1 NATURE OF BINOCULAR VISION ANOMALIES

Introduction

Binocular vision is the coordination and integration of what is received from the two eyes separately into a single binocular percept. Proper functioning of binocular vision without symptoms depends on a number of factors, which can be considered under three broad headings:

(1) The anatomy of the visual apparatus
(2) The motor system that coordinates movement of the eyes
(3) The sensory system through which the brain receives and integrates the two monocular signals.

Anomalies in any of these can cause difficulties in binocular vision, or even make it impossible. This is illustrated schematically in Figure 1.1. In considering the binocular difficulties of a particular patient, therefore, all three parts of the total system need to be investigated:

(1) *Anatomy*. Abnormalities in the anatomy of the visual system can be either developmental, occurring in the embryological development of

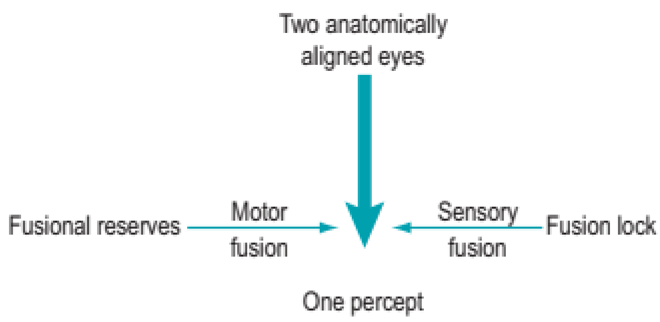

Figure 1.1 Simplified schematic model illustrating the interaction of an ocular motor function (fusional reserves) with a sensory system (sensory fusion) to achieve binocular single vision.

the bony orbit, ocular muscles or nervous system; or acquired through accident or disease.

(2) *Motor system*. Even if the motor system is anatomically normal, anomalies can occur in the functioning that can disturb binocular vision or cause it to break down. These may be due to disease or they may be malfunctions of the physiology of the motor system. For example, excessive accommodation due to uncorrected hypermetropia can result in excessive convergence due to the accommodation–convergence relationship. This is a fairly frequent cause of binocular vision problems. Examples of disease affecting the motor system are haemorrhages involving the nerve supply to the extraocular muscles, local changes in intracranial pressure near the nerve nuclei, or pressure on the nerves or nerve centres from abnormal growths of intracranial tissue. Such conditions require urgent medical attention to the primary condition and early recognition is therefore essential. The investigation for this type of pathology is discussed in Chapter 17.

(3) *Sensory system*. Anomalies in the sensory system can be caused by such factors as a loss of clarity of the optical image in one or both eyes, an image larger in one eye than the other (aniseikonia), anomalies of the visual pathway or cortex, or central factors in the integrating mechanism. Difficulties in the coordinating mechanism of the motor system can also be accompanied by adaptations and anomalies in the sensory system, such as suppression, abnormal retinal correspondence or amblyopia. These may occur in order to lessen the symptoms caused by the motor anomaly but are adaptations of the sensory system.

The anatomical, motor and sensory systems must be adequate for normal binocular vision to be present. The position of the eyes relative to each other is determined first by their anatomical position. Humans have forward-looking eyes placed in the front of the skull, and this brings the visual axes of the two eyes almost parallel to each other. In most cases, they are slightly divergent when the position is determined only by anatomical factors, and this is known as the *position of anatomical rest*. In normal circumstances, this state seldom exists, as physiological factors are nearly always operative also. When a person is conscious, muscle tone and postural reflexes usually make the visual axes less divergent: the *position of physiological rest*. Another physiological factor affecting the position of the eyes is the accommodation–convergence relationship: the eyes will converge as accommodation is exerted, and this is known as *accommodative convergence*. The final adjustment of the eyes is made to achieve single binocular vision. This is known as *fusional (disparity) vergence* and positions the retinal images on corresponding points (or within corresponding Panum's areas). For distance vision, this will produce parallel visual axes.

If fusional vergence is suspended, for example by covering one eye, the eyes will adopt a *dissociated position*. This is slightly deviated from the *active position* that is maintained when all of the factors are free to operate. This slight deviation from the active position when the eyes are dissociated is known as *heterophoria*, sometimes abbreviated to phoria. It is present in most people. The situation where a heterophoria is not present and the dissociated position is the same as the active position is known as *orthophoria*. It is stressed that the term 'heterophoria' applies only to the deviation of the eyes that occurs when the fusional factor is prevented by covering one eye or dissociated by other methods such as distorting one eye's image so that it cannot be fused with the other, e.g. the Maddox rod method (p 68). Heterophoria is sometimes described as a latent deviation: it only becomes manifest on dissociation of the two eyes. Sometimes the eyes can be deviated even when no dissociation is introduced. This more permanent deviation is called *heterotropia* or *strabismus*. Other, less favoured terms include *squint* (a confusing term because it is often used by patients to refer to half-closed eyes) or *cast*. Ocular deviations can, therefore, be classified as either heterophoria or strabismus, but there are other important practical classifications that need to be considered in investigating the binocular vision of a patient.

The symptoms and clinical features of most binocular vision anomalies fit into recognizable patterns. The recognition of these patterns is the process of diagnosis and this is an obvious preliminary to treatment. The classifications adopted here are intended to assist diagnosis (Fig. 1.2). The term *deviation* is used generically to describe strabismus and heterophoria. Cyclotorsional and vertical deviations often occur together, when they may be described as *cyclovertical deviations*.

Prevalence of binocular vision anomalies

Strabismus and amblyopia affect 2–4% (Adler 2001) and 3% of the population respectively. Between 18% (Pickwell et al 1991) and 20% (Karania & Evans 2006) of patients consulting a primary care optometrist have a near heterophoria that has the signs and symptoms indicating that it may be a decompensated heterophoria. Some authors give even higher prevalence figures (Montes 2001), so it could be said that every eyecare practitioner needs to have a working knowledge of binocular vision anomalies (orthoptics). Binocular performance is better than monocular at a wide range of tasks (Sheedy et al 1986).

Comitancy

Ocular deviations can be classified as comitant or incomitant. Comitant deviations are the same in all directions of gaze for a particular distance of fixation. Incomitant deviations vary with the direction of gaze; that is, as the patient moves the eyes to fixate objects in different parts of the field of fixation, the degree or the angle of the deviation will vary (Ch. 17). There may be no deviation in one part of the motor field but a marked deviation

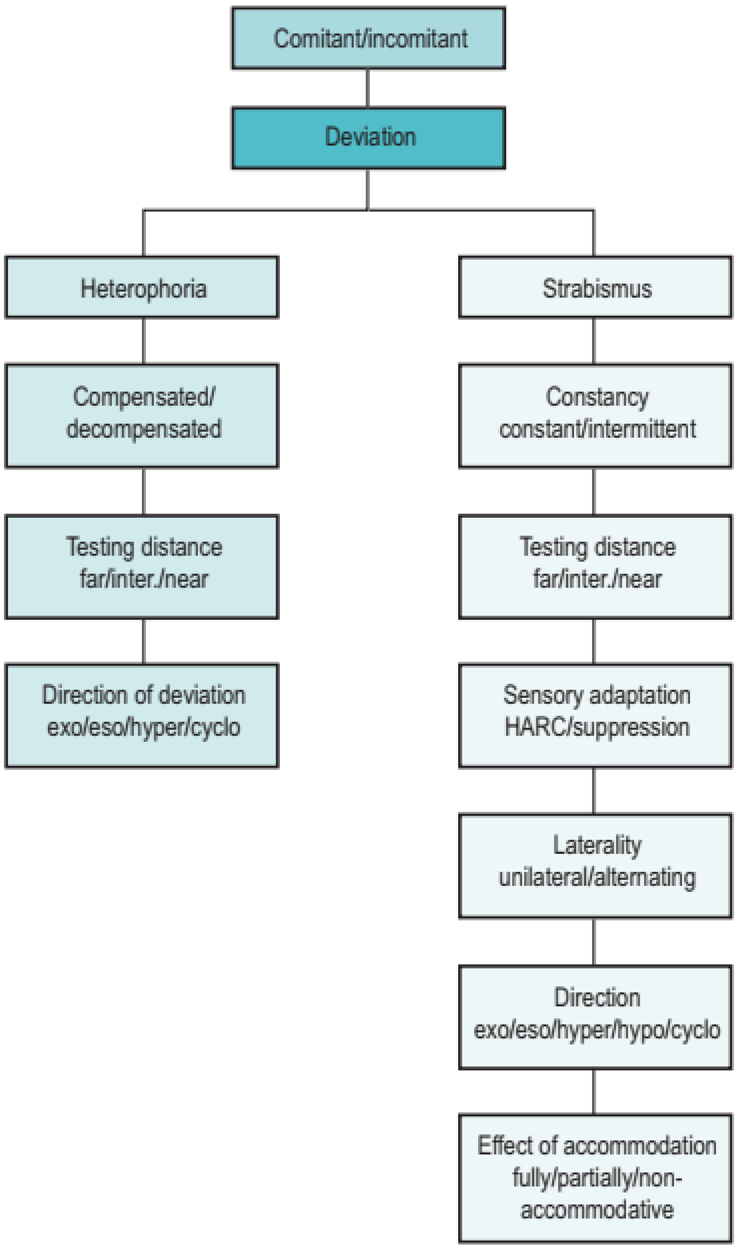

Figure 1.2 Classification of ocular deviations. Inter., intermediate; exo, exophoria or exotropia; eso, esophoria or esotropia; hyper, hyperphoria or hypertropia; cyclo, cyclophoria or cyclotropia; HARC, harmonious anomalous retinal correspondence; hypo, hypotropia.

in other parts. In incomitant deviations, the angle of deviation will also vary depending on which eye is fixating. Incomitant deviations are also referred to as paralytic or paretic: a paresis is a partial paralysis. Usually they are caused by abnormalities of anatomy or functioning of the motor system due to accident or disease, or abnormal development. It is important to distinguish incomitant deviations from those that are comitant as the treatment can be quite different and have different priorities. An incomitant deviation of sudden onset is usually caused by an accident or active pathology requiring immediate medical attention.

Classification of heterophoria

Heterophoria can be classified clinically by the direction of the deviation, by the fixation distance at which the heterophoria occurs, or whether it is compensated.

Direction of deviation

When the eyes are dissociated, the deviation that occurs can be in any direction or may be a combination of more than one direction. Classification according to the direction of the deviation is as follows:

(1) *Esophoria:* visual axes convergent when the eyes are dissociated
(2) *Exophoria:* visual axes divergent when the eyes are dissociated
(3) *Hyperphoria:* visual axes vertically misaligned when the eyes are dissociated: if the right eye is higher than the left it is 'right hyperphoria' and if the left eye is higher 'left hyperphoria'
(4) *Cyclophoria:* the eyes rotate about the visual axes when dissociated – if the top of the primary vertical meridian rotates nasally it is called 'incyclophoria' and if it rotates temporally 'excyclophoria'. It is doubtful whether cyclophoria exists in isolation without hyperphoria.

It should be noted that right hyperphoria is the same as a dissociated deviation of the left eye downwards. It can therefore be referred to as 'left hypophoria'. In practice, the term 'hypophoria' is seldom used, these deviations being referred to as right or left hyperphoria.

An excyclophoria of one eye is not the same as an incyclophoria of the other eye. For example, a right excyclophoria can, if the test conditions are manipulated, be made to 'transfer' to an excyclophoria of the other eye.

Fixation distance

The second method of classifying heterophoria is according to the distance of fixation. This is usually either at 6 m, which is the distance used for testing the patient's distance vision, or at the distance the patient uses for near vision, which is usually 30–45 cm. These are known as the 'distance phoria' and 'near phoria' respectively and they may differ in degree and direction from each other. The phoria may cause symptoms only for visual tasks at a particular distance. It is important to investigate the phoria at the distances at which the patient normally uses the eyes and to discover if the symptoms are associated with vision at any of these distances.

The vast majority of children are orthophoric at distance and are orthophoric or have a low degree of exophoria at near (Walline et al 1998). Between the ages of 5 and 10 years there is a very slight shift in the near heterophoria of decreasing exophoria and increasing esophoria (Walline et al 1998). During adult life, the average phoria for distance vision remains the same but at 65 years the mean near exophoria has increased by 6 Δ

(Δ is the symbol for prism dioptres). This exophoric difference for near vision is called *physiological exophoria* (Freier & Pickwell 1983).

One way of conceptualizing motor fusion is to link these mean heterophorias to the resting position of the vergence system (tonic vergence; Rosenfield 1997). If a person is in a totally darkened room with no visual stimuli then, typically, the eyes take up a position where they are aligned on a plane about 1 m away from the observer (although there is considerable intersubject variation). If this is taken to be the resting position of the vergence system then distance vision can be thought of as an active divergence and near vision as an active convergence away from the resting position. This model would explain why the average heterophoria at distance is a very slight esophoria and the average heterophoria at near is an exophoria (Freier & Pickwell 1983) and the effect of some drugs is to produce an eso-shift at distance and an exo-shift at near (Rosenfield 1997).

Duane (1896) suggested a method of classification for strabismus based on whether the vergence was greater for distance or near vision. This Duane–White classification is applied below in a modified form to heterophoria. It is useful in relating the patient's symptoms to the actual problem, and in selecting the most appropriate treatment.

(1) Esophoria
- **(a)** *Divergence weakness esophoria:* usually considered an anomaly of distance vision: the degree of esophoria is greater for distance than for near vision.
- **(b)** *Convergence excess esophoria:* a higher degree of esophoria for near vision than for distance.
- **(c)** *Basic (or mixed) esophoria:* the degree of esophoria does not differ significantly with the fixation distance.

(2) Exophoria
- **(a)** *Convergence weakness exophoria:* a higher degree of exophoria for near vision than for distance.
- **(b)** *Divergence excess exophoria:* a higher degree of deviation for distance vision than for near. This type often breaks down into a strabismus for distance vision and can also be classified as an intermittent heterotropia.
- **(c)** *Basic (or mixed) exophoria:* the degree of exophoria does not differ significantly with the fixation distance.
- **(d)** *Convergence insufficiency:* an inability to maintain sufficient convergence for comfortable near vision. It is often, but not always, accompanied by clinically detectable convergence weakness exophoria.

Compensation

The third and clinically very important classification of heterophoria is as either compensated or decompensated (Marton 1954). As already stated, heterophoria is a normal condition present in the vast majority of people. It is considered a physiological condition, as in most cases it is not harmful and causes no symptoms. In these circumstances it is described as 'compensated'. Sometimes, however, there are abnormal stresses on the binocular vision that result in symptoms and the heterophoria is described as being 'decompensated'. This is more likely to happen if there are developmental abnormalities in the anatomical, motor or sensory systems. These may not in themselves make the phoria decompensated and in very many cases do not. The trigger or catalyst that causes a heterophoria to become decompensated is often a change in the patient's general or visual conditions. The factors that may bring about such a change are listed in Chapter 4. The first consideration in treatment is to remove as many as possible of these decompensating factors.

Classification of strabismus

As well as deciding whether strabismus or heterotropia is comitant or incomitant, it can be classified according to constancy, eye preference and the direction of deviation. In some patients the angle varies with the accommodative state. Strabismus may also be present for both distance vision and for near vision, or at only one fixation distance. The angle of deviation may also vary with the fixation distance, giving classifications of divergence weakness, convergence excess or basic (mixed) types of convergent strabismus; and convergence weakness, divergent excess or basic types of divergent strabismus. These correspond with the classifications of heterophoria (above). A new system of classification has recently been suggested (Committee for the Classification of Eye Movement Abnormalities and Strabismus 2001), which is generally similar to that described here. It remains to be seen whether some of the new terminology that this committee has suggested will take hold (e.g. replacing 'Duane's retraction syndrome' with 'co-contractive retraction syndrome').

Constancy

Strabismus can be classified as either (1) constant or (2) intermittent. It is described as constant if it is present all the time and under all circumstances and intermittent if it is present at some times and not at others. Some cases of strabismus are intermittent in the sense that patients have coordinated binocular vision most of the time but when the visual system or general wellbeing is under stress the strabismus occurs. In these cases, binocular vision does not show the signs of decompensated heterophoria but breaks down into a strabismus. In some cases, an intermittent strabismus will develop into a constant strabismus if left untreated, but in others it remains intermittent. A rare form of intermittent strabismus in which the patient has a large convergent strabismus on alternate days only is referred to as 'cyclic strabismus' or 'alternate day squint'. Costenbader & Mousel (1964) found it to be less than 0.1% of all strabismus. The cyclic strabismus usually becomes constant after a few months.

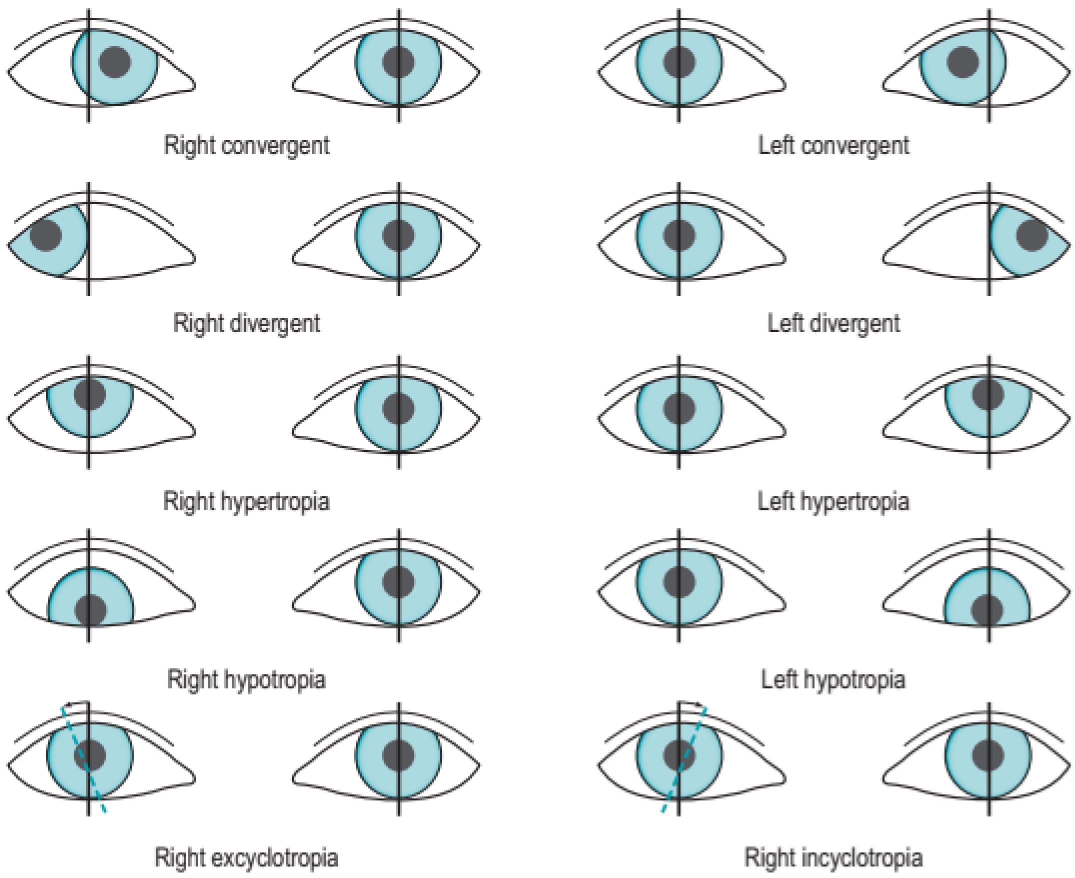

Figure 1.3 Classification of strabismus by direction of deviation.

In the case of intermittent strabismus, it is useful to assess the proportion of time when the strabismus is present. A patient who has binocular vision for most of the time may have a better prognosis.

Direction of deviation

The classification by the direction of the deviation is illustrated in Figure 1.3.

Eye preference

In strabismus, an image of the object of regard will be maintained on the fovea of one eye while the other eye is deviated. Some patients always use the same eye for fixation and others can fixate with either eye. Strabismus then can be classified as (1) unilateral or (2) alternating.

In alternating strabismus, the eye chosen for fixation at any given time can depend on:

(a) *Fixation distance*. Some patients will use one eye for distance vision and the other for near.
(b) *Direction of gaze*. In some patients the eye used for fixation will depend on the direction of gaze. In convergent strabismus, this often indicates

a congenital impairment in the abducting function of one or both eyes. The right eye fixates objects in the left of the field, and the left eye in the right; this is known as 'crossed fixation'.

(c) *Vision and refraction*. If the vision and the refractive error are equal or nearly equal, the choice of eye for fixation may appear indiscriminate. Some cases of this type are considered to lack the ability to fuse, and these have been called 'essentially alternating' (Worth 1903). These are often divergent strabismus and very rarely respond to treatment to establish binocular vision. Some other alternating strabismus will become unilateral if left untreated. In young children this is undesirable because it can result in amblyopia.

Accommodative state

The angle of the strabismus may vary with the amount of accommodation exerted. In hypermetropes this is an important factor in the treatment, so that strabismus may be classified as: (1) fully accommodative, (2) partially accommodative or (3) non-accommodative.

It is estimated that about two-thirds of cases of comitant convergent strabismus have an accommodative element. This means that the angle will be reduced by a refractive correction for hypermetropia; fully in some cases and partially in others. In such cases, the refractive correction forms a major part of the treatment of the deviation.

In about one-third of cases of comitant convergent strabismus, the refractive correction does not change the angle of deviation. These are non-accommodative strabismus. However, some patients who overconverge for near vision have non-accommodative strabismus. In these cases, the convergence excess is not stimulated by the accommodative effort.

Importance of classification

In the clinical assessment of both heterophoria and strabismus, the classification will assist in deciding what can be done to help the patient: the clinical management.

In cases of heterophoria, for example, the most important consideration is whether the deviation is compensated or decompensated (Ch. 4). Compensated heterophoria usually requires no action. The management of esophoria is different from that of exophoria. It will also differ if the heterophoria is present for near vision, as accommodation is normally active compared to distance vision. In the same way, the management of strabismus will depend first on the classification. This is further elaborated in Chapter 15.

Although classification is important, it must be borne in mind that some cases are difficult to classify and may be best described by their clinical features. Classifications often merge into one another, for example decompensated exophoria and intermittent exotropia.

Clinical Key Points

- Binocular coordination depends on anatomy, the motor system and the sensory system
- Binocular vision anomalies affect between 1 in 5 and 1 in 10 of patients seeing an optometrist
- Heterophoria can be classified according to the direction of deviation, fixation distance and compensation
- Strabismus can be classified according to constancy, direction of deviation, eye preference and accommodative state