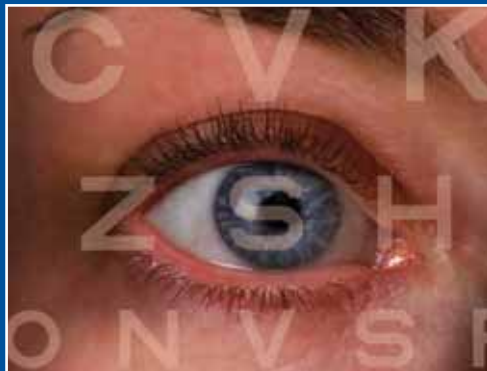


**VISION & READING DIFFICULTIES PART 2****COURSE CODE: C-10577**

# Optometric Correlates of Reading Difficulties



Bruce JW Evans, Peter M Allen, Arnold J Wilkins

In this second article of the series on vision and reading difficulties, the optometric factors (for example refractive error and orthoptic function) that may be associated with reading problems are discussed in detail. The first article of this series introduced the correlates of, and interventions for, reading difficulties that have been supported by evidence-based research. This present article describes the optometric correlates more specifically, providing details of the aspects of visual function that ought to be considered for further investigation.

## Ocular health

Thankfully, ocular pathology is rare in children and there is no evidence to suggest that eye diseases are correlated with reading problems, including dyslexia. However, many of the symptoms that are described in this series of articles (e.g. reading difficulties, blurred vision, double vision, and headaches) might be described medically as 'soft neurological signs'. The vast majority of optometric patients with these symptoms will not have any neurological anomalies, but the sudden onset of these symptoms, particularly in the presence of general health changes, should alert the optometrist to a possible need for referral to a neurologist. Indeed, acquired dyslexia by itself can be a sign of neurological anomalies (e.g. from a stroke).

## Visual fields and colour vision anomalies

A literature review found little evidence for an association between clinical visual field deficits and dyslexia,<sup>1</sup> and this is supported by recent research.<sup>2</sup> A possible exception

to this however is observable using frequency-doubling perimetry (see later section on the magnocellular deficit).

The consensus from the literature is that colour vision anomalies have a normal prevalence (approximately 8%) in people with specific learning difficulties (SpLD).<sup>3</sup> The next two articles in this series will deal with visual stress in much more detail, since this is a condition that affects about one third of people with dyslexia and is treated with individually prescribed coloured lenses. The evidence suggests that basic colour perception is normal, and colour vision anomalies are of normal prevalence, in people with visual stress.<sup>3</sup> Occasionally, people with severe visual stress may have specific difficulties with the Ishihara test, although their colour perception on other colour vision tests is normal. The present authors are unaware of any research on this, although it could be hypothesised that their visual stress may cause difficulties in perceiving strong colour contrasts, which are present in the Ishihara test.

## Refractive errors and visual acuity

Refractive errors that require correction with spectacles can, of course, occur in any child, but the evidence suggests that these are not especially prevalent in children with SpLD. However, optometrists will occasionally encounter people whose underachievement at school seems to be attributable to uncorrected refractive error and Table 1 presents an example of such a case. Note that the retinoscopy reflex and keratometry results for this person were normal, so it is believed that the astigmatism was long-standing. Vision screening for children in the UK now only takes place once, at primary school age, and is usually no longer provided in secondary schools, so it is likely that many more cases of this will be seen in optometric practice.

### Do low plus lenses help?

Some optometrists believe that children with SpLD should be prescribed low plus lenses (e.g. of power +0.50DS) to each eye as 'reading lenses'. However, it has been reported that there is no convincing

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experimental evidence of such a benefit from low plus prescriptions.<sup>4</sup> There are, of course, occasional cases where low plus lenses are indicated, for example cases of decompensated esophoria with a high AC/A ratio, or cases of accommodative insufficiency.<sup>5</sup> Prescribing in these cases however should be supported by the individual clinical results obtained.

When a patient has an ocular motor anomaly (e.g. binocular instability, decompensated heterophoria, or accommodative insufficiency) it can be helpful to investigate the effect of borderline refractive corrections on the ocular motor status. This is discussed in the later section on decompensated heterophoria.

One study that compared refractive errors in a group of children with dyslexia to a group of control children without dyslexia found that three times as many participants with dyslexia (42%) had been prescribed spectacles compared to the control group (14%).<sup>6</sup> However, the proportion of children in both groups that were actually using spectacles was similar,<sup>6</sup> whilst the distribution of refractive error in the two groups was also similar.<sup>7</sup> There are several likely explanations for this finding; parents of children with dyslexia are more likely to have sought optometric care,<sup>6</sup> or optometrists may be predisposed to correct low refractive errors because they genuinely want to try to help children with reading difficulties, or the increased prevalence of symptoms from other conditions such as visual stress and binocular instability may be misinterpreted by practitioners as a need for refractive correction. Nonetheless, the peer-reviewed evidence does perhaps justify a conservative approach to prescribing in these cases.

### Strabismus & incomitancy

Strabismus<sup>1</sup> and amblyopia<sup>8</sup> do not seem to be correlated with reading difficulties. The reason why strabismus does not impair reading is probably because of sensory adaptations.<sup>5</sup> People with long-standing strabismus usually have a stable sensory adaptation such as

Background	<ul style="list-style-type: none"> <li>• 29-year-old female adult student</li> <li>• Patient had underachieved throughout school, but this had never been investigated and there had been no previous eye care</li> <li>• Patient worked at a supermarket, but felt she could achieve more and entered adult education. Her tutors felt that her performance should be better and referred her to an optometrist</li> </ul>
Symptoms	<ul style="list-style-type: none"> <li>• Words blur and move</li> <li>• Skips words when reading</li> <li>• Reading causes sore eyes and headaches</li> </ul>
Presenting vision	<ul style="list-style-type: none"> <li>• Right Eye: 6/15</li> <li>• Left Eye: 6/24</li> </ul>
Refractive error	<ul style="list-style-type: none"> <li>• Right Eye: -0.25/-3.25X180 VA = 6/9</li> <li>• Left Eye: -0.25/-3.25X180 VA = 6/9</li> </ul>
Ocular health	<ul style="list-style-type: none"> <li>• Visual Fields, ophthalmoscopy, pupil reactions, and colour vision all normal</li> </ul>
Ocular motor balance	<ul style="list-style-type: none"> <li>• Ocular motility, cover test, near point of fixation (NPC), fixation disparity, fusional reserves, and accommodation all within normal limits.</li> <li>• No visual stress.</li> </ul>
Management	<ul style="list-style-type: none"> <li>• Prescribed spectacles to correct astigmatism</li> </ul>
Follow-up	<ul style="list-style-type: none"> <li>• Spectacles were worn most of time and now patient finding her education to be much easier and she is performing better</li> </ul>

➔ **Table 1**

Case study of a person who underachieved at school due to uncorrected refractive error

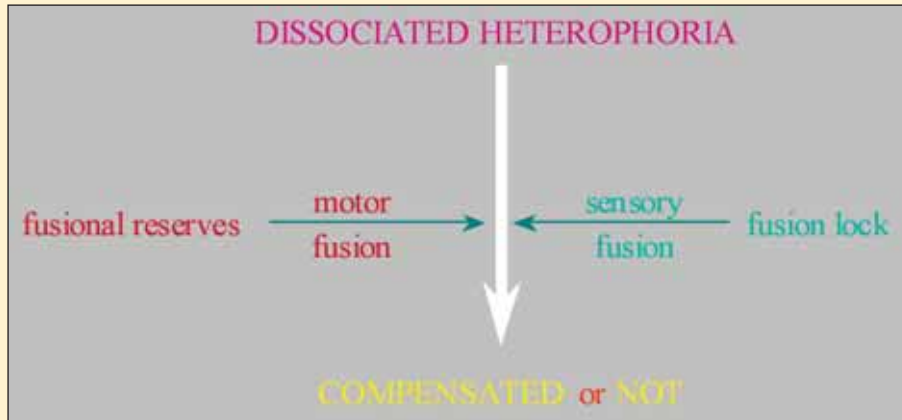
harmonious anomalous retinal correspondence (ARC) or suppression. This prevents the strabismus from interfering with visual perception.<sup>5</sup> Occasionally, eye care practitioners encounter patients whose sensory adaptation to strabismus is unstable and these people may benefit from treatment, sometimes in the form of eye exercises.<sup>5</sup> These cases are very rare and should be referred to eye care practitioners who have specialised in treating binocular vision anomalies.

### Decompensated heterophoria

Heterophoria is a normal feature of binocular vision status for most people. This is characterised by a misalignment between the eyes, either when one eye is covered or when the two eyes are presented with dissimilar

images. There is no consistent evidence of a predisposition towards any particular type of heterophoria (exophoria, esophoria, hyper/hypo-phoria or cyclophoria) in children with reading problems.<sup>1</sup>

During normal everyday visual activity we exert motor fusion, via fusional reserves, to align the eyes so that sensory fusion can take place. With sensory fusion, the two monocular percepts are fused into a single image, and this usually provides additional information on the relative depth of adjacent objects. The role of sensory and motor fusion in allowing a person to compensate for heterophoria is summarised in Figure 1. If the dissociated heterophoria is excessive and/or if the sensory and motor fusion are inadequate then heterophoria may decompensate, in which case the



➔ **Figure 1**

A simple model of binocular vision. Reproduced with permission from Evans, B.J.W. (2007) *Pickwell's Binocular Vision Anomalies*, 5th edition, Butterworth-Heinemann

patient is likely to suffer from symptoms<sup>9</sup> and decreased visual performance.<sup>10</sup>

The diagnosis of decompensated heterophoria is usually based on symptoms, cover test recovery, fixation disparity on the Mallett unit, and, in the case of exophoria, on the adequacy of the fusional reserve that opposes the heterophoria.<sup>5</sup> Relatively few studies have investigated whether decompensated heterophoria is correlated with dyslexia, but most of those that have done so have failed to find any significant association.<sup>1</sup>

Although decompensated heterophoria is not particularly correlated with reading problems, it may occur in any child and this could make reading more difficult. The management of decompensated heterophoria is usually by one of three options; eye exercises, refractive correction, or prismatic correction. The first two of these are the most common approaches in children, and the choice of treatment largely depends on the child's motivation.<sup>5</sup>

It was noted earlier in this article that it could be useful to investigate the effect of low refractive errors on decompensated heterophoria. They can influence the situation in three ways, reflecting the three key variables in Figure 1. If a patient has significant uncorrected hypermetropia then they may over-accommodate and this can cause a

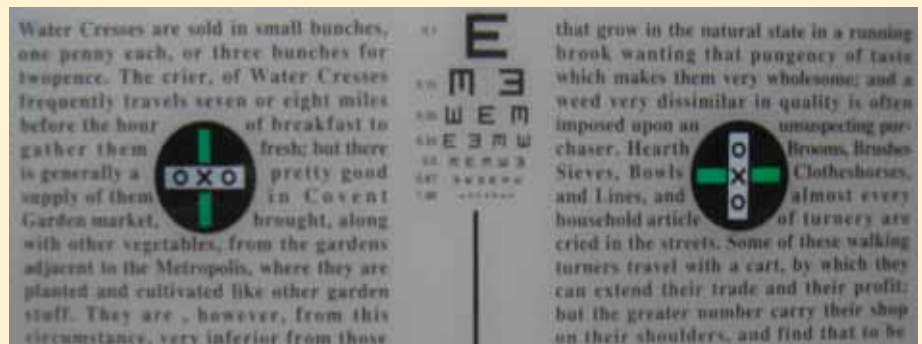
decompensated esophoria. In such a case, plus lenses will reduce the heterophoria, changing the motor fusion variable in Figure 1. If an emmetropic patient with good accommodation has a decompensated exophoria, the prescription of negative lenses will induce accommodative-convergence, which may render the heterophoria compensated via motor fusion. If the patient has a refractive error or visual stress that is causing blur or other visual perceptual distortions, then this will interfere with sensory fusion, the right hand variable in Figure 1. Correction of the visual stress or refractive error may be all that is required to render the heterophoria compensated. This may explain why, exceptionally, patients may be encountered where correction of a low degree of hypermetropia may render an exophoria compensated, although this is counter-intuitive if one just considers accommodative-

convergence. These factors can be investigated clinically by using the Mallett fixation disparity test (Figure 2): the refractive error that eliminates any misalignment of the nonius bars is likely to alleviate symptoms.

### Convergence insufficiency

Convergence insufficiency, in its simplest form, is characterised by a remote near point of convergence. The term is also sometimes used to describe a decompensated convergence weakness exophoria (problematic exophoria at near).

There is some controversy over whether convergence insufficiency is a correlate of dyslexia. Only one study since 2001 has found a slightly more remote near point of convergence in a group of children with dyslexia than in a control group.<sup>11</sup> In any event, convergence insufficiency is such a common condition that even if its prevalence is no higher in children with reading problems than in good readers, it will be encountered quite commonly. The management is similar to that of decompensated exophoria, and exercises are very often effective. A range of exercises (Figure 3) developed at the Institute of Optometry has been found to be helpful for this condition.<sup>12</sup> These are designed to be carried out by the patient, usually a child, at home. There are a series of four target cards that the patient views, which create a variety of stereoscopic perceptions. The exercises come with detailed documentation, which gives the



➔ **Figure 2**

The Mallett fixation disparity test



parent (or the patient if an adult) a programme of instructions to take them through a series of tasks, each gradually building-up their convergent fusional reserves. There are also instructions for the practitioner, who typically sees the patient for a first follow-up about three weeks after the exercises are dispensed.

### Binocular instability

Binocular instability is a condition characterised by low fusional reserves and an unstable heterophoria. An unstable heterophoria can be detected with the Maddox wing test if the arrow moves by more than  $\pm 2\Delta$ . However, it is most likely to be clinically significant if it is present under fused conditions, using the Mallett fixation disparity test. Research with this test shows that it is important to ask patients whether there is any movement of one or both bars; such a finding is often associated with symptoms.<sup>9</sup>

The fusional amplitude is defined as the range between the divergent and convergent break points of the fusional reserve measurement. In binocular instability, this is typically less than  $20\Delta$  and using this criterion, binocular instability has been found to affect about 15% of people with dyslexia compared to only 5% of controls.<sup>6</sup> This does not mean that 15% of people with dyslexia will require treatment, since more than one diagnostic sign is usually required to reach a firm diagnosis (see later).

Binocular instability is not the same as decompensated heterophoria,<sup>5</sup> although it is debatable whether decompensated heterophoria could be described as a form of binocular instability. A key difference is that in binocular instability the patient does not have to demonstrate a heterophoria. During normal eye movements, small vergence errors occur which mean that, even in an orthophoric patient, adequate fusional reserves are required to maintain comfortable fusion. There is some evidence of poor binocular co-ordination during saccades in children with dyslexia, which might be a contributor to reading difficulties.<sup>13</sup>

### Accommodative problems

One study found that a group of children with dyslexia had, on average, a slightly lower amplitude of accommodation (by about 3.00D) than a group of control children without dyslexia.<sup>6</sup> This study found no difference between the groups in accommodative lag whilst the marginally reduced accommodation amplitude was not found to significantly impair reading performance. However, this finding might indicate that children with reading problems are slightly more likely to suffer from accommodative insufficiency compared to good readers, so it is sensible for children with reading problems to have a careful assessment of their accommodative function.

Accommodative function can be assessed in three main ways, and these will be described in more detail in the last article of this series. The most common test used however is the push up test, which measures the amplitude of accommodation, typically using an RAF rule. Another very useful method of assessing accommodative function is the monocular estimation method (MEM) of retinoscopy, and this approach has the advantage of not requiring a subjective response from the patient. The third test of accommodative function is that of accommodative facility testing, which assesses the patient's ability to change their accommodation. This is especially relevant if a child has problems copying from the board (i.e. changing focus from distance to near and vice versa) although this symptom can result from non-optometric problems too, such as poor short-term memory. Two studies, one of accommodative facility<sup>14</sup> and one of combined accommodative and vergence facility,<sup>6</sup> have failed to find a relationship between infacility and dyslexia.

### When are eye exercises necessary?

The views expressed in this article might result in about 5-15% of children with reading problems receiving eye exercises, although some optometric



➔ **Figure 3**

Institute Free-Space Stereogram (IFS) exercises. Reproduced with permission of i.O.O Sales Ltd., London

philosophies argue that a much higher proportion of children with reading problems should be treated. If there is even a faint possibility that optometric treatment will help, then why not have a go?

Optometrists have a duty to treat patients who need treatment, but also to only treat those cases that are likely to benefit from intervention. Parents of children with reading problems are often desperate to do anything they can to help their children, but financial resources and time will inevitably be limited. Time is especially relevant, because these children will often require extra teaching and homework. Specialist teaching is the most proven intervention for reading problems, and this can be especially effective if it is on a one-to-one basis. If an optometrist is not reasonably confident that an optometric intervention (e.g. eye exercises or spectacles) will help, then they might do better to advise the parents to use their resources to fund one-to-one support from a special needs teacher.

People with reading or other academic problems should be referred to eye care practitioners who have specialised in vision and learning and who will carry out an in-depth assessment of visual function. This 'special investigation' will require about a dozen different tests of binocular and accommodative function. The probability of failing a test increases with the number of tests that is carried out. So, if practitioners prescribe eye exercises (or spectacles) to every



DISTANCE / NEAR (delete)	Score
1. Does the patient have one or more of the symptoms of decompensated heterophoria (headache, aching eyes, diplopia, blurred vision, distortions, reduced stereopsis, monocular comfort, sore eyes, general irritation)? If so, score +3 (+2 or +1 if borderline) Are the symptoms at D <input type="checkbox"/> or N <input type="checkbox"/> All the following questions apply to D or N, as ticked (if both ticked, complete 2 worksheets)	
2. Is the patient orthophoric on cover testing? Yes <input type="checkbox"/> or No <input type="checkbox"/> If no, score +1	
3. Is the cover test recovery rapid and smooth? Yes <input type="checkbox"/> or No <input type="checkbox"/> If no, score +2 (+1 if borderline)	
4. Is the Mallet horizontal aligning prism: <math><1\Delta</math> for patients under 40, or <math><2\Delta</math> for pxs over 40? Yes <input type="checkbox"/> or No <input type="checkbox"/> If no, score +2	
5. Is the Mallet aligning prism stable (Nonius strips stationary with any required prism)? Yes <input type="checkbox"/> or No <input type="checkbox"/> If no, score +1	
6. Using the polarised letters binocular status test, is any foveal suppression < one line? Yes <input type="checkbox"/> or No <input type="checkbox"/> If no, score +2	
<b>Add up score so far and enter in right hand column</b> <b>if score: &lt;math&gt;&lt;4&lt;/math&gt; diagnose normal, &gt;5 treat, 4-5 continue down table adding to score so far</b>	
7. Sheard's criterion: (a) measure the dissociated phoria (e.g., Maddox wing, prism cover test); record size & stability (b) measure the fusional reserve opposing the heterophoria (i.e., convergent, or base out, in exophoria). Record as blur/break/recovery in $\Delta$ . Is the blur point, or if no blur point the break point, [in (b)] at least twice the phoria [in (a)]? Yes <input type="checkbox"/> or No <input type="checkbox"/> If no, score +2	
8. Percival's criterion: measure the other fusional reserve and compare the two break points. Is the smaller break point more than half the larger break point? Yes <input type="checkbox"/> or No <input type="checkbox"/> If no, score +1	
9. When you measured the dissociated heterophoria, was the result stable, or unstable (varying over a range of $\pm 2\Delta$ or more). (e.g., during Maddox wing test, if the Hz phoria was $4\Delta$ XOP and the arrow was moving from 2 to 6, then result unstable) Stable <input type="checkbox"/> or Unstable <input type="checkbox"/> If unstable, score +1	
10. Using the fusional reserve measurements, add the divergent break point to the convergent break point. Is the total (=fusional amplitude) at least $20\Delta$ ? Yes <input type="checkbox"/> or No <input type="checkbox"/> If no, score +1	
<b>Add up total score (from both sections of table) and enter in right hand column. If total score: &lt;math&gt;&lt;6&lt;/math&gt; then diagnose compensated heterophoria, if &gt;5 diagnose decompensated heterophoria or binocular instability.</b>	

➔ **Table 2**

Scoring system for diagnosing decompensated heterophoria and binocular instability. Reproduced with permission from Evans, B.J.W. (2007) Pickwell's Binocular Vision Anomalies, 5th edition, Butterworth-Heinemann. Note that this scoring algorithm is most appropriate for horizontal heterophoria. For vertical cases, if aligning prism of  $0.5\Delta$  or more is detected then, after checking trial frame alignment, measure the vertical dissociated phoria. If this is more than the aligning prism and there are symptoms then diagnose decompensated heterophoria. Still complete the worksheet for any horizontal phoria.

patient who fails one test from a large battery of tests then they will end up treating a high proportion of cases, probably including many who do not

need treatment. Optometrists will be familiar with this problem when they diagnose glaucoma. If they referred every patient with pressures over 21

mmHg, or with any abnormality on a single visual field test, then they would refer a great many patients.

The solution to this problem, for



example in glaucoma diagnosis, is to combine test results. The same approach has been taken in the algorithm in Table 2 for the diagnosis of decompensated heterophoria and binocular instability. Such an approach can never be infallible and experienced clinicians will always make a careful decision about whether to treat based on the complete clinical picture, and on the results of repeated measurements over time.

Another factor that needs to be considered when deciding whether to treat a binocular vision anomaly is that these anomalies are very rarely completely stable. If the optometrist is seeing the child at the weekend then it is very likely that the situation may worsen when the child is tired, towards the end of a day at school. An indication of the likely effect of fatigue can be obtained by repeating the key ocular motor tests right at the end of the eye examination.

### Saccadic and pursuit eye movements

Reading involves saccadic eye movements, so it seems plausible to argue that reading difficulties might result from a problem with these. However, saccades are not unique to reading, but are the fundamental way that organisms with a highly differentiated retina (e.g. fovea vs. peripheral retina) use their visual

system. When patients have unequivocal problems with their saccadic eye movements (e.g. patients with congenital nystagmus) then they tend to have general visual problems and not specific reading problems. This is one reason why the notion of abnormal saccadic eye movements contributing to SpLD is controversial.

This controversy has been fuelled by the observation, first made more than 70 years ago, that children with reading problems make more fixations and regressions when reading text. But the key question is whether this simply reflects the fact that they are searching for meaning because of their reading difficulty, rather than indicating saccadic dysfunction.<sup>1</sup> This question still has not been unequivocally answered.<sup>15, 16</sup>

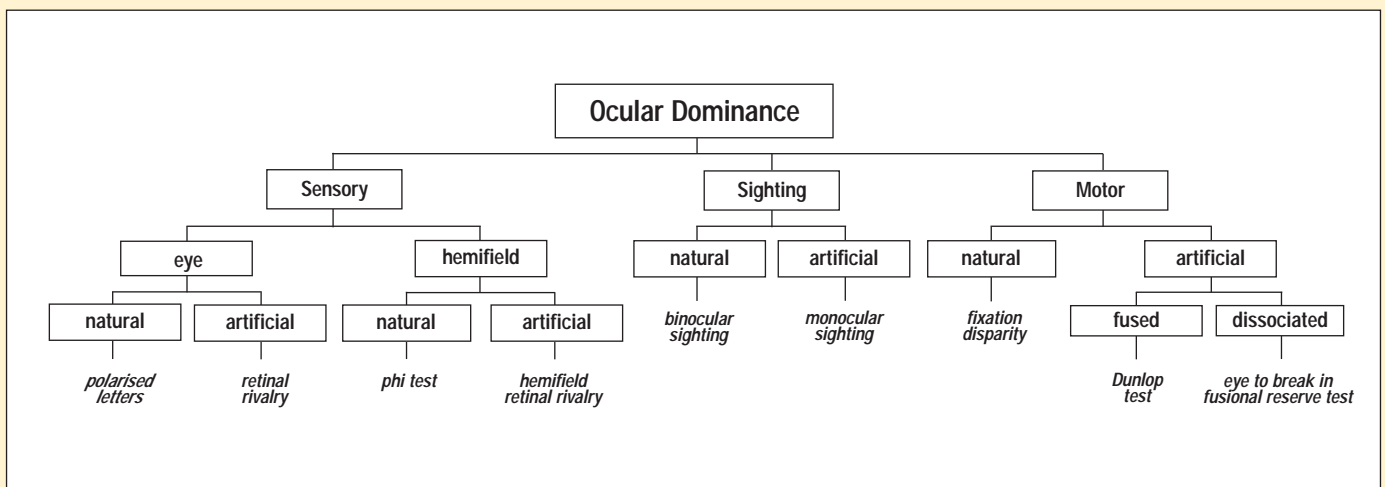
In the 1980s attempts were made to address this controversy by recording eye movements whilst children with dyslexia, and controls, fixated a series of lights that were presented in sequence. Some studies found differences between the groups, but most controlled studies did not. A review of this research<sup>1</sup> noted that at this time, good research controlled for IQ but did not control for attention deficit disorder (ADD), since this was not so widely recognised at this time. ADD often co-exists with dyslexia and may be a confounding factor in this type of research. It is quite likely that

attention will wander during the boring task of tracking lights, and this might be misinterpreted as an eye movement problem. The controversy about saccadic eye movements and dyslexia still continues, with some recent studies showing no abnormality of eye movements in dyslexia during a simulated reading task.<sup>17, 18</sup>

More recently, it has been suggested that subtle attentional factors may impair the ability of people with dyslexia to process rapid stimulus sequences, but it is argued that this is unlikely to cause any significant direct effects on reading.<sup>19</sup> Visuospatial attention is discussed further later.

Although some studies have used sensitive eye movement recording equipment to measure binocular coordination during saccades,<sup>20</sup> it is questionable whether clinically available eye movement recording devices have the required accuracy to reliably detect, for example, the subtle binocular misalignments in binocular instability.

It has also been suggested that smooth pursuit eye movements may be abnormal in dyslexia. This type of eye movement is not normally involved in reading, so it is not surprising that the smooth pursuit impairments did not seem to be a significant cause of poor reading.<sup>21</sup>



➔ **Figure 4**

Schematic classification of ocular dominance. Classifications are in normal text in boxes and the text in italics provides examples of specific tests. Reproduced with permission from Evans (2001) *Dyslexia and Vision*. Wiley, Chichester.



Characteristic	Magnocellular (M, transient)	Parvocellular (P, sustained)
Type of cell in the optic nerve	Magno or M-cells	Parvo or P-cells
Ultimate destination in the brain	Parietal lobe (this part of the brain covers about the same area as a cardinal's skullcap)	Temporal lobe (the part of the brain adjacent to the temple and ear)
Sensitivity to movement and flicker	Very sensitive	Insensitive
Ability to resolve detail	Good at resolving coarse detail	Good at resolving fine detail
Ability to detect contrasts	Sensitive to low contrast objects	Sensitive to high contrast objects
Effect of blur	Relatively insensitive to blur	Greatly affected by blur
Area of visual field where most sensitive?	Peripheral vision	Central vision
Persistence of response to a stimulus	Nerve cells respond briefly at the onset and offset of a stimulus (transient)	The response of the nerve cells persists throughout the stimulus (sustained)
Ability to discriminate colours	Unable to discriminate colours	Good at discriminating colours

➔ **Table 3**

Comparison of magnocellular and parvocellular subsystems

In summary, since it is doubtful whether saccadic or pursuit eye movements are abnormal in people with reading problems, it is doubtful whether it is useful to assess or treat these basic visual functions. It has been argued that a number reading task, the developmental eye movement (DEM) test, measures saccadic function (sometimes called oculomotor skills) but the present authors have not been able to find any research that compares performance in this test with the results of objective eye movement recording equipment.

### Ocular dominance & the Dunlop Test

There have been many theories over the years about possible relationships between the results of tests of ocular dominance and reading problems.<sup>1</sup> A difficulty is that there are many different tests of ocular dominance (Figure 4) and the eye that is dominant in a given person will vary with the task, and indeed from one moment to another.<sup>22</sup> The Dunlop Test, which

became popular in some orthoptic clinics in the 1980s and 1990s, is based on a test of motor ocular dominance. However, this approach no longer seems to be used. Indeed, ocular dominance no longer seems to be routinely tested in people with reading difficulties and is not considered to be a major aspect of this disorder; the interested reader however is referred to previous reviews.<sup>1, 23</sup>

### Behavioral Optometry

Behavioral optometry (BO) is a small sub-speciality of optometry that has attracted some controversy. Behavioral optometrists may provide specialist services to people with reading difficulties.<sup>24</sup>

The College of Optometrists commissioned a review of BO in 2000, which concluded that it was 'unlikely that, at present, behavioural optometry can satisfy evidence-based scrutiny; indeed there must be concern that groups of optometrists following idiosyncratic management strategies within areas traditionally associated

with other professions might hinder the credibility and development of optometry as a whole'.<sup>4</sup> Recently, the College of Optometrists commissioned an updated review, which reached similar conclusions: 'the continued absence of rigorous scientific evidence to support behavioural management approaches, and the paucity of controlled trials in particular, represents a major challenge to the credibility of the theory and practice of behavioural optometry'.<sup>24</sup>

### Balance & cerebellar theories

Over the years, several theories have been proposed which suggest that dyslexia is associated with balance problems or cerebello-vestibular disorders.<sup>1</sup> Experimental studies generally do not support this hypothesis<sup>25</sup> and do not support associated training programs.<sup>26</sup> These training programs typically provide general co-ordination exercises, often including eye movement training, and



are commonly accompanied by extravagant claims about curing or ameliorating conditions such as dyslexia, dyspraxia, and ADD. The best advice is to adopt a sceptical approach towards any new treatment that is not supported by double-masked randomised placebo-controlled trials.

## The magnocellular ("magno") deficit

The human visual system processes the visual world via parallel pathways. The two most prominent of these pathways are the parvocellular (sustained) and magnocellular (transient) pathways (Table 3) and these are discussed also in parts 3 and 4 of this series of articles.

A review in 2001 summarised a large body of research indicating that up to two thirds of people with dyslexia have a deficit of the magno subsystem.<sup>1</sup> More recent studies have generally supported this association,<sup>27-29</sup> although a few studies have not supported the magno deficit hypothesis.<sup>14, 30, 31</sup> Several methods have been used to detect the magno deficit, including motion perception, which has been linked with particular types of reading deficit.<sup>32</sup> It has been suggested that the magno deficit is associated with timing or temporal functions in other modalities (e.g. auditory), although one study did not support this.<sup>27</sup> It has even been argued that 'temporal vision therapy' can be used to help reading disability,<sup>33</sup> although there appear to have been no randomised controlled trials.

Recent evidence suggests that the magno deficit may actually be quite rare in dyslexia, is unrelated to visual stress, and is unlikely to be causally related to the poor reading.<sup>34</sup> In contrast, it has been argued that the magno deficit might contribute causally to poor reading by resulting in saccadic dysfunction. A recent study however indicates that this is not the case.<sup>18</sup> Instead, the magno deficit has also been linked with visuospatial attention,<sup>35</sup> which is discussed later.

The magno deficit hypothesis is of questionable clinical significance to the practising optometrist. The magno deficit may be associated with

impaired results on visual field tests that use the frequency-doubling technique (e.g. the Humphrey FDT perimeter),<sup>36, 37</sup> although these effects seem to be subtle and unlikely to confound the use of FDT perimetry for the detection of glaucoma.<sup>2</sup> The magno deficit has been associated with reading and spelling errors that might be expected to result from visual confusions.<sup>1, 27</sup> The magno deficit is correlated with binocular instability,<sup>38, 39</sup> and it is therefore possible that it is the binocular instability that accounts for these visual confusions.<sup>40</sup>

## Visuospatial attention

The perceptual span or form resolving field are terms used to describe the size of the area around the fixation point within which letters are recognised. It has long been argued that this may be abnormal in dyslexia,<sup>1</sup> and there is some evidence that this can be modified with training and that this might help reading.<sup>41</sup> This may relate to the span of visual attention, which a previous review suggested may be atypical in dyslexia<sup>1</sup> and which has been associated with the magno deficit.<sup>35</sup> There is growing evidence of abnormalities in visuospatial attention in people with reading problems,<sup>42-48</sup> and this seems to be similar across the various subtypes of dyslexia.<sup>49</sup> Treatment regimens based on visuospatial attention have been developed,<sup>50</sup> but do not seem to have been validated with randomised controlled trials in English-speaking populations.

The visuospatial attention deficit in dyslexia has been characterised by some workers as a weakened spotlight of visual attention. In 1999, the first author of this article proposed a unifying hypothesis that such a weakened spotlight might cause poor readers to become more aware of the peripheral detail on the page, resulting in the characteristic symptoms of visual stress; this might also impair the fusion lock (see Figure 1) resulting in binocular instability.<sup>51</sup>

## Summary

People with reading difficulties have a higher than usual prevalence of certain

visual problems, most notably visual stress, binocular instability, and possibly convergence insufficiency and accommodative insufficiency. These visual problems cause symptoms that could contribute to reading difficulties. People with reading problems should therefore be referred to eye care practitioners who have specialised in vision and learning and who can carry out a specialised investigation to detect these problems, and any other visual factors that may be relevant. These other visual factors include conventional visual problems (e.g. refractive error), and an assessment of ocular health.

## Ethical declaration

Bruce Evans developed the IFS exercises (Figure 3), which are marketed by i.O.O Sales Ltd., and receives a royalty based on sales of this product.

## About the authors

Bruce Evans is Director of Research at the Institute of Optometry and Visiting Professor to City University. He spends most of his working week in an independent optometric practice in Essex. Bruce first started researching visual factors in dyslexia in 1988 and he is author of the book "Dyslexia and Vision".

Peter Allen is a Principal Lecturer and Director of Clinics at Anglia Ruskin University. Peter is an examiner and assessor for the College of Optometrists. He is an active member of the Myopia and Visual Function research group including research in recent years on visual stress, reading, and accommodative facility.

Arnold Wilkins is Professor of Psychology at the University of Essex and Director of the Visual Perception Unit. His career has been spent mainly in research at the Medical Research Council Applied Psychology Unit in Cambridge where for many years he studied photosensitive epilepsy, a study that later generalised to an investigation of visual stress.

## References

See [www.optometry.co.uk/references](http://www.optometry.co.uk/references)



## Module questions

Course code: c-10577

Please note, there is only one correct answer. Enter online or by the form provided

**An answer return form is included in this issue. It should be completed and returned to CET initiatives (c-10577)  
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- 1) Which of the following is NOT an optometric correlate of reading difficulties?
  - a. Visual stress
  - b. Binocular instability
  - c. Accommodative insufficiency
  - d. Ocular pathology
- 2) Which of the following is TRUE about refractive errors and dyslexia?
  - a. Refractive errors are correlated with dyslexia
  - b. Refractive errors can be present in dyslexia but play no causal role in the reading difficulties
  - c. Refractive errors can be present in dyslexia and can contribute to the reading difficulties
  - d. Refractive errors are not present in dyslexia.
- 3) Which of the following statements about low plus lenses is MOST accurate?
  - a. Low plus lenses can help in decompensated esophoria
  - b. Low plus lenses are a validated treatment for dyslexia
  - c. Low plus lenses prevent myopia
  - d. Low plus lenses improve tracking
- 4) Which of the following binocular vision anomalies is MOST strongly correlated with dyslexia?
  - a. Strabismus
  - b. Binocular instability
  - c. The presence of a heterophoria
  - d. The presence of a decompensated heterophoria
- 5) Which of the following is NOT a treatment for decompensated heterophoria and binocular instability?
  - a. Eye exercises
  - b. Refractive modification
  - c. Prisms
  - d. Precision tinted lenses
- 6) Which of the following statements about the fusional amplitude is TRUE?
  - a. In binocular instability, it is usually less than  $20\Delta$
  - b. In binocular instability, it is usually more than  $30\Delta$
  - c. It is measured from base in recovery to base out break
  - d. It is measured from base out recovery to base in break
- 7) Accommodative function can be assessed by which of the following:
  - a. The amplitude of accommodation
  - b. MEM retinoscopy
  - c. Accommodative facility
  - d. All of the above
- 8) Which of the following statements about eye movements is TRUE?
  - a. Abnormal saccadic eye movements are the cause of dyslexia
  - b. Smooth pursuit eye movements are not normally involved with reading
  - c. Clinical eye movement recording devices are accurate enough to detect binocular instability in people with reading difficulties
  - d. All of the above
- 9) Which of the following statements about ocular dominance is TRUE?
  - a. It can be sub-divided into sensory, motor and sighting dominance
  - b. The dominant eye in a given person is constant whatever the task
  - c. The dominant eye in a given person is constant over time
  - d. The Dunlop test is commonly used by practitioners in SpLD clinics
- 10) Which of the following statements about behavioral optometry is TRUE?
  - a. Eye exercises are only prescribed by behavioral optometrists
  - b. Behavioral optometry is well-supported by evidence-based research
  - c. It is impossible to research behavioral optometry using double-masked randomised controlled trials
  - d. Reviews commissioned by the College of Optometrists have noted a lack of rigorous scientific evidence for behavioral optometry
- 11) Which of the following regarding the magno deficit hypothesis is FALSE?
  - a. It is of questionable clinical significance to the practising optometrist
  - b. It has been linked to binocular instability
  - c. It is the cause of visual stress
  - d. It has been associated with reading and spelling errors that might be expected to result from visual confusions.
- 12) Which of the following statements about visuospatial attention is FALSE?
  - a. It can be characterised as a spotlight of visual attention
  - b. Treatments for visuospatial attention deficit in dyslexia have been validated with randomised controlled trials
  - c. Visuospatial attention deficits are similar in different subtypes of dyslexia
  - d. A weakened spotlight of visual attention could provide a unifying explanation for visual correlates of dyslexia

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