desktop and laptop PCs, tablets, smartphones) have been collectively referred to as digital eye strain (DES) or computer vision syndrome (Rosenfield, 2016; Sheppard & Wolffsohn, 2018). The aetiology of DES can be divided into the same external and internal factors as conventional asthenopia (Gowrisankaran & Sheedy, 2015). Viewing distances are closer and asthenopic symptoms worse after reading from a smartphone for 60 minutes (Long, Cheung, Duong, Paynter, & Asper, 2017). Low power adds (+ 0.75) often improve symptoms and sometimes performance in DES (Yammouni & Evans, 2020).

A Swedish study suggested that asthenopia in school children is largely attributable to refractive error (Abdi, Lennerstrand, Pansell, & Rydberg, 2008). However, these authors did not use a standardised questionnaire for detecting asthenopia and graded their orthoptic test results rather than treating them as continuous variables (Cumberland et al., 2014). Another study argued that asthenopia is present in one-quarter of unselected children aged 6−16 years. Asthenopia is more likely to occur when there is a combination of visual compromise and cognitively demanding tasks (Nahar, Gowrisankaran, Hayes, & Sheedy, 2011).

There is considerable overlap between symptoms related to dry eye and binocular/accommodative anomalies and this emphasises the need for careful differential diagnosis (Rueff, King-Smith, & Bailey, 2015). Indeed, these researchers found that the correlation between the results of two dry eye questionnaires is lower than the correlation between a dry eye questionnaire and a questionnaire designed to detect binocular vision anomalies.

Dizziness and Vertigo

Dizziness and vertigo may occur in incomitant heterophoria (Chapter 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, 2007).

Monocular Eye Closure or Occlusion

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, Truong, & Hayes, 2003). 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). Photophobia commonly occurs in intermittent exotropia, and successful surgery only alleviates the photophobia in about half of cases (Lew, Kim, Yun, & Han, 2007).

Monocular eye closure under normal lighting conditions can occur to avoid diplopia or other visual symptoms associated with binocular vision anomalies. This is a relatively common sign of a binocular anomaly and some patients adopt an unusual head posture, so the nose occludes the view of one eye (e.g., reading or writing with the head on the page).

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. The history or symptoms may suggest trauma or pathological conditions which contribute to the cause of the strabismus (Chapter 17). Questions should be asked about the possibility of birth trauma (e.g., the use of forceps) and whether the birth was full term. Prematurity is associated with an increased risk of hypermetropia and anisometropia (Lindqvist, Vik, Indredavik, & Brubakk, 2007) and a fivefold increased risk of esotropia (Robaei, Huynh, Kifley, & Mitchell, 2006). If postnatal trauma is suspected, the practitioner should always be mindful of the possibility of nonaccidental 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, 1995).

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 and effect of treatment given. Generally, if a treatment has been tried and proved unsuccessful, it is not worth trying again. An exception is a child whose motivation to undertake eye exercises or wear spectacles might change over time.

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.

Many developmental conditions are associated with a higher than usual prevalence of binocular and accommodative anomalies and these are summarised in Table 2.1. Dyslexia (specific reading difficulty) affects about 7% of children (Hulme & Snowling, 2016). The main predictors of reading performance are nonvisual (e.g., phonemic awareness) and the relative contribution of visual-motor skills is small (Santi, Francis, Currie, & Wang, 2014). Dyslexia is sometimes associated with binocular instability (Chapter 5) although, in most cases, this is not a major cause of the dyslexia (Evans, Drasdo, & Richards, 1994). If patients with reading difficulties report asthenopia, this can be the result of binocular or accommodative anomalies or might be a sign of sensory visual stress (p. 64). As highlighted in the Preface, much research on this subject is of limited value for one or more of the following reasons (Evans, 2001a): excluding a high proportion of the relevant population (Shin, Park, & Park, 2009), lack of a control group (Christian, Nandakumar, Hrynchak, & Irving, 2018), not randomly allocating participants to treatment and control groups (Dusek, Pierscionek, & McClelland, 2011), not controlling for confounding variables (Palomo-Alvarez & Puell, 2010), dichotomising continuous variables (Shin et al., 2009), or assuming a correlation indicates a causal relationship (Hopkins, Black, White, & Wood, 2019).

Research on normal students may help to understand the relationship between binocular vision anomalies and dyslexia. For normal participants, when researchers induced a vergence conflict with prism or spherical lenses, performance at a cognitive task was impaired (Daniel & Kapoula, 2019). It is as if students had to reallocate some of their cognitive resources to maintain single and clear vision, causing a decrease in performance at the cognitive task. Tolerance to vergence/accommodation mismatch was lower in more difficult cognitive tasks. These researchers did not investigate dyslexics, but it could be speculated from this research that binocular instability might be more problematic for a dyslexic than for a good reader.

TABLE 2.1 ■ Some Developmental Conditions Associated With Binocular and Accommodative Anomalies.

Condition	Binocular and Accommodative Anomalies That are Prevalent in the Condition
Albinism	Low amplitude of accommodation (Karlén, Milestad, & Pansell, 2019) Nystagmus Stereoblindness, strabismus
Autism	Strabismus and amblyopia (Gowen et al., 2017) Reduced convergence and high accommodative lag (Little, 2018) Abnormal smooth pursuit and saccades (Gowen et al., 2017) (also, refractive errors [Little, 2018; Neuenschwander, Rohrbach, & Schroth, 2018], sensory visual stress [Ludlow, Wilkins, & Heaton, 2008])
Down syndrome	Reduced accommodative response; bifocals successful in 65% (Al-Bagdady, Stewart, Watts, Murphy, & Woodhouse, 2009) 29% risk of strabismus (Cregg et al., 2003); bifocals reduce the proportion with strabismus and the angle of strabismus (de Weger, Boonstra, & Goossens, 2019) Incomitant deviations Infantile nystagmus syndrome (also, keratoconus, cataract, iris pigmented spots, blepharitis, refractive errors, colour vision defects)
Fragile X syndrome	30% exhibit strabismus (also, refractive errors and visual motion processing)

Attention deficit/hyperactivity disorder (ADHD) has a higher prevalence in children with visual problems not correctable with spectacles or contact lenses (DeCarlo et al., 2014). Children with reading or other learning problems need a thorough vision assessment and vision screening is inadequate for these cases (Solebo, 2019).

FAMILY HISTORY

The highest familiar 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, Woodruff, Smith, & Thompson, 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 methods may be more appropriate (Chapter 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. 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, the 95% limits are approximately ±1 line (Smith, 2006). In children aged 6—11 years, 95% of cases are repeatable to within ±1.5 lines (Manny, Hussein, Gwiazda, Marsh-Tootle, & COMET study group, 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, a common feature of strabismic amblyopia (Chapter 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).

VISUAL CONVERSION REACTION (PSYCHOGENIC VISUAL LOSS; FUNCTIONAL VISION LOSS)

Reduced vision can result from a **visual conversion reaction** (VCR; psychogenic visual loss, functional visual loss). Typically, a child complains of blurred vision (Middleton, Sinason, & Davids, 2007) and the practitioner detects reduced visual acuity for no apparent reason. In about one-third of cases (Lim, Siatkowski, & Farris, 2005), the problem only affects one eye and might be misdiagnosed as amblyopia. It can occur at any age, affects mostly females, 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 (Lim et al., 2005).

Up to half of adults and a quarter of children with VCR have coexisting real pathology (Scott & Egan, 2003). Therefore, the term VCR is appropriate: it is as if the patient has subconsciously converted a real anomaly into a nongenuine anomaly with symptoms. For the practitioner, this means the presence of illogical or inconsistent symptoms should motivate them to redouble their efforts at searching for a genuine problem and monitor the patient closely. There is a complex interaction between psychogenic factors and visual function: sometimes there may be a measurable visual problem that nonetheless is thought to have a psychogenic function (see Case Study 2.1 on p. 35).

A vertical prism dissociation test has been shown to rapidly differentiate VCR from poor vision due to pathology (Golnik, Lee, & Eggenberger, 2004). The procedure is summarised in

TABLE 2.2 ■ **Test Routine and Norms for the 4Δ Vertical Prism Test.**

1. Have the child view an isolated letter from two lines larger than the visual acuity of their better eye, wearing any refractive correction required.
2. Hold a 4Δ trial lens base down in front of the better eye.
3. Ask the patient what they see.
4. If they only see one letter, they have very poor vision in one eye.
5. If they see two letters, ask how they are orientated and to describe the letters.
6. If they see one clear letter and one blurred letter, they have poor vision in one eye.
7. In visual conversion reaction (VCR), they will see two letters and will not comment that one is clearer than the other.

TABLE 2.3 ■ **Test Routine for the Paired Cylinders Test.**

1. A plus cylinder and a minus cylinder of the same power (e.g., 4 DC) are placed at parallel axes in front of the 'normal' eye in a trial frame.
2. The patient's normal correction is placed in front of the eye with poor acuity.
3. The patient is asked to read, with both eyes open, text that previously could be read with the normal eye but not with the poor eye.
4. As the patient begins to read, the axis of one of the cylinders is rotated about 10–15 degrees. The axes of the two cylinders thus will no longer be parallel, blurring vision in the normal eye.
5. If the patient continues to read the line or can read it again when asked to do so, he or she must be using the affected eye.

Table 2.2. An ingenious approach is the **paired cylinders test** in Table 2.3 (Miller, 2011). Another useful test is to measure the visual acuity twice, once at half the full testing distance (Zinkernagel & Mojon, 2009).

A useful way to explain VCR is that some people cannot describe their emotional difficulties in words and can only express them physically (Middleton et al., 2007). Counselling or psychiatric referral can be helpful.

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 (Simmons, 2017).

A basic investigation of ocular motor function normally includes:

1. *Cover test:* revealing 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, whilst 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 discussed. A summary of the procedure with this most important of binocular vision tests can be found at the end of this section.

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 which 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, a spotlight should be used for fixation. For preschool children, an animated cartoon movie may be an appropriate target (Troyer, Sreenivasan, Peper, & Candy, 2017). If it is known from previous eye examinations that a patient has a permanent or intermittent strabismus in one eye, the nonstrabismic eye should be covered first. Translucent occluders are available which allow the practitioner to observe the approximate position of the eye behind the occluder, without allowing the patient any form vision. 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. In performing the cover test, the eye is usually covered only for 1 or 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 strabismus, 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 Fig. 2.2, which shows the movements in right convergent strabismus (esotropia), and in Fig. 2.3, which shows right divergent strabismus (exotropia) with right hypertropia. The cover test will also help in investigating 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 typically reverts to the preferred eye. In other cases, the patient may be able to maintain fixation with either eye at will.
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

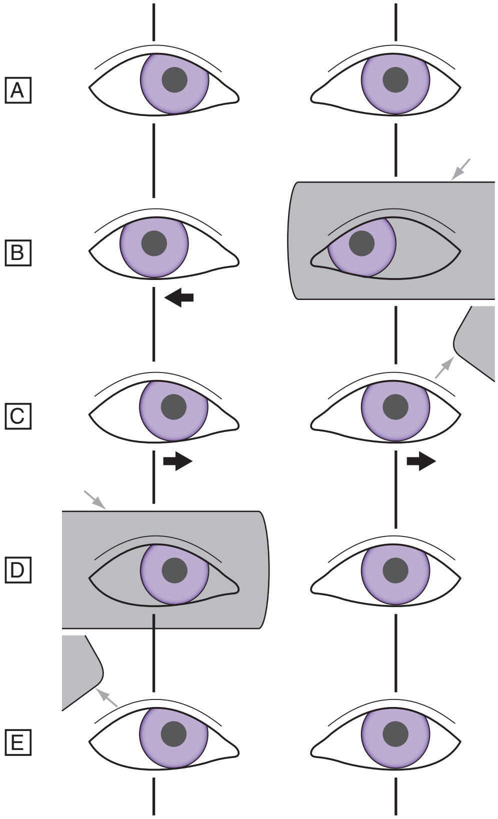

Fig. 2.2 Cover test in right convergent strabismus. (Movement of the eye is signified by the *bold black arrow*, movement of the cover by the *grey arrow*.) (A) Deviated right eye; (B) left eye covered, both eyes move to the right so that the right eye takes up fixation; (C) left eye uncovered, both eyes move to the left as the left eye again takes up fixation; (D) right eye covered, no movement of either eye; (E) cover removed, no movement. Note: both eyes move together in accordance with Hering's law (see Glossary).

of known magnitude. For example, an eye will make a version movement of 1Δ when the person looks between two objects 6 cm apart at 6 m. 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, then the resulting saccadic eye movement is 2Δ. On a typical LogMAR (ETDRS) chart, an eye movement from letters at one end of the 6/9 line (LogMAR 0.2) to the other end is equivalent to approximately 2Δ.

Cover Test in Heterophoria

This is illustrated with respect to esophoria in Fig. 2.4. The eyes are straight until they are dissociated by covering one. Then the covered eye deviates into the heterophoric position behind the cover. It will be seen to make a recovery movement when the cover is removed. In the simplest cases (Fig. 2.4A–C), the eye which is not covered will continue to fixate without making any movements when the other is covered or when the cover is removed. It should be noted that this is not in accordance with Hering's law of equal eye movements (see Glossary).

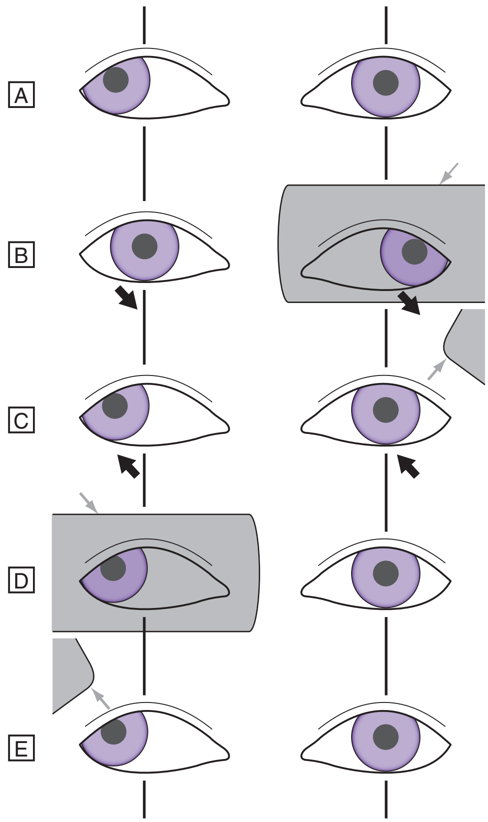

Fig. 2.3 Cover test in right divergent strabismus with right hypertropia. (Movement of the eye is signified by the *bold black arrow*, movement of the cover by the *grey arrow*.) (A) Right eye deviated out and up; (B) left eye covered – both eyes move left and downwards for the right eye to take up fixation; (C) left eye uncovered – both eyes move right and upwards as the left eye again takes up fixation; (D) and (E) no movement of either eye as the strabismic right eye is covered and uncovered.

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 and cases of strong ocular dominance (Peli & McCormack, 1983). 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 which has been covered, the second part of the recovery will be in the same direction as the versional movement. For the noncovered eye, the second movement will be a return to its fixation position. That is to say, the eye which 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 which 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. 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 (see Chapter 17).