The Mallett Fixation Disparity Test: influence of test instructions and relationship with symptoms

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Abstract
Fixation disparity is a minute ocular misalignment under conditions of binocular single vision and is typically detected in primary eye care practices in the UK using the Mallett Unit Fixation Disparity Test. This instrument creates natural viewing conditions, when the patient's binocular system is fused using both central and peripheral fusion locks. This allows the examiner to determine the minimum prism power that eliminates the fixation disparity: the associated phoria or aligning prism. The spherical power that eliminates the fixation disparity, the aligning sphere, can also be determined. The near Mallett Unit Fixation Disparity Test has been shown to have good sensitivity and specificity for detecting symptomatic heterophoria. Cases of decompensated heterophoria tend to have a fixation disparity and the aligning prism or aligning sphere is a good indicator of the correction that will render the heterophoria compensated. The purpose of this study was, for the first time, to investigate the effect of test instructions on the results of the Mallett Unit Fixation Disparity Test. In study 1, we surveyed and observed practitioners to determine the instructions that are typically used. In study 2, we compared results obtained with this ‘standard’ method of questioning with a more ‘specific’ form of questioning that has been suggested in the literature. The participants for study 2 were 105 patients aged 7–70 years who were randomly selected from those attending a community optometric practice. Significantly different results were obtained with the two sets of instructions. The specific form of questioning revealed more cases of fixation disparity and the results with this method showed a better correlation with symptoms. This only held for near vision: for distance vision, symptoms were not significantly correlated with the presence of fixation disparity. This agrees with previous work with the Mallett unit, which showed a significant relationship with symptoms only at near. We also found that patients with more severe symptoms had greater degrees of aligning prism. Our study supports previous work indicating that the Mallett unit is a useful tool for detecting symptomatic heterophoria at near. However, we found that the testing method is important: patients need to be asked not just whether the nonius strips are aligned but also whether one or both of the strips ever moves. More research is needed to investigate the significance of precise test instructions in other optometric and orthoptic tests.

Keywords: aligning prism, associated heterophoria, decompensated heterophoria, fixation disparity, Mallett unit, nonius markers, visual symptoms

Introduction
During normal binocular vision the object of regard stimulates retinal elements in each eye which give rise to the same subjective visual direction, so that the person perceives one image of the object. These elements have conventionally been described as corresponding retinal points or elements (Tschermak, 1924 cited in Ogle, 1964). The term corresponding retinal points is really a misnomer as there is a point to area correspondence.
This area is called Panum’s fusional area, following a description by Panum, 1858 (cited in Carter, 1957). Panum’s fusional areas are elliptical with their long axes horizontal and they increase in size in the periphery (Mitchell, 1966).

Panum’s fusional space is the spatial counterpart of Panum’s fusional area and is contained within two curved surfaces, one on each side of the horopter surface (Mallett, 1974). All objects lying within this three dimensional space will fall in Panum’s areas and will therefore be seen singly. Panum’s area allows for some imprecision in eye movements without the introduction of diplopia (Nelson, 1988). Objects lying outside Panum’s fusional space may appear in physiological diplopia.

Fixation disparity occurs when the images of a binocularly fixated object do not stimulate corresponding retinal points but still fall within Panum’s fusional areas, the object thus being seen singly (Cline et al., 1967; Hebbard, 1964; Schor and Tyler, 1981). Ogle (1989). If the image is blurred then the fixation disparity increases (Hebbard, 1964; Schor and Ciuffreda, 1983). The finding that the apparent dimensions of Panum’s areas vary with different testing conditions and target parameters may help to explain studies indicating that Panum’s areas may be much larger than the conventional view (Fender and Julesz, 1967; Hyson et al., 1983; Erkelens and Collewijn, 1985; Collewijn et al., 1991).

Mallett interpreted fixation disparity as a sign of stress when the fusional reflexes are incapable of maintaining perfect superimposition of normally corresponding receptive fields (Mallett, 1974, 1988), and there is considerable evidence to support this view. Joshua and Bishop (1970) found that the binocular response from optimally superimposed receptive fields is greater by about 45% than the sum of unisocular responses. Fixation disparity, as detected with the Mallett unit, is associated with a reduction of the binocular visual evoked potential (Heravian-Shandiz et al., 1993) and of binocular visual acuity (Pickwell, 1991; Jenkins et al., 1994a,b, 1995). Similarly, fixation disparity is associated with a reduction in stereoscopic visual acuity (Cole and Boisvert, 1974; Saladin, 1995; Ukwade et al., 2003). Fixation disparity can be induced in normal subjects under abnormal test conditions such as reducing the ambient lighting to mesopic levels (Pickwell et al., 1987a,c) or reading at an unusually close working distance (Pickwell et al., 1987b). Computer users who prefer longer than average viewing distances have abnormal fixation disparity curves and are more likely to experience symptoms if forced to work at a normal viewing distance (Jaschinski, 2002).

Several authors have concluded that fixation disparity tests should include both foveal and peripheral fusion details (Jampolsky, 1956; Hebbard, 1960; Carter, 1964; Lyons, 1966; Ogle et al., 1949). The lack of a central fusion lock destabilises (Wildsoet and Cameron, 1985) and increases (Brownlee and Goss, 1988) fixation disparity and under these unnatural conditions fixation disparity is therefore a less useful indicator of visual stress (Evans, 2002).

Instrumentation

Many studies of fixation disparity have used the technique of moving monocular markers (bars or lines) until they are perceptually aligned in a binocular vernier alignment task. The amount through which the line has to be moved is translated into an angular measurement of fixation disparity. Examples of instruments that measure the actual fixation disparity are the Sheedy Disparometer (Sheedy and Saladin, 1975) and Wesson Card (Wesson and Koenig, 1983), neither of which is widely used in the UK. These devices can be used to plot the forced vergence fixation disparity curves showing the
effect of horizontal prisms on fixation disparity. Ogle et al. (1967) first described these and classified them into four types and their clinical relevance was evaluated by Sheedy and Saladin (1977). Yekta et al. (1989a) found that the central slope of the forced vergence vergence curve was not significantly associated with symptoms.

Instruments that measure the angular fixation disparity tend not to have a central fusion lock so that the monocular marker lines are directly adjacent. This facilitates the vernier alignment task, but leads to higher levels of fixation disparity and less stable results than when a central fusion lock is present (Brownlee and Goss, 1988). Indeed, fixation disparity measurements are affected by a number of target design characteristics (Goss and Patel, 1995; Ukwade, 2000) and by inclination of gaze (Jaschinski et al., 1998).

The Mallett Unit Fixation Disparity Test (Figures 1 and 2) is commonplace in optometric practices in the UK. The central fixation target OXO is seen with both eyes and the two monocular markers (nonius strips) in line with the ‘X’ are seen one with each eye using cross polarising filters. The instrument detects fixation disparity, but instead of measuring angular fixation disparity the instrument determines the prismatic or spherical power that eliminates the fixation disparity. This variable has been termed the associated phoria or, more recently (as suggested by the International Standards Organisation) the aligning prism or aligning sphere (Evans, 2002). Jaschinski described a simple method of estimating the fixation disparity with this instrument by asking patients to indicate the amount of nonius offset as a percentage of the width of the nonius lines (Jaschinski, 2001, 2002).

The Mallett distance (Figure 1; Mallett, 1966; Mallett and Radnan-Skibin, 1994) and near (Figure 2; Mallett, 1964) tests were designed so that the only disturbances to normal binocularity are the monocularly viewed nonius markers (Goss, 1995) and the reduction of ambient lighting by the cross-polarising visor. To allow for this reduction, the ambient lighting should be increased. The original distance test (Figure 1, left hand figure) employed a target that could be rotated for investigating vertical and horizontal heterophoria independently (Mallett, 1966). This was later modified (Figure 1, right hand figure) so that both horizontal and vertical heterophoria could be assessed without adjusting the test and this was shown to produce similar results to the original design (Mallett and Radnan-Skibin, 1994). Mallett (1966) explained some design details by which the distance chart differs from the near unit.

Apart from the Mallet unit, other instruments that measure aligning prism are the American Vectographic Slides (Goss, 1995; Griffin and Grisham, 1995), the Zeiss Polatest (Haase, 1962; Cameron, 1982), Berrnell Test Lantern (Brownlee and Goss, 1988), Borish Near Point Card (Borish, 1978), and RMS Rotary Near Point Card (Goss, 1991). The present paper concentrates on the Mallett unit as this is widely used in the UK.

Measurement of aligning prism is a useful clinical test in the investigation of binocular stress but should not be considered in isolation from other test results and must be related to the presence or absence of symptoms (Yekta et al., 1987). Mallett (1974) claimed that patients with decompensated heterophoria all have fixation disparity with his test; and conversely the absence of fixation disparity demonstrates the adequacy of the fusional reserves to cope with whatever heterophoria may be present. Research investigating these claims is discussed below.

**Figure 1. Mallett Distance Fixation Disparity Test.** The left hand picture is the original design, which can be rotated through 90° to either test vertical deviations (as shown) or horizontal deviations. The right hand picture is the newer Dual Fixation Disparity Test.

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Evans (2002) classified the symptoms of decompensated heterophoria into three categories: visual symptoms (blur, diplopia, distorted vision); binocular difficulties (difficulty with stereopsis, improved comfort with monocular viewing, difficulty changing focus); and asthenopia (headache, aching eyes, sore eyes, general irritation). These symptoms can arise from other causes, which is why clinical tests are necessary to confirm the diagnosis of decompensated heterophoria.

Mallett (1974) stated that there could be three reasons why, in rare cases, decompensated heterophoria might be present without any associated symptoms: deep foveal suppression in one eye as a sensory adaptation to avoid symptoms, lack of critical visual tasks, or
testing with a different refractive correction. These cases, where decompensated heterophoria is not synonymous with symptomatic heterophoria, are said to be rare affecting only 6% of a clinical sample who exhibited a fixation disparity with the Mallett unit (Mallett, 1974).

The use of fixation disparity tests to detect symptomatic heterophoria

Sheedy and Saladin (1977, 1978) performed two studies of the relationship between asthenopia and various diagnostic criteria for horizontal imbalances, including fixation disparity. However they used the Sheedy disparometer, which does not have a good foveal fusion lock.

Yekta and Pickwell (1986) investigated the Mallett fixation disparity unit, which was modified so that the angular fixation disparity could be measured as well as the aligning prism. They found a low correlation between the magnitude of the heterophoria and fixation disparity. There was no significant difference in heterophoria between symptomatic and asymptomatic subjects, but the symptomatic participants did have significantly higher degrees of fixation disparity. This agrees with the suggestion of Mallett (1974) and Sheedy and Saladin (1978) that fixation disparity is a better indicator of decompensated heterophoria than the degree of heterophoria. Yekta et al. (1989a) again found no significant relationship between symptoms and heterophoria, but found that both fixation disparity and aligning prism for near vision were associated with symptoms. They concluded that, compared with heterophoria, fixation disparity and aligning prism are better indicators of decompensation of binocular vision at near and that they are more useful tests to incorporate in the routine optometric examination.

Jenkins et al. (1989) investigated the relationship between aligning prism at near and symptoms. Their data (Figure 3) suggest that if an aligning prism of 1 Δ or more is taken as indicating a test fail for the Mallett test, then the sensitivity would be 75% and specificity 78% for detecting symptomatic heterophoria in pre-presbyopes.

Pickwell et al. (1991) investigated the relationship between Mallett aligning prism and symptoms. They were unable to demonstrate any useful relationship for distance vision but found that aligning prism can be very useful in the detection of decompensated heterophoria at near.

The Mallett Fixation Disparity Test in clinical use

On the distance Mallett unit, the nonius test lines are 18.3 and 5.2 min of arc in length and width respectively.
to differ depending on the precise instructions that were used, and this led to a recommendation for testing method and instructions (Figure 4; Evans, 2002).

The goal of our first study was to obtain an indication of the diversity of instructions that are currently used with this test and to determine the typical testing method. The goal of the second study was to determine if the precise test instructions influence the result and if so to evaluate which instructions are associated with results that best predict symptoms.

Study 1

Study 1: Method

A questionnaire was distributed to approximately 90 optometrists. The selection criteria were broad: approximately 20 were attending continuing professional development courses or were colleagues of the authors; 50 were posted to practitioners randomly selected from the General Optical Council (GOC) register; and 15 responded to an invitation to participate publicised on the UK Optometry E-Mail Discussion List.
The questionnaire assessed how frequently various binocular vision tests were used including the Mallett Fixation Disparity Test (Karania, 2004). In order to minimise response bias, the practitioners were told that the study related generally to binocular vision tests and they were unaware that we were specifically investigating the Mallett unit.

Fifty-three responses were received and 85% of these reported regularly using the Mallett Fixation Disparity Test. Of these, 27 practitioners indicated that they were willing to be contacted for the second part of the survey for the researcher to observe them whilst carrying out a routine eye examination to discover normal testing methods. Eleven practitioners were contacted to arrange this, of whom 10 gave consent. Because of time constraints and distances involved, eight practices (10 practitioners in total) were visited concentrating in the London/Essex area.

Practitioners had all been qualified within the last 5–10 years except for one who had < 5 years experience. They were asked not to change any part of their habitual routine. These practitioners were unaware that the research was about the fixation disparity test. The age group of patients being examined and observed varied from approximately 7–60 years. Following informed consent from both practitioners and patients, the eye examinations were observed and in particular, the instructions applied when carrying out the fixation disparity test were noted and audio recorded in some cases. Only the testing methods were recorded and no details that would identify any patients or practitioners were noted.

Study 1: Results

Of the survey respondents, 35% always used the Mallett Unit Fixation Disparity Test, 50% sometimes, and 15% never. Of the 50% who reported using the test ‘sometimes’ an equal proportion were using it for distance as for near. In response to another question, most practitioners only reported using the test when signs and/or symptoms are present. Most practitioners (66%) who participated in the study and used a Mallett unit worked in independent practices, with 23% employed by corporate bodies. The remainder worked in both types of practices and one did not specify the type of practice.

Five practitioners were using the Dual Mallett Fixation Disparity Test (Figure 1, right hand figure). One practitioner was using a projector chart copy of the Mallett test, but the instructions this practitioner used were found to be similar to the others. A set pattern of questions emerged as being typical, as described in Table 1.

### Table 1. Results of Study 1. Phrases used with the Dual Mallett Fixation Disparity Test are quoted, but similar instructions were used with other versions, just replacing ‘four lines’ with ‘two lines’

<table>
<thead>
<tr>
<th>Instructions to the patient</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>‘Can you see the circle with the four red lines and the cross’ and ‘are each of them lined up with the cross?’</td>
<td>Can you see the circle with the two red/green lines and the cross?</td>
</tr>
<tr>
<td>‘Are the four lines forming a cross with the X in the middle?’ or ‘Are the strips directly above and below the X?’</td>
<td>Can you see the two red/green lines and are they lined up with the cross in the middle?</td>
</tr>
<tr>
<td>‘Are the lines lined up with the X in the centre?’</td>
<td>Can you still see the red/green lines and are they lined up with the cross in the middle?</td>
</tr>
</tbody>
</table>

Study 1: Discussion

The typical instructions as determined from the survey were used to derive the instructions for the ‘standard method’. The exact wording for this was adopted as follows:

1. ‘Can you see the OXO with the two red/green lines?’
2. ‘Good, keep looking at the OXO; can you say whether the two red/green lines are lined up with the X or not?’
3. ‘Now turning it the other way, can you still see the red/green lines and are they lined up with the cross in the middle?’
4. When the dual fixation disparity unit was used, the question was changed to: ‘Can you see the noughts and crosses with the four red lines and the cross in the middle? Can you see all the red lines and if so, are they lined up with the cross in the centre?’

The main difference between this standard method and that described in Figure 4 is that the method in Figure 4 not only asks if the nonius markers are precisely aligned, but also asks if one or both of the markers ever moves. Anecdotally, the second author had observed that many patients who report that the nonius markers are aligned also report that one or both move. The significance of this was investigated in study 2 where the standard method using the instructions outlined above was compared with the specific method using the instructions in Figure 4.

Study 2: Effect of instructions

Study 2: Participants.

A group of 107 participants were randomly selected from patients consulting the first author for routine eye examinations. Selection criteria were aged 7–70 years, able to understand and follow the test instructions, visual acuity of at least 6/9 in each eye, no strabismus (as determined by cover testing), no history of eye surgery, normal visual fields, no ocular pathology, and provision of informed consent. The study was approved by the City University Research Ethics Committee.

Study 2: Procedure.

Participants completed a symptom and history questionnaire (see Appendix) whilst waiting for the eye
examination. The symptom data were summed to give a
distance symptom score and a near symptom score. The
following symptoms were scored as 0 if absent at the
appropriate distance and 1 if present at the appropriate
distance: blurred vision, double vision, sore tired eyes,
rubs eyes when reading, holds books unusually close or
far, closes or covers one eye, blinks excessively, tilts head
when reading/writing, poor concentration, tires easily
when reading. If patients reported one of these symp-
toms but it was not clear from the questionnaire
response whether it was with distance or near visual
tasks then a score of 0 was given for both distances.
Headaches were reported as never/seldom/often, which
were scored as 0/1/2 respectively for distance or near. If
the comments on the questionnaire indicated that the
headaches were non-visual (e.g. hormonal), then a score
of zero was given for headache. After the symptom
questionnaire had been completed, a full eye examina-
tion was carried out including the tests listed in Table 2.

For aligning prism measurement, standard Mallett
units were used. At distance, approximately one third of
participants were tested with a Mallett–Hamblin motor-
ised two-position model (Figure 1, left hand figure) and
approximately two-thirds with a Dual Mallett Fixation
Disparity Test (Figure 1, right hand figure). At near a
unit was used with the horizontal and vertical fixation
disparity test targets (see Figure 2).

Each patient was tested at both distance and near
twice, once with the ‘standard’ instructions and then
with the ‘specific’ instructions, wearing their current
optical correction for each appropriate distance (includ-
ing bifocals and varifocals). The type and level of
lighting throughout was a mixture of background
fluorescent lights and an incandescent reading lamp
directly illuminating the near Mallett unit (luminance
measured as 35–40 cd m\(^{-2}\)).

Cross-polarised filters were used so that one eye saw
each nonius marker in the usual way. Subjects were
asked to concentrate on the letter ‘X’ of the OXO and to
report the position of the red or green monocular
markers, as described above. They were then asked to
report if there was any flickering/flash/lingering of the
nonius markers. With both methods, the horizontal
reading was taken first followed by the vertical, and the
minimum amount of prism found to realign the nonius
markers was recorded. Each prism was presented briefly
for a maximum of 5 s each time to minimise adaptive
effects. The prisms were increased in 1 \(\Delta\) increments
(0.50 \(\Delta\) for particularly precise patients) and placed
before the eye(s) with the fixation disparity. Between
changes of prism the patient was asked to read a few
letters on the six-metre chart or read a few lines from the
text surrounding the OXO on the near Mallett unit to
stabilise accommodation and convergence (Dowley,
1989). The type and degree of aligning prism were
recorded, together with details of any suppression. For
near the subject was asked to hold the near Mallett unit
at 40 cm and to read a few sentences from the text
before starting.

Usual research practice in a study of this type is to
randomise the order of testing, so that half the
participants would be tested first with the standard
method, and half first with the specific method.
However, in the present study there is a contra-
indication to this usual practice, as the two testing
methods are not independent. The specific instructions
contain all the information in the standard instruc-
tions, and additional information. Once participants
have been given the specific instructions then they have
been in essence trained in the specific method, and if
they are subsequently tested using the standard method
then the additional information that they have been
trained to look for would contaminate the results with
the standard method. So, it would be meaningless in
this study to test participants with the standard
instructions after they had been tested with the specific
instructions. Therefore, all participants were first tested
with the standard instructions, and then afterwards
with the specific instructions.

**Study 2: Results**

Two participants were excluded from the study: one
did not understand the instructions and gave unreliable
responses and the other failed to meet the visual acuity
selection criterion. Usable data were obtained for 105
subjects, of whom 54% were females. The mean age was
37.4 years (S.D. 18.5, range 8–71 years).

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**Table 2. Components of the eye examination. The tests were
carried out in the order in which they are listed. All ocular motor
balance tests were carried out with any refractive correction that was
usually worn at the relevant distance**

<table>
<thead>
<tr>
<th>1. Symptoms and history</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. Unaided vision at distance and near</td>
</tr>
<tr>
<td>3. Distance and near visual acuities with current spectacles</td>
</tr>
<tr>
<td>4. Cover test distance and near</td>
</tr>
<tr>
<td>5. Near point of convergence</td>
</tr>
<tr>
<td>6. Ocular motility</td>
</tr>
<tr>
<td>7. Pupil reactions</td>
</tr>
<tr>
<td>8. Ophthalmoscopy</td>
</tr>
<tr>
<td>9. Mallett fixation disparity test for distance ‘standard method’</td>
</tr>
<tr>
<td>10. Mallett fixation disparity test for near ‘standard method’</td>
</tr>
<tr>
<td>11. Mallett fixation disparity test for distance ‘specific method’</td>
</tr>
<tr>
<td>12. Mallett fixation disparity test for near ‘specific method’</td>
</tr>
<tr>
<td>13. Retinoscopy</td>
</tr>
<tr>
<td>14. Subjective refraction and visual acuities</td>
</tr>
<tr>
<td>15. Amplitude of accommodation</td>
</tr>
<tr>
<td>16. Binocular status (foveal suppression test on Mallett unit)</td>
</tr>
<tr>
<td>17. Stereopsis (Randot Stereotest)</td>
</tr>
<tr>
<td>18. Intra-ocular pressure (Keeler Pulsair Tonometer)</td>
</tr>
<tr>
<td>19. Visual field (Zeiss Humphrey Field Analyzer)</td>
</tr>
<tr>
<td>20. Visual field (Zeiss Humphrey Field Analyzer)</td>
</tr>
</tbody>
</table>
All participants achieved N5 at near in each eye except for one who achieved N6 in each eye and one who read N5 in one eye and N6 in the other. There was no pre-existing horizontal or vertical prism in the ‘current’ spectacles for any of the subjects (this was not a selection criterion). The mean spherical component of the refractive error was low hypermetropia (R +2.00 DS, L +2.25 DS; range –2.75 to +6.50), the mean cylindrical error was –0.60 in each eye (maximum negative cylinder –2.00), and there was no anisometropia over 3.00 D (Karania, 2004).

The majority of subjects had apparent orthophoria on cover testing. At distance, 6.6% were exophoric and 0.9% esophoric. At near, 25.7% were exophoric and 8.6% esophoric. No cases of vertical heterophoria were detected by cover test at distance or near. Other binocular vision test results (e.g., near point of convergence, amplitude of accommodation, stereopsis) were unremarkable and are described in more detail in Karania (2004).

Table 3 lists the proportion of participants exhibiting a fixation disparity. For horizontal results the specific instructions reveal a fixation disparity in about twice as many cases at distance and about three times as many at near. A few participants exhibited a fixation disparity with the standard method and not with the specific method (for the horizontal readings, 8% of participants at distance and 3% at near), but many more participants demonstrated a fixation disparity with the specific method and not with the standard method (for the horizontal readings, 29% of participants at distance and 25% at near).

Table 4 shows the proportion of participants who had eso- and exo-aligning prisms. This shows a higher prevalence of exo-aligning prism than eso, particularly at near. The total horizontal aligning prism was calculated for each participant under each condition and for each distance by summing the monocular aligning prisms. The descriptive statistics for this variable are shown in Table 5. The median and 25th and 75th quartiles were zero at both distances by both methods.

The magnitude of aligning prism required in the specific fixation disparity method was significantly different to that required in the standard fixation disparity method, at both distance (Wilcoxon test, p = 0.014) and near (Wilcoxon test, p < 0.001). Usually, the recommended method of assessing the agreement between two methods of clinical measurement involves plotting the difference vs the mean and using the standard deviation of the difference to calculate the 95% limits of agreement of the difference (Bland and Altman, 1986; Zadnik et al., 1994). In view of the nonparametric nature of our data, we used the modified nonparametric approach recommended by Bland and Altman (1999). This involves plotting the usual diagrams, but including as reference lines the values of difference between which 90% of the population lie, as defined by the 5th and 95th centiles (see Figure 5).

The relationship of aligning prism with symptoms

Of the 105 participants, 22 (21%) reported some symptoms relating to distance vision and 54 (51%) reported some relating to near vision. The distance symptom score ranged from 0 to 3 with a median of 0 and the near symptom score ranged from 0 to 7 with a median of 1.

If the presence or absence of fixation disparity (either horizontal or vertical) is considered as a possible screening test for the presence of symptoms, then the sensitivity, specificity, positive predictive value, and negative predictive value can be calculated (Table 6). Table 6 shows that for distance vision testing, neither set of instructions achieved good sensitivity. For near vision testing, the standard instructions achieved low sensitivity but the specific instructions achieved a higher level of sensitivity (39%), with a specificity of 78%. These data are based on the ability of the presence of any degree of aligning prism to predict any symptoms attributable to work at the appropriate distance. Figure 6 shows the receiver operating characteristics (ROC) for near vision

<table>
<thead>
<tr>
<th>Analysis</th>
<th>Condition</th>
<th>eso</th>
<th>exo</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance vision</td>
<td>Standard</td>
<td>6.5</td>
<td>8.5</td>
</tr>
<tr>
<td></td>
<td>Specific</td>
<td>15</td>
<td>21</td>
</tr>
<tr>
<td>Near vision</td>
<td>Standard</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Specific</td>
<td>11</td>
<td>19</td>
</tr>
</tbody>
</table>

Table 3. Proportion (%) of participants exhibiting a fixation disparity for standard and specific instructions at distance and near

Table 4. Proportion (%) of the total sample with eso- and exo-aligning prism for standard and specific methods at distance and near

Table 5. The median and 25th and 75th quartiles were zero at both distances by both methods.
testing which shows that the best compromise between sensitivity and specificity was obtained with the specific questions using the cut-off of 0.50\(\Delta^+\) or 1\(\Delta^+\). The same values of sensitivity and specificity were obtained for 0.50\(\Delta^+\) as for 1\(\Delta^+\), but only a few participants were tested with 0.50\(\Delta^+\) prisms (see Discussion). This type of analysis will inevitably be influenced by limitations in the symptoms data, and this is considered further in the discussion.

This approach, of classifying patients by the presence or absence of symptoms, can be taken further by comparing the absolute (unsigned) magnitude of aligning prism in participants with symptoms to those without symptoms. Any type of aligning prism (horizontal or vertical) that was present was included in this calculation and for the very few participants who had both a horizontal and vertical aligning prism by a given method at a given distance, then the higher value was taken. For either method of test instruction at distance and for the standard method of test instruction at near the magnitude of aligning prism did not differ significantly in those participants with symptoms compared to those without symptoms (Mann–Whitney U-test, \(p > 0.18\)). However, for the specific method of test instruction at near, participants with symptoms

Table 5. Descriptive statistics for total (sum of right and left) horizontal aligning prism. Eso-aligning prism is scored as positive, exo- as negative

<table>
<thead>
<tr>
<th>Analysis</th>
<th>Condition</th>
<th>(N)</th>
<th>Median</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Absolute median</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance vision</td>
<td>Standard</td>
<td>105</td>
<td>0.00</td>
<td>-2.00</td>
<td>4.00</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>Specific</td>
<td>105</td>
<td>0.00</td>
<td>-5.00</td>
<td>3.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Near vision</td>
<td>Standard</td>
<td>105</td>
<td>0.00</td>
<td>-2.00</td>
<td>4.00</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>Specific</td>
<td>105</td>
<td>0.00</td>
<td>-6.00</td>
<td>6.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>

Table 6. Descriptive statistics for screening test variables of the presence of fixation disparity (screening test) for detecting the presence of symptoms

<table>
<thead>
<tr>
<th>Condition</th>
<th>Sensitivity (%)</th>
<th>Specificity (%)</th>
<th>Positive predictive value (%)</th>
<th>Negative predictive value (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance vision standard instructions</td>
<td>18</td>
<td>83</td>
<td>22</td>
<td>79</td>
</tr>
<tr>
<td>Distance vision specific instructions</td>
<td>27</td>
<td>57</td>
<td>14</td>
<td>75</td>
</tr>
<tr>
<td>Near vision standard instructions</td>
<td>13</td>
<td>94</td>
<td>70</td>
<td>51</td>
</tr>
<tr>
<td>Near vision specific instructions</td>
<td>39</td>
<td>78</td>
<td>66</td>
<td>55</td>
</tr>
</tbody>
</table>

Figure 5. Difference in total horizontal aligning prism (specific method – standard method) plotted against their average. Base out prism is scored as positive, base in as negative. The chart includes ‘sunflowers’ to indicate cases that are overlapping or nearly overlapping: each petal or spike on a sunflower represents one case. The upper reference line represents the value below which 95% of the population falls and the lower reference line represents the value below which 5% of the population falls.

Figure 6. Receiver operating characteristics (ROC) curve illustrating the ability of aligning prism to predict the presence of any symptoms relating to near vision.

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had significantly higher readings of aligning prism than those without symptoms (Mann–Whitney U-test, \( p = 0.039 \)).

The two methods of analyses used so far consider symptoms only as being present or absent, which is dependent largely on the questions that are asked and ignores data on the severity of symptoms. We therefore compared the symptom scores of participants with a fixation disparity with the scores of those who do not have a fixation disparity, for a given instruction method (Figure 7). At distance, the symptom scores of participants with a fixation disparity were not significantly different to the scores of those without a fixation disparity, for either the standard method of instruction or the specific method of instruction (Mann–Whitney U-test, \( p > 0.23 \)). At near, using the specific instructions, the patients with a fixation disparity had a significantly (Mann–Whitney U-test, \( p = 0.011 \)) higher symptom score than those without a fixation disparity. A similar effect was apparent in the data from the standard test method at near, but this did not reach significance (Mann–Whitney U-test, \( p = 0.14 \)).

Finally, we investigated the Spearman correlation coefficients between the symptom scores and the absolute magnitudes of aligning prism (horizontal or vertical, as defined above). At distance, the correlation between these two variables was low and not significant for either the standard or the specific method (\( r_s < 0.1 \)). At near, the correlation between symptom score and aligning prism was low for the standard method (\( r_s = 0.15, p = 0.12 \)), but was higher and significant for the specific method (\( r_s = 0.27, p = 0.005 \)). This latter relationship is illustrated in Figure 8, which shows the mean near vision symptom score plotted for different magnitudes of aligning prism. The subject numbers for higher degrees of aligning prism are small (quoted on the graph immediately below the horizontal axis) which is why, for Figure 8, aligning prisms of two or more has been collapsed into one category of ‘2+’. For the 1 and 2+ categories of aligning prism the symptom scores are normally distributed, but this is not the case for the 0 category of aligning prism owing to a disproportionately high number of participants with a symptom score of zero. The mean and standard error of symptom score within this 0 aligning prism group should therefore be viewed with caution.

**Discussion**

The practitioner survey in study 1 reveals that 85% of optometric practitioners surveyed sometimes use the Mallett Unit Fixation Disparity Test and the typical instruction set is to ask whether the nonius markers are aligned. The more specific question of whether one or both strips ever move does not seem to be routinely asked. Limitations of study 1 include the small sample size and the restriction to the south-east of the country. However, we did use a range of different types of practices and conversations with participating practitioners suggest that they had varied experience both clinically and in terms of the optometry schools in which they were trained.
Study 2 was designed to investigate the significance of the question set that is used with the Mallett Fixation Disparity Test in an optometric patient population. Patients were tested twice, first with the standard instruction set (as identified in study 1) and then with the specific instructions (Figure 4). The order of the two conditions could not be randomised because knowledge of the specific instructions would have contaminated participants’ interpretation of the standard instructions (see Study 2: Procedure).

Our data suggest that patients are two to three times more likely to exhibit a fixation disparity with the specific instructions compared with the standard instructions. Figure 5 shows that, although at both distance and near the difference between the two methods is usually 0 ± 1Δ (90% confidence limits by percentile rankings), the two measurements can differ quite markedly on occasion and they differ significantly from one another at both distance and near.

A study of Mallett Fixation Disparity Test results in 383 patients seen in optometric practice found that 23% exhibited an aligning prism at distance and 37% at near (Pickwell et al., 1991). A direct comparison with the data in Table 3 is of limited value as Pickwell et al. (1991), in common with other research using the Mallett unit, did not state the precise test instructions used.

At distance, exo-aligning prism is a little more common than eso-aligning prism, but at near exo-aligning prism is about twice as common as eso-aligning prism (Table 4). These findings seem unsurprising considering our cover test results and the values for Morgan’s mean heterophoria of 1Δ exophoria at distance and 3Δ exophoria at near quoted by Goss (1995), p. 63). However, we did find a lower prevalence of exo-aligning prism at near than Pickwell et al. (1991).

At distance, they found that 11% had an exo-aligning prism and 12% an eso-aligning prism, and at near 35% had an exo-aligning prism and 2.5% an eso-aligning prism. From the age distributions that Pickwell et al. (1991) quote it seems likely that their sample was older than ours, which may partly explain the different results. As previous research, including Pickwell et al. (1991), does not specify the test instructions used with the Mallett unit, it is not clear whether differing test instructions might contribute to the different results.

An interesting question with the Mallett Fixation Disparity Test is the accuracy to which the aligning prism should be measured. Mallett (1964) originally stated that the prism should be prescribed if 1Δ or more horizontally and if 0.50Δ or more vertically, and in a later paper by Mallett and Radnan-Skibin (1994) 0.50Δ increments were only recorded in two of 25 cases requiring prisms. The research study reported by Yekta et al. (1989a) only measured (horizontal) aligning prism and the data in these papers suggest that 1Δ increments were used. Inspection of their receiver–operator curves suggests that it is unlikely that an aligning prism smaller than 1Δ would have been strongly associated with symptoms. Pickwell et al. (1991) measured aligning prism with the Mallett unit in 0.5Δ increments at distance and 1Δ increments at near, but only found it to be significantly associated with symptoms when 1Δ or greater. Our procedure of typically measuring aligning prism in 1Δ increments, but exceptionally in 0.5Δ increments with very precise patient responders, has some clinical face validity but does represent a departure from the exact procedure in Figure 4. We feel that this is unlikely to have had a marked effect on the results, but it would be interesting for further research to investigate this systematically.

The clinical investigation of heterophoria is primarily concerned with detecting cases that are decompensated, typically giving rise to symptoms. Previous studies investigating the relationship between symptoms and clinical tests of heterophoria have used differing methods to quantify symptoms (Sheedy and Saladin, 1977, 1978; Jenkins et al., 1989; Yekta et al., 1989a). We have therefore included full details of our symptom questionnaire (Appendix) and of the method of scoring (see Study 2: Procedure) and we discuss the limitations of this below.

In our sample, symptoms were reported by 21% of participants for distance vision and 51% at near. This apparently high prevalence of symptoms is probably a reflection of the clinical population and of the detailed questionnaire that was used (Appendix).

The data in Table 6 suggest that at distance vision the Mallett Unit Fixation Disparity Test, regardless of the instructions used, does not perform well at detecting symptomatic patients. This agrees with the literature (Pickwell et al., 1991). At near, the standard instructions achieve inadequate sensitivity (ability to detect symptomatic patients), but the specific instructions improved the sensitivity to 39% without causing too great a compromise of specificity. Figure 6 indicates that the approach in this analysis of considering the presence of any aligning prism as abnormal may be appropriate. However, we feel that our sample size is not large enough to state whether this is true for all age groups and Jenkins et al. (1989) did find that 1Δ of aligning prism was the best predictor of symptoms in presbyopes whilst 2Δ was the best cut-off for presbyopes. Although Figure 6 shows the same data for 0.50Δ+ and 1Δ+, very few (<5%) of our measurements were taken to 0.50Δ accuracy and we would again suggest that the optimum step size that is needed for this test should be further researched.

The specificity of 78% in Table 6 for the specific questioning is identical to that obtained by Jenkins et al. (1989), although our sensitivity of 39% is lower than the 75% that they obtained. This relatively low sensitivity is...
perhaps not surprising as the wide range of symptoms that we addressed (see Appendix) are likely to have several causes, not just decompensated heterophoria. We felt that it was necessary to address a wide range of symptoms because there has been little research to indicate which symptoms are most strongly associated with decompensated heterophoria. A limitation of our questionnaire is that some of the items did not force participants to state whether they suspected a visual cause of their symptoms, or to state whether the problem was attributable to distance vision or near vision. Even when a symptom was attributed to a visual task at a certain distance, it could of course have aetiology other than decompensated heterophoria. In particular, it is quite likely in an optometric clinic population that many of the patients reported blur at a given distance because of refractive errors. The precise phrasing of questions about symptoms may be important, but is often not described in the literature. In summary, we would suggest from our experience in attempting to detect and measure visually related symptoms that future work should carefully design, test, and calibrate symptom questionnaires.

To summarise the data for near testing, when participants are grouped according to the presence of symptoms then symptomatic participants have significantly higher degrees of aligning prism and when participants are grouped according to the presence of fixation disparity then those with a fixation disparity have higher degrees of symptoms. Both these findings were only significant for near vision testing with the specific instructions. It is therefore not surprising that the correlation between the magnitude of aligning prism and the severity of symptoms was only significant at near and with the specific instructions (Figure 8).

Our data do not specifically relate to prescribing, although the association that we have demonstrated between aligning prism and symptoms implies that treatment in many of these cases might be helpful. A small double-masked study by Payne et al. (1974) showed that patients consistently preferred spectacles with prisms prescribed using the Mallett Unit rather than spectacles without a prism. Recent research suggests that prismatic correction prescribed on the basis of the Mallett Fixation Disparity Test may also bring about an improvement in rate of reading (O’Leary and Evans, in press). However, most clinicians would be reluctant to prescribe prisms on the basis of one test result alone (O’Leary and Evans, 2003), and Evans (2002, Appendix 3) suggested an algorithm for determining cases of decompensated heterophoria that require treatment.

In conclusion, our data suggest that the instructions that are used with the Mallett Unit Fixation Disparity Test are important. For near vision testing, specific instructions as outlined in Figure 4, are more likely to reveal results that are associated with symptoms than the more commonly used, less specific, instructions. Two questions follow from these findings: why is the Mallett Fixation Disparity Test so much more useful for near vision testing and why are the specific instructions superior?

Previous research has also found the Mallett Unit Fixation Disparity Test to be useful for detecting symptomatic heterophoria at near (Yekta and Pickwell, 1986; Jenkins et al., 1989; Yekta et al., 1989a; Pickwell et al., 1991), but not at distance (Pickwell et al., 1991). Pickwell et al. (1991) suggested that this might be because cases of decompensation in distance vision are relatively rare. The lack of a clear relationship between symptom score and aligning prism with distance vision might lead one to question whether it is worthwhile using the Mallett Fixation Disparity Test at distance. However, it is possible that some patients with a distance aligning prism and no symptoms might have impaired performance at distance, such as binocular visual acuities that are relatively reduced compared with monocular (Jenkins et al., 1994a), reduced stereopsis, or...
reduced time to obtain clear and single distance vision after reading. Our study was designed to concentrate on symptoms and therefore we can only speculate on these other possibilities, which could conceivably justify the assessment of fixation disparity at distance. One recent study has shown a significant improvement in dynamic visual performance (rate of reading) at near with aligning prism as indicated by the Mallett unit (C. I. O’Leary and B. J. W. Evans, unpublished data).

Although the present study has shown that the specific instructions (Figure 4) are more useful than the standard instructions, we do not know what aspects of the specific instructions are of particular value. We suspect that the key component is asking whether one or both of the nonius markers ever moves. There is a subtle, but we think important, distinction between this and the standard instructions, which just ask whether the nonius markers are aligned. For example, consider a patient who is first shown the test without the polarised visor, and then the visor is inserted and they are asked, ‘Are the strips still aligned?’ This is a closed and leading question, implying that the strips ought to be aligned, especially as the patient has just seen the test without the visor when the strips were aligned. If the strips move in and out of alignment then it is just as true for the patient to say that the strips are aligned as it is for them to say that they are misaligned. So, the patient is quite likely to follow the leading question and report that the strips are aligned. The situation is easily resolved by adding the question: ‘Do one or both of the strips ever move?’ Our data suggest that this additional question considerably improves the usefulness of the test.

Many optometric measurements require a subjective response from the patient, which is likely to be influenced by the precise instructions given by the practitioner. It is perhaps surprising that the importance of the phrasing of optometric test instructions has received little attention.

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References


Appendix

Symptom and History Questionnaire used in study 2.

Confidential
Symptom questionnaire and patient consent form to be completed prior to the eye examination
Date of appointment: ______
Patient ID code: ______

Date of last eye examination: ________
Do you currently wear spectacles? Yes No
If yes when are they worn (e.g. for reading)? ______
If you do not currently wear spectacles, but have been prescribed spectacles in the past, please state your approximate age(s) when you were given these________

Have you ever had an eye operation? Yes No
Please give any details you can of what the operation was for and how old you were at the time. __________

Have you ever received eye exercises or patching as a form of treatment? Yes No
Please give details of the type of treatment and your age at the time. __________

General health
Are you in good physical condition and healthy? Yes No
Do you have any allergies, including hay fever, asthma, and eczema? ______
Please list any tablets or medicines that you are currently taking __________

Visual symptoms
Have you now or ever suffered from the following:
1. Blurred Vision? Yes No
Is it when reading or when looking at writing on the board, or for adults, road signs in the distance
If so, please give details ______________

2. Double Vision (i.e. seeing two things when there is only one)? Yes No
3. Sore tired eyes? Yes No
If you do suffer from sore or tired eyes, please tick, which of the following describes what makes your eyes feel sore or tired
   a) Reading for a long time
   b) Reading for a short time
   c) Looking in the distance for a long time
   d) Looking in the distance for a short time.

Headaches
Do you suffer from headaches? Seldom Never Often
If you do suffer from headaches please try and give details of how often, associated with any activity like reading, how bad are the headaches and where are they located and how long do they last? ______________

Visual behaviour
Have you or anyone else ever noticed that you do any of the following:
Frequently rub eye(s) when reading? Yes No
If so, please give details __________
Holds book unusually close or far away when reading? Yes No
If so, please give details __________
Closes or covers one eye? Yes No
If so, please give details __________
Blinks excessively? Yes No
If so, please give details __________
Tilts head when reading/writing? Yes No
If so, please give details __________
Poor concentration? Yes No
If so, please give details __________
Tires easily when reading? Yes No
If so, please give details __________

Family history
Is there any family history of eye problems, eye disease, or wearing spectacles?
Please give details __________