Aetiology, epidemiology of heterophoria & Symptomatology of ocular motor anomalies

Outline notes to accompany City University 2nd year undergraduate Clinical Practice course lecture

Dr Simon Barnard PhD BSc FCOptom FAAO DCLP

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Introduction

Stevens (1886), cited by von Noorden, (1990) introduced the term heterophoria which is derived from the Greek words, heteros, meaning different from; and phora, meaning bringing or carrying.

Heterophorias may be described as ocular deviations kept latent by the fusion mechanism. If sensory fusion is suspended, or in some patients ‘embarrassed’ then a deviation in the visual axes will appear. This deviation is termed a heterophoria or phoria. It has also been defined as the locus of intersection of the lines of sight, measured with respect to the object of regard, in the absence of fusional vergence response (Rosenfield, 1997). Fry (1964) described the phoria position as “the position taken by the visual axes relative to one another, in the absence of all stimuli to fusion”. The presence of a leaky integrator (Zuber & Stark, 1968; Krishnan & Stark, 1977) allows for the return to the “phoria position” upon the application to one eye of an occluder in the cover test (Stark et al, 1980).
Aetiology of heterophoria

Lyle & Bridgemann (1959) suggested four main categories of causes of heterophoria. These are anatomical causes, refractive causes, uniocular activity and trauma.

Anatomical causes include an abnormal interpupillary distance. For example, hypertelorism, an abnormally wide interpupillary distance, might predispose a patient to a tendency for divergence. Orbital asymmetry may also give rise to heterophoria although Lyle & Bridgemann do not state whether this would induce a difference in phoria amplitude between the two eyes. Relative exophthalmos or enophthalmos may produce an exo- or esophoric tendency respectively. Finally, an abnormality of orbital fascia or ligaments may be a cause of an imbalance.

Refractive causes relate to the relationship between accommodation and convergence with, for example, uncorrected hypermetropia having a tendency to induce a shift towards esophoria.

The repeated and prolonged use of one eye, for example by a watchmaker, is also suggested as being a possible cause of heterophoria.

Prevalence and distribution of heterophoria

There appears to be a high prevalence of distance orthophoria in the population despite a large number of mechanical, neural, and sensory variables (Schor & Ciuffreda, 1983) and it has been suggested that this apparent orthophorization is due to vergence adaptation (Ogle & Prangen, 1953; Carter, 1965). Crone & Hardjowijoto (1979) suggest that orthophorization (or prism
adaptation) is abnormal in heterophoria. Dowley (1990) looked at a sample of 925 subjects and demonstrated a significantly non-normal ($p = < 0.05$) frequency distribution (see Figure 1) which supported the theory of orthophorization.

![Frequency distribution of 925 symptom-free heterophoric subjects (from Dowley D, 1990).](image)

Dowley (1990) suggests that orthophoria is achieved when vergence adaptation is unsaturated and the total deviation is well within a comfortable operating range for vergence adaptation and that distance heterophoria arises when vergence adaptation is partially saturated.

Eames & Cambridge (1933) measured near phoria for 212 non-presbyopes and found an average phoria of $0.4 \Delta$ exophoria. He also reported that the average phoria amplitude for a sample of 90 presbyopes was $7\Delta$ exophoria although he did not specify whether or not the amplitude was measured with a near reading addition in place.
It is interesting to note that manifest exo-deviations are reportedly more prevalent amongst females (Gregerson, 1969; Krzystkowa & Pajakowa, 1972), particularly as some authors have suggested a psychogenic cause for some exo-deviations (Knapp, 1958; Taylor, 1990) whilst others have reported a higher prevalence of psychosomatic visual anomalies in females (Mantyjarvi, 1981; Barnard, 1989).

An increase in exophoria for near vision with age has been described by a number of researchers (Morgan & Peters, 1951; Snydacker, 1962; Sheedy & Saladin, 1975; Freier & Pickwell, 1983). Snydacker (1962) found that the amount of exophoria increased in amplitude by $1.5^\Delta$ for every 20 years of age.

Yekta et al (1989) reported an increase in exophoria, associated heterophoria and fixation disparity with increasing age. They also found no evidence that a presbyopic reading addition accelerates an increase in fixation disparity or associated phoria with age and they concluded that there is an adaptation of these parameters to the reading addition.

Graefe (1967) (cited by von Noorden, 1990) reported an increase in the amplitude of deviation for near fixation under “the influence of bright light” in those patients with exophoria.

**Symptomatology of oculomotor problems**

Patients with oculomotor anomalies report various symptoms. Because of the close relationship between vergence and heterophoria anomalies it is difficult to attribute separately any particular group of symptoms to solely one or other entity.:

a) symptoms due to muscular fatigue caused by continuous use of reserve neuromuscular power
1. Headaches or aching eyes, referred to the muscles of which an excessive effort is demanded. Such symptoms occur during or after prolonged use of the eyes. A characteristic is that they disappear on closing one eye.
2. Difficulty in changing focus from distance to near objects of fixation or vice versa.
3. Photophobia, from which relief is obtained not by the wearing of dark glasses, but by closing one eye.

However, it should be noted that Eustace et al (1973) suggested that the photophobia reported by patients with poorly compensated exophoria associated with divergence excess, could be reduced with photochromic lenses.

b) symptoms due to the failure to maintain constant binocular vision
1. Blurring of print or "running together of words" when reading
2. Intermittent diplopia under conditions of fatigue

c) symptoms due to defective postural sensation
   This sensation is transmitted from the ocular muscles as a result of alteration of muscle tone causing difficulty in judging distances and position, especially moving objects.

c) head posture
   In exophoria the chin may be elevated and in esophoria the chin may be depressed. In cyclophoria the head may be tilted to one side.

Specific symptoms
Headache: Mallett (1966) suggested that the most common symptom in uncompensated oculo-motor imbalance is headache. Porcar & Martinez-Palomera found a prevalence of 18.5% in a population of students who were judged to have binocular dysfunction. They found asthenopia to be slightly more prevalent (21.5%). A summary of prevalence of symptoms in that study is shown in Table 1.

<table>
<thead>
<tr>
<th>Symptom</th>
<th>Prevalence (%)</th>
<th>Number of subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asthenopia after 1 or 2 hours</td>
<td>7.7</td>
<td>5</td>
</tr>
<tr>
<td>Asthenopia towards the end of the day</td>
<td>13.8</td>
<td>9</td>
</tr>
<tr>
<td>Headaches after 1 or 2 hours</td>
<td>10.8</td>
<td>7</td>
</tr>
<tr>
<td>Headaches towards the end of the day</td>
<td>7.7</td>
<td>5</td>
</tr>
<tr>
<td>Intermittent blurred vision at distance and difficulty in focusing when looking from far to near</td>
<td>12.3</td>
<td>8</td>
</tr>
<tr>
<td>Sensitivity to light</td>
<td>9.2</td>
<td>6</td>
</tr>
<tr>
<td>Intermittent blurred vision or words appearing to move</td>
<td>4.6</td>
<td>3</td>
</tr>
<tr>
<td>Intermittent diplopia</td>
<td>3.1</td>
<td>2</td>
</tr>
<tr>
<td>Poor concentration</td>
<td>3.1</td>
<td>2</td>
</tr>
</tbody>
</table>

Table 1 Prevalence of symptoms in a population of students manifesting binocular dysfunctions (from Porcar & Martinez-Palomera, 1997)

The position and characteristics of the headache are of limited diagnostic value (Mallett, 1966). However, Mallett claimed that most headaches due to esophoria, exophoria and convergence insufficiency will tend to affect the frontal or supra-orbital regions and, less often, the temporal and parietal areas. Hyperphoria tends to cause occipital headaches and cyclophoria usually prompts complaints of a “tight band around the head”, often associated with nausea. The headaches may be dull throbbing aches, aggravated by critical vision, and sometimes relieved by closing one eye. Mallett (1966) also believed that
heterophoric headaches usually accompany the visual act promoting the stress but suggested that esophoric induced headache may not commence until the following day. The duration of the headaches is variable.

_Diplopia:_ Mallett (1966) suggested that diplopia occurs frequently in uncompensated exophoria and convergence insufficiency but is rarely experienced in esophoria.

_Blurring:_ This may occur when the oculo-motor imbalance has an accommodative element (Mallett, 1966). A further symptom or sign, to be exact, is an interference in binocular visual acuity in the presence of horizontal associated phoria reported by Jenkins et al (1994).

_Asthenoopia:_ This may be described as a generalised discomfort and irritability of the eyes. The term is derived from the Greek: στήνος, strength; and ἄος, eye. Clarke (1893) described asthenopia as a symptom or group of symptoms that result from straining some part of the eye apparatus. It is worth noting that Sheedy & Saladin (1978) carried out an investigation into the association of symptoms with measures of oculomotor deficiencies. The questionnaire used in the study seeks to rank asthenopic symptoms but does not use headache as a separate symptom.

_Photophobia:_ An intolerance to bright light has been reported for patients with exo-deviations (Lyle & Bridgemann, 1959; Eustace et al, 1973; von Noorden, 1990).

_Other symptoms:_ Anecdotal reports of general ocular fatigue and strain, blepharitis, lacrimation, irritation, conjunctival hyperaemia (especially nasally), changes in head posture, and difficulty in judging distances have also been suggested (Lyle & Bridgemann, 1959; Purcell, et al, 1983).
**Suppression**: Deep central suppression can develop after a poorly compensated heterophoria has been present for some time. Suppression may cause a lessening or complete resolution of symptoms. Jampolsky (1964) suggested that manifest exo-deviations usually begin as an exophoria that may deteriorate into intermittent and constant exotropia as suppression develops.

The **relationship between oculomotor function and symptoms**

Over the years, various vergence criteria have been suggested as prerequisites for binocular comfort.

Donders (1864) (cited by Birnbaum, 1993) was the first to use a graphical form to portray the relationship between accommodation and convergence. He analysed the limits of accommodation that could be elicited at given levels of convergence, and postulated that accommodation could be comfortably sustained at a given fixation distance only if positive relative accommodation was greater than negative relative accommodation. Birnbaum (1993) goes on to cite Landolt (1886) who added the ranges of relative convergence to the graph, and proposed that not more than one third of the absolute range of convergence could be maintained without asthenopia.

The use of Sheard’s criterion (Sheard, 1957) is a method of prescribing prism that has been popular in the USA. Worrell et al (1971) described the criterion as ‘a classical, easily applied, and commonly used method to determine the amount of prism to be incorporated in spectacles for patients with neuromuscular imbalance and/or asthenopia’. Sheard claimed that for patient comfort, the demand on fusion (phoria) should be no greater than half the fusional ability (opposing relative fusional response). Specifically, for comfort, the amount of prism required equals two thirds of the phoria minus one third the compensating duction. If the result is positive, prism is needed in the amount
represented by the result; if negative, no prism is needed. The compensating duction is base-out to blur (or break if there is no blur) for exophoria and base-in for esophoria.

Percival’s criterion suggests that vergence demand should lie in the middle third of clear binocular single vision. This is sometimes known as the middle third technique (Solomons, 1978).

Mallett (1966), in his discussion on symptoms and signs of heterophoria, states that the degree of heterophoria may bear little relationship with the patient’s symptoms. He observes that a patient with less than $2\Delta$ lateral heterophoria may have severe discomfort and that higher degrees may be fully compensated. Here there is an allusion to a hypothesis that decompensated phoria is likely to cause symptoms. Fixation disparity and associated phoria (the degree of prism required to eliminate the fixation disparity) have been thought to be an indicator of decompensation of the heterophoria (Mallett, 1974).

Using a double blind experimental procedure, Worrell et al (1971) evaluated prism prescribed on the basis of Sheard’s criterion for 43 patients with muscular imbalance and asthenopic complaints. An evaluation of symptoms appeared to be made simply on patient preference to one of two pairs of spectacles. No attempt was made to evaluate symptoms in detail. They reported that the pre-presbyopic exophores did not prefer spectacles that contained prism, whereas the majority of the presbyopic group did.

Sheedy & Saladin (1977) examined two groups of subjects in an attempt to establish which optometric measures could be used to identify patients with oculomotor symptoms. The sample consisted of two groups of pre-presbyopic subjects. The first group comprised of 32 subjects selected from 50 optometry students with no ocular symptoms. The presence and strength of symptoms was evaluated by questionnaire and interview. Details of the questionnaire and how
the asthenopia was scored were not included in the paper. The authors stated that the study was double masked in that neither the subject nor the investigator had available the diagnostic data. The second group was comprised of 28 patients from the orthoptic clinic complaining of symptoms associated with near vision and diagnosed as having a lateral binocular oculomotor deficiency. They measured horizontal phoria, vergence ranges and forced vergence fixation disparity curves. Eleven clinical indicators or variables were derived from the data and discriminant analysis was used to determine which tests or group of tests best discriminated between the two groups and for exophoric and esophoric sub-samples. They reported that Sheard’s criterion was the best discriminator for the exophoric group, and the amplitude of heterophoria was the best discriminator for the esophoric group. The next best discriminator was a fixation disparity variable.

Sheedy & Saladin (1978) criticised their study as producing a biased symptomatic group as this group may have been affected by the referral criteria used by individual practitioners. Sheedy & Saladin (1978) repeated their previous study and removed any possible referral bias by dividing 103 optometry students into symptomatic and non-symptomatic groups based entirely on results of a symptom questionnaire. The average asthenopia level of the symptomatic group might be expected to be less severe than that of the symptomatic group in their previous study because the subjects were deliberately not drawn from a clinic population. An asthenopia scale of 1 to 8 was determined for both distance and near vision. Phoria, fusion ranges and forced fixation disparity curves were measured for each subject at 6 m and 40 cm. Only the near data was analysed as there were few high asthenopia ratings for distance. Subjects with an asthenopia rating of 1 were analysed as one group (n = 44) and subjects with ratings of 4 - 8 were treated as the second group (n = 33). Ratings of 2 and 3 were treated as borderline asthenopes and were excluded from the analysis. The data were analysed using discriminant analysis. Discriminant analysis may be used to distinguish
statistically between two or more groups, here symptomatic and asymptomatic, on the basis of a set of discriminating variables. For each variable, an F value is calculated on the basis of the values of the variables in the two populations (Sheedy & Saladin, 1978). Seventeen variables were selected or calculated from the clinical test results to serve as the discriminating variables.

Sheedy & Saladin reported that:

- Sheard’s criterion is the best discriminator for the entire sample and was a better discriminator for exo deviations compared to eso deviations
- Fixation disparity variables were good discriminators between the two groups
- Percival’s criterion was the best discriminator for the esophores

They argued that implicit in Sheard’s criterion is the concept of an opposing vergence compensating for a deviation. The concept that positive vergence is a more active process than negative vergence, together with the clinical impression that positive fusional vergence is more easily trained than negative vergence, is then meaningful in terms of Sheard’s criterion proving to be a better discriminator of symptoms in the exo population than in the eso group. Similarly, implicit in Percival’s criterion is the concept that visual comfort is found in the middle of the vergence range that suggests a passivity of vergence. The superiority of Percival’s criterion as a discriminator for eso deviations implies that the negative vergence is indeed passive.

Teitelbaum et al (1985) examined ninety optometry students and divided them into a symptomatic and an asymptomatic group on the basis of case history. One student was eliminated due to suppression. All subjects were correctable to 6/6 acuity. Symptoms reported by the subjects and used for categorisation included headache, asthenopia with near work, blurring or doubling of vision at near. However, no further details were given as to how these symptoms were graded. A forced vergence fixation disparity curve was
generated for each subject using a Disparometer. Slopes were calculated for each curve. In addition, each curve was labelled steep or flat. They reported that the gradient of the curves did not correlate well with the presence of symptoms. An independent t-test found no significant difference between the two groups, contrary to the findings of Sheedy & Saladin (1978).

Pickwell & Hampshire (1981) tested 455 patients and found that poor convergence movements were associated with decompensated exophoria for near vision as diagnosed on the Mallet unit. No evidence was found to associate an NPC greater than 10 cm with a high incidence of symptoms. However, poor jump-convergence movements were more frequently associated with symptoms.

Pickwell et al (1987) measured fixation disparity in a group of 40 binocular and mainly symptom-free subjects, at a good and at a poor level of illumination. Measurements were taken for near vision (40 cm) without prism, with 4Δ in, and with 4Δ out. In a second procedure, associated phoria was measured for fifty-seven subjects at the high illumination level and then they were asked to read for 10 minutes in reduced illumination. They were then asked to report any visual discomfort. A third experiment was carried out on 20 subjects to note discomfort after more prolonged reading under reduced illumination. The phoria at near was measured using the Mills test and the Mallett near vision fixation disparity unit was also used at 40 cm

They concluded that a reduction in illumination, when added to prism stress, will increase fixation disparity. The stress created by asking subjects to read in reduced illumination for half an hour resulted in the mean associated heterophoria being increased, and over half the subjects reported symptoms of stress. They further concluded that fixation disparity is changed by the visual stress employed in the study in some subjects, and in near vision is increased to a more marked exo-disparity. Most of this increase occurs in the first ten minutes
Yekta et al (1987) investigated oculomotor characteristics in eighty-four young adults in the morning and again in the afternoon. They reported an increase in the amplitude of associated phoria and fixation disparity at the end of the working day and that this seems to be related to the increase in the visual symptoms and discomfort. They found that associated phoria and fixation disparity showed a better correlation with visual symptoms than dissociated phoria readings and that as associated phoria and fixation disparity increase towards the end of the working day, the visual symptoms increased.

Jenkins et al (1989) examined two groups of patients, one under 40 years of age and the other 40 years and over. They used a method based on 'signal detection theory' to determine whether a value could be found for dissociated heterophoria (measured with the Mills test), or associated heterophoria (measured with the Mallett unit), which could predict which patients had symptoms due to decompensated heterophoria in normal routine investigation. Patients were categorised as either being symptomatic or symptom-free further grading. Measurements of dissociated phoria had little value in terms of discriminating between symptomatic and asymptomatic patients and concluded that the measurement of heterophoria amplitude is not useful as a routine procedure. In the case of associated heterophoria, for the under 40 years age group, patients with a value of $1^\Delta$ or more were more likely to have symptoms than not, and one-third of patients with close-work problems had a value of $2^\Delta$ or more. It was rare to find any asymptomatic patient with a value as high as this. In the 40 years and over age group 64% of patients with an associated phoria of $2^\Delta$ or more were symptomatic.

Feldman et al (1992) demonstrated significantly higher ratings of asthenopia after induced vergence compared to version. However, they were unable to show a significant correlation between asthenopia scores before and after induced vergence in their sample of normal subjects ($n = 30$). Possible reasons noted for this result were that subjects in their sample were largely
asymptomatic with restricted asthenopia scores. They also suggested that the experimental task was not representative of the tasks normally carried out by the subjects environment and that the experimental intervention may not have been prolonged enough to produce stress.