Optometry in Practice 2016 Volume 17 Issue 2 xx – xx

COMMUNICATION STANDARDS OF PRACTICE OPTICAL APPLIANCES
Approved CET For Optometrists

Visual stress and dyslexia for the practising optometrist

Arnold J Wilkins[1] BSc(Hons) FBPsS HonFCOptom, Peter M Allen[2] BSc(Hons) PhD FCOptom FHEA, Laura J Monger[2] BOptom(Hons) MCOptom and James M Gilchrist[3] BSc(Hons) MPhil PhD FCOptom

[1]University of Essex, Colchester, [2]Anglia Ruskin University, Cambridge, [3]University of Bradford, Bradford

EV-xxxxx C-xxxxx

1 CET point for UK optometrists

Abstract

Visual stress should not be confused with dyslexia. It refers to symptoms of discomfort and perceptual distortion that have a neurological origin. Pattern 2 of the Pattern Glare Test can be used to elicit symptoms of visual stress, but pattern 3 is of relatively little clinical use. The symptoms sometimes remit with tints, but studies consistently show that tinting precision well within 0.07 in the CIE 1976 UCS diagram is necessary for optimal effect (see Precision is necessary – strong evidence is now available, below). An improvement in reading speed with filters (overlays or lenses) can be measured using the Wilkins Rate of Reading Test, and an increase in reading speed of 15% is likely to indicate an improvement that exceeds any due to random variation. Visual stress remains a controversial issue, partly because of the publicity surrounding untrialled methods and partly because of reviews that are partial.

Visual stress should be dissociated from dyslexia

Dyslexia and coloured glasses have become associated in the public mind. BBC television documentaries (Kara Tointon, *Don't Call Me Stupid*: see YouTube) and other media sources have highlighted the benefits of tints in certain high-profile individuals with dyslexia, and some dyslexia charities promote the idea that visual stress is associated with dyslexia (http://www.bdadyslexia.org.uk/dyslexic/eyes-and-dyslexia). Nevertheless, visual stress and dyslexia are not strongly associated. Estimates of the proportion of individuals with dyslexia who experience visual stress vary, and in some sources are as high as 30–40% (Kriss and Evans 2005), but the accuracy of such estimates may be uncertain due to variations in how dyslexia and visual stress are defined. Notwithstanding this difficulty, it is clear that the majority of those diagnosed with dyslexia do not experience visual stress, and there are many individuals with visual stress who can read quite normally and are not considered to be dyslexic. It is time to dissociate visual stress from dyslexia and consider it as a separate, but comorbid, condition.

Definition of dyslexia

From a medical viewpoint, dyslexia is a congenital and developmental condition associated with neurological anomalies in the brain. From an educational viewpoint, the term was used in the past to refer to a person with selective, persistent and significant problems with reading, writing, spelling and sometimes mathematics and musical notation, where these problems were not explained by a general intellectual deficit. It has proved difficult to show any differences between reading difficulties in individuals with dyslexia (ie a specific deficit) and those without (ie reading difficulties that may be accompanied by a general intellectual deficit). As a result, the requirement for discrepancies between reading and other abilities has now been discontinued.

In his report undertaken for the UK government, Rose (2009) defines dyslexia as 'a learning difficulty that primarily affects the skills involved in accurate and fluent word reading and spelling', characteristic features of which are 'difficulties in phonological awareness, verbal memory and verbal processing speed'. Rose also emphasises that dyslexia occurs across a range of intellectual abilities and that a variety of co-occurring difficulties may be seen, but that 'these are not, by themselves, markers of dyslexia'. Such difficulties include visual stress.

Use of the dyslexia 'label' itself has been vigorously challenged by Elliott and Grigorenko (2014), who argue that problems with definition and interpretation of the term 'dyslexia' could prove to be a major disservice to many children with difficulties. The label 'dyslexia', however, serves two important functions: (1) it provides an 'explanation' of the reading difficulties an individual experiences, helping to restore self-esteem; and (2) it provides for resources and dispensation in examinations.

Regardless of the label attached to them, reading problems and spelling difficulties continue to cause concern and controversy. Reading is a complex visual, phonological, linguistic and cognitive skill, and might be expected to fail for a large number of different reasons. It may be more appropriate to concentrate on the reasons for reading failure than on the classification of individuals with such failure.

Date of acceptance: 22 September 2015. Address for correspondence: Professor Arnold Wilkins, Department of Psychology, University of Essex, Colchester CO4 3SQ, UK. arnold@essex.ac.uk

Characteristics of visual stress

Visual stress is one possible contributor to reading difficulty. The condition is usually recognised in terms of a cluster of symptoms that have been attributed to cortical neurological mechanisms (Wilkins et al. 1984). Perhaps the most prominent symptom is discomfort, often associated with perceptual distortion, particularly when reading. The distortion can take a wide variety of forms, sometimes florid, sometimes more subtle. The patient usually reports some perceptual instability of the visual world, particularly prominent in text; the words or letters appear to move in some manner. Sometimes the illusions of motion are accompanied by illusions of shape, including blurring, and illusions of colour (halos behind the letters). Sometimes patients are unaware of the symptoms until a coloured filter is used and the symptoms remit, so a failure to report perceptual distortions cannot be taken at face value. There is sometimes a family history of migraine, dyslexia or visual stress.

These symptoms may, however, have a variety of other possible aetiologies. Furthermore, no one symptom in the symptom cluster is invariably present. The routine optometric examination gives little indication of visual stress (Monger et al. 2015). Accommodative and vergence amplitudes are often slightly depressed (Evans et al. 1995; Scott et al. 2002), but not to an extent that would be likely to explain the symptoms. Indeed, many of the symptoms experienced in visual stress are also typical in cases of uncorrected refractive error and accommodation-vergence anomalies.

Because the symptoms may result from many possible causes, it is essential to conduct a full assessment of refractive status and binocular vision and to treat any anomalies conventionally before considering treatment with coloured filters. That said, anecdotal observations suggest that visual stress may exacerbate difficulties with accommodation and vergence and that these difficulties can sometimes be reduced when coloured filters are used.

Purpose of this article

This article is not a review of visual stress. Those practitioners who wish to familiarise themselves with the area are referred to the following reviews (Allen et al. 2009; Wilkins 1995, 2003; Wilkins et al. 2009). Instead, this paper is aimed at those who already have an interest in coloured filters, particularly coloured overlays, and their use not only in reading difficulties, but in a range of other disorders. It addresses some of the subtle difficulties of interpretation that need to be negotiated by a practitioner who wishes to assess visual stress in a patient. It is intended to update the resources that are already available and tackles some of the problems that can arise.

Neurological correlates of visual stress

In practice, visual stress is generally recognised through subjective reports of the characteristic symptoms described above, but there is also objective evidence of neurological responses associated with this subjective experience. For example, Adjamian et al. (2004), using magnetoencephalography, found that the strength of high-frequency ‘gamma’ oscillations in the primary visual cortex when viewing grating-pattern stimuli was highly correlated with the experience of visual illusions and discomfort. Furthermore, imaging studies have revealed an excessive haemodynamic response to stressful patterns in individuals with migraine (Huang et al. 2003, 2011) and also an excessive response in a patient with visual stress (Chouinard et al. 2012). It has been argued that the discomfort is a homeostatic response, as with other pain. It may act to reduce the hypermetabolism (Wilkins and Hibbard 2014).

Overlays – an important question

It is now well established that the use of appropriate coloured filters (as overlays or lenses) can alleviate symptoms of visual stress and may improve performance in some types of visual task, notably reading speed.

The 10 intuitive overlays, the 12 cerium overlays or the 10 crossbow overlays all provide at least 30 shades of colour when combined. The process of selection involves the pairwise comparison of overlays placed upon the page either individually or in combination. Initially the comparison is between an overlay and the white page, but if an overlay makes the text clearer and more comfortable to read than the white page, subsequent comparisons are made against this overlay using a process of elimination. If any benefit from an overlay is marginal, then it is quite possible that the final choice of colour will also offer marginal benefit. It is therefore essential for the patient to be asked whether the final choice of overlay is better than the white page, in order to ensure an individual will benefit from the dispensing of an overlay (Wilkins 2003, p. 61).

Precision is necessary – strong evidence is now available

The appropriate colour for a coloured filter depends on whether the filter in question is placed upon a page of text as an overlay, or is worn as spectacles (Lightstone et al. 1999). The optimal colour differs in these two contexts, perhaps because of colour adaptation. This means that the colour of an overlay chosen as optimal cannot be used as a guide to the colour that is optimal for lenses.

In early studies (Wilkins and Neary 1991; Wilkins et al. 1992a, b), children with reading difficulty observed text illuminated by coloured light in an instrument that permitted the separate manipulation of hue and saturation at constant luminance, an instrument that subsequently became the intuitive colorimeter. Each child was able to discover a range of colours in which the perceptual distortions abated. These regions were represented in the CIE 1976 uniform chromaticity scale diagram, which is a perceptual colour space in which equal distances correspond (approximately) to equally discriminable colours. The effective colours could be represented as circumscribed regions of this space.

These observations were confirmed in a double-masked clinical trial (Wilkins et al. 1994) in which children who had used coloured overlays were asked to observe text illuminated in the intuitive colorimeter and again choose a colour that best improved the comfort and clarity of the text. They were then asked to change the setting of hue from optimal until distortions and discomfort began to return. The colour of the setting for the optimal benefit and the colour of the setting at which the distortions just returned were colours that were separated by an average distance of 0.065 in the CIE 1976 UCS diagram (Hunt 1991). This distance corresponds to about six just-noticeable differences of colour (based on the MacAdam ellipses). This is six times the difference in colour that can just be detected when two coloured surfaces are presented side by side. Readers may wish to access http://www.konicaminolta.com/instruments/knowledge/color/part4/08.html to get a rough idea of the size of the difference. When tints were presented in succession, as in this study, the colours could not be distinguished, partly because people tend to remember colours in terms of their verbal label (D'Ath et al. 2006), which was usually similar for the active and control colours.

In a subsequent small-scale double-masked trial of ophthalmic tints in migraine prophylaxis, patients once again selected the hue and saturation optimal for comfort. A set of control tints was provided, which proved less effective than those matching the optimal settings. The control tints had hues that differed in chromaticity from the optimal by 0.06 in the CIE 1976 UCS diagram (Wilkins et al. 1992b).

These behavioural studies have now been corroborated by two imaging studies in which patients with migraine chose an optimal tint in the intuitive colorimeter. Another tint, differing in colour by 0.07 in the CIE UCS diagram, was randomly selected as a control by computer. The patients showed an abnormal cortical haemodynamic response to gratings with mid spatial frequency, as mentioned previously. However, this response was normalised with the optimal tint. The control tint had no beneficial effect, notwithstanding the small difference in colour (Coutts et al. 2012; Huang et al. 2011).

The above studies have looked at the effects of precision on discomfort and on its haemodynamic correlates, in both children with reading difficulties and adults with migraine. They have consistently shown that a tinting precision well within 0.06 in the CIE 1976 UCS diagram was necessary.

A further study has investigated the effects of precision on reading speed (Wilkins et al. 2005a). Five volunteers who had used tinted lenses selected the hue and saturation of coloured illumination optimal for clarity. They then repeatedly read paragraphs of randomly ordered common words as quickly as possible, both under illumination of the optimal colour and under a wide range of other colours. On average, the optimal colour of illumination doubled the reading speed. As the colour of the illumination departed from this optimum, so reading speed decreased, and it did so consistently in two sessions separated by at least 2 weeks. When the chromaticity of the illumination differed by 0.07 in the CIE 1976 UCS diagram, there was no benefit to reading speed. Although there were only 5 participants, the way in which the reading speed decreased with the change in colour was similar for all.

Modelling the decrease in reading speed with colour difference led to an estimate that about 6000 tints are required if all colours are to be available with the degree of precision necessary (Wilkins et al. 2005b). These can be provided by combining a relatively small number of coloured trial lenses, as in the intuitive colorimeter system. This system uses five or six levels of dye deposition of each of seven dyes, a total of 37 lenses for each eye. The lenses provide for a geometric series of dye deposition, so all lens combinations can be used to provide subtly different shades of colour. With the intuitive colorimeter the tint selected as optimal is that suitable for use under 'white' fluorescent lighting, which has a chromaticity midway between that of incandescent lighting and daylight.

According to the model, the tints are slightly less effective under incandescent lighting and daylight, but most retain some benefit (Wilkins et al. 2005a, b), with the possible exception of tints that are purple.

Precision is possible with coloured lenses, but is not practical when overlays are used. Perhaps in consequence, lenses are usually more effective than coloured overlays. Nevertheless, clinical experience has shown that overlays are suitable in determining whether assessment for coloured lenses is likely to be useful. Some children use their overlays for a while, and then stop using them, saying they no longer need them. Although this might at first glance suggest that they never needed them in the first place, there is another, more interesting, interpretation. In their small-scale investigation of patients with multiple sclerosis, Newman Wright et al. (2007) compared two randomly selected groups of patients tested on two sessions separated by an interval of 2 weeks. One group received an overlay of their chosen colour at the first session. The other group were given a grey overlay instead and received their coloured overlay at the second session. The coloured overlay but not the grey increased reading speed, as expected. But the group who had been using a coloured overlay during the interval read more quickly both with the overlay, and (to a slightly less extent) without. It would appear that there may be some generalisation over time in the benefit derived from an overlay. If an individual uses the overlay for a period and then discards it, it therefore does not necessarily mean that the overlay has been of little use.

There are two investigations that may be helpful in complementing the description of symptoms, and assisting in the assessment and treatment of visual stress: the Pattern Glare Test and the Wilkins Rate of Reading Test (WRRT).

Pattern Glare Test and viewing distance

The Pattern Glare Test consists of three horizontal square-wave gratings with different spatial frequency, numbered 1–3. Monger et al. (2016) have shown that, when patterns with similar spatial frequency are presented at a variety of distances (larger patterns for larger distances), the number of illusions reported depends on the spatial frequency of the pattern and not on viewing distance. This would suggest that the illusions are not influenced by accommodation, and is consistent with their hypothesised cortical origin.

The second of the three patterns in the Pattern Glare Test, pattern 2 (which has a spatial frequency of 4.4 cycles/cm) is particularly aversive for patients with visual stress, those with migraine (Chronicle and Wilkins 1991) and sometimes those with dyslexia (Evans et al. 1994). It is also capable of inducing a seizure in patients with photosensitive epilepsy (Wilkins et al. 1979). Patients who find the pattern uncomfortable usually report a large number of anomalous visual effects within the pattern (Wilkins et al. 1984). The anomalous visual effects are recorded using a list of illusions of colour shape and motion. The illusions are dependent on the spatial frequency of the pattern according to the curve shown in Figure 1.

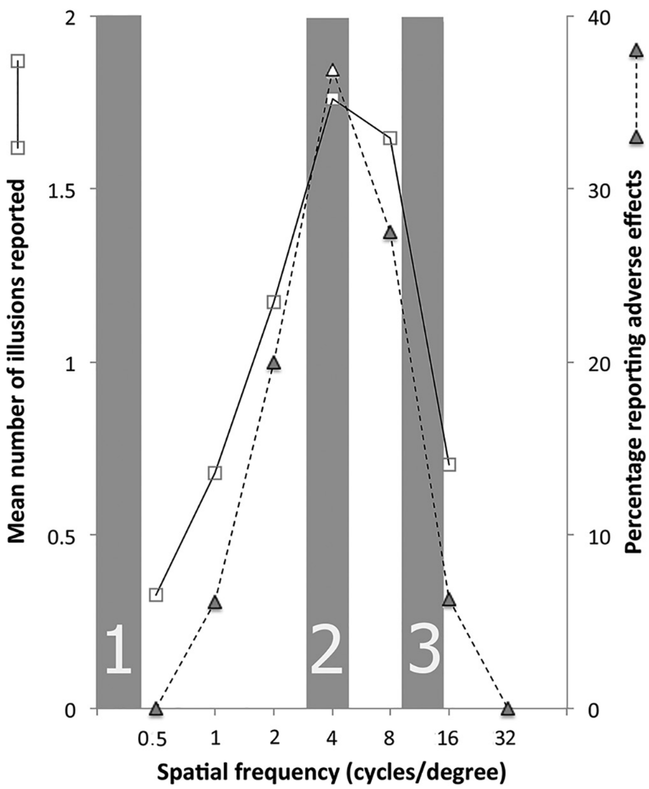

Figure 1. The mean number of illusions reported (squares) and the percentage of observers reporting adverse effects (triangles) in response to a square-wave grating, shown as a function of the spatial frequency of the grating, from experiments 1 and 4 by Wilkins et al. (1984). The three shaded bars show the range of spatial frequency for patterns 1, 2 and 3 of the Pattern Glare Test for viewing distances in the range 0.4–0.6m.

The spatial frequency of the pattern depends both on the number of cycles of the pattern in a given distance, and also on the distance from which the pattern is viewed. The shaded areas in Figure 1 show the range of spatial frequencies when patterns 1–3 are presented at viewing distances in the range from 0.4m (left-hand border of the shaded area) to 0.6m (right-hand border). It can be seen that illusions are rarely reported for pattern 1 at any viewing distance in this range, and pattern 1 can therefore be used to assess the patients' acquiescence to suggestion in reporting symptoms. Pattern 2 is likely to provoke illusions and again viewing distances within the range 0.4–0.6m do not affect spatial frequency sufficiently to alter the probability of reporting illusions (although at 0.6m the pattern has a smaller subtense, and this may reduce the illusions by about 10%[1]). The response to pattern 3, however, is strongly affected by the distance from which the patient views the pattern. This is because the pattern has a spatial frequency of 9.4 cycles per degree at 0.4m and 14 cycles per degree at 0.6m. The literature would indicate that, whereas neurological factors are responsible for the illusions reported in response to pattern 2, which has midrange spatial frequency, optometric anomalies that affect the quality of the retinal image are more likely to affect the perception of the grating with high spatial frequency (Conlon et al. 2001).

It can be seen that a comparison of the effects of pattern 2 and pattern 3, as highlighted by Evans and Stevenson (2008), is critically dependent on the distance from which pattern 3 is viewed. Evans and Stevenson (2008) suggested that an alternative method of detecting pattern glare is simply to consider the score with pattern 2 (which they showed is abnormal if greater than 3). This criterion may be preferable.

A further problem of interpretation arises from the fact that it is technically difficult to print gratings with high spatial frequency, and the quality of the reproduction was poor in early editions of the test available to Evans and Stevenson (2008). Under these circumstances, it may be more reliable to use the innocuous pattern 1 as a control for possible acquiescence when reporting symptoms from a list, comparing the response to pattern 1 with that to pattern 2.

As we have seen, three factors conspire to make pattern 3 problematic: (1) the steepness of the high-frequency arm of the curve in Figure 1; (2) the challenges of printing high spatial frequency gratings; and (3) the optical demands of seeing high spatial frequencies. If pattern 3 is used at all, it should only be used at a controlled viewing distance, with attention to the spatial frequency at that distance. It might be helpful to compare the response to pattern 3 at 0.4m with that at 0.6m, but no studies have investigated this formally.

Notwithstanding the above issues, Hollis and Allen (2006) showed that the reports of illusions on the Pattern Glare Test (pattern 2) predicted the increase in reading speed with coloured filters, and did so more reliably than the response to a questionnaire concerning symptoms. They used a slightly larger list of illusions than that offered in the published version of the test, but an analysis undertaken by Monger et al. (2016) suggests that this had little effect.

Measuring improvements in reading speed

The WRRT was conceived as a simple means of measuring the effects of visual factors on reading speed by removing the variability due to word recognition and comprehension (Wilkins et al. 1996). The patient is required to read aloud paragraphs of randomly ordered common, simple words printed in a closely spaced typeface. Those individuals who report improved clarity of text with an overlay usually

[1]Based on calculations from the data in Table 8 from Wilkins et al. (1984).

read more quickly with the overlay on this test both before (Wilkins et al. 1996) and after (Jeanes et al. 1997) long-term use of the overlay. Similarly, those individuals who read more quickly are usually those who subsequently continue to use the overlay voluntarily in the long term (Wilkins 2002). The overlay may also improve reading speed when conventional prose is read, although this improvement may be measurable only after a lengthy period of reading, sufficient to iron out the variability due to comprehension (Tyrrell et al. 1995).

An interesting feature of the WRRT is that, in two studies, one with 7-year-olds (Figure 8 in Wilkins et al. 2001) and the other with 13-year-olds (Scott et al. 2002), the correlation of reading rate with scholastic attainment in reading was 0.5–0.6. In both studies the highest rate of reading (>160 words per minute) was more than four times the slowest (<40 words per minute) for children with similar scholastic reading ability. This range does not reflect random variation: scores from individual children vary from one examination to another by about 7 words per minute on average. Evidently some children are consistently fast readers and some slow, quite irrespective of their ability to recognise and understand words. There are no optometric findings that explain this variation, even though it presumably reflects a largely visual, as opposed to linguistic, difficulty. There is evidence that some individuals with reading difficulty are more susceptible to visual crowding than others (Bellocchi 2013), and an explanation of reading speed in terms of the effects of crowding may prove possible.

The increase in reading speed with an overlay has generally been expressed as percentage change, because in early work this appeared to provide an index that was independent of baseline reading speed. Studies in the literature have chosen different percentage criteria as reflecting a benefit from overlays (Table 1). The prevalence of benefit reflects the criterion and the population sampled.

The increment in reading rate from the use of an overlay is best expressed in terms of the variability in individual performance. One way of doing this is to calculate the standard deviation of each individual's reading rate when no overlay is used and express any increment with the overlay as a ratio of the standard deviation, ie as a *z*-score. The recommended method of using the test is to give the test four times, initially with the overlay, then without the overlay, then again without, and finally with the overlay once again. The two test scores in each condition can be used to estimate the standard deviation. We calculated the *z*-scores for the sample of 137 patients examined by L Taylor (Scott et al. 2002). There were more individuals with a positive *z*-score than a negative *z*-score. This reflects the fact that an overlay improves reading speed more often than it impairs it. We can regard the *z*-scores from –2 to +2 as reflecting most of the random variation. In 4/137 the *z*-score was less than –2; ie 3% individuals showed a decrement in performance with an overlay. In contrast, 22/137 individuals had a *z*-score greater than +2, and therefore showed an increment. In 15 of the 22 the change was greater than 15%. This was the case for only 4 individuals with a *z*-score within the range –2 to +2 and for none of the individuals whose *z*-scores were less than –2.

As can be seen from Table 1, a confusing range of criteria has been used in the literature, and further analysis of the WRRT scores is needed. While in principle it is preferable to study the increase in reading speed in relation to the individual variability in scores, in clinical practice, a stable estimate of this variability may take too long to acquire. The above reanalysis would suggest that, for a given individual in this sample of children, a criterion of 15% improvement in

Table 1. Criteria for a beneficial effect of colour in the literature

Criterion	Age (years)	Prevalence	Sources
>5% increase on WRRT	6–17	22–43%	Kriss and Evans (2005); Singleton and Henderson (2007); Wilkins et al. (1996, 2001)
	18–44	34–58%	Evans and Joseph (2002); Henderson et al. (2013)
>8% increase on WRRT	7–17	18–28%	Kriss and Evans (2005); Singleton and Henderson (2007)
	19–34	46%	Henderson et al. (2013)
>10% increase on WRRT	7–17	13–22%	Kriss and Evans (2005); Singleton and Henderson (2007)
	19–34	35%	Henderson et al. (2013)
>25% increase on WRRT	6–8	5%	Wilkins et al. (2001)
	18–44	2%	Evans and Joseph (2002)
Use overlay for >8 weeks	8–11	20%	Wilkins et al. (1996)
Use overlay for >3 months	5–12	35–36%	Jeanes et al. (1997)
Use overlay for >8 months	6–8	31%	Wilkins et al. (2001)
Use overlay for >10 months	5–12	9–38%	Jeanes et al. (1997)

WRRT, Wilkins Rate of Reading Test.

reading rate is likely to indicate an increase in reading speed beyond intraindividual variability and may be considered an acceptable criterion to use in the absence of other confirmatory evidence of visual stress. In adult samples the percentage criterion may be lower. If the overlay is being dispensed on a trial basis for later assessment, then a less conservative criterion might be acceptable.

Various systems for tinting

The web is full of disinformation concerning systems for ophthalmic tinting. The Irlen system was the first to offer a wide range of tints, although the system has never been described in the scientific literature. Irlen claims that her lenses 'reduce the input of specific wavelengths of light' – a claim that seems unlikely, given that the lenses usually have broadly varying spectral transmission. The tinted trial lenses are held to the eyes by the patient, one after another in a lengthy process of elimination. Tints that offer relief of symptoms are set aside, and these are then combined by superimposing the effective trial lenses, apparently without any constraint as to the colours of the lenses or the number to be combined. When lenses have similar chromaticity their superposition provides for a chromaticity that is a compromise between that of the two lenses; when the two lenses have complementary colours, however, the combination bears no resemblance to the shades originally chosen. As might be expected, the final tints are often rather grey, and often consist of many dyes in combination. The large number of dyes makes the dyeing process difficult to control because a dye tends to leach out when the lenses are placed in the next dye bath.

It has already been shown that the Irlen overlays do not sample chromaticity systematically (Wilkins 1994) even though, subsequent to the introduction of the intuitive overlays, a purple overlay was added to the Irlen set.

The intuitive colorimeter provides a large range of chromaticities with the same spectral power distribution as that obtained when the trial lenses are worn under typical artificial lighting. The lenses sample chromaticity systematically and densely, using only two dyes. The average efficacy[2] of tinting systems with 30 lenses has been estimated to be 75% (Wilkins et al. 2005b). It will be poorer for systems with fewer lenses.

Controversy continues

Treatment with coloured filters remains controversial. A study by Richie et al. (2011) is widely cited as demonstrating that coloured filters are of no benefit. This study used one individual trained using the Irlen methods to identify individuals with 'Irlen syndrome' (presumed synonymous with visual stress). No improvement in reading speed with overlays was obtained on the WRRT. Most other studies of coloured filters have demonstrated an improvement with overlays on this test, even the study by Henderson et al. (2013). Henderson et al. (2013) showed an effect of overlays on reading speed but not on reading comprehension and argued that overlays are therefore of questionable value. Whereas we might expect reading rate to be increased when the visual clarity of text is improved, whether as the result of an overlay or indeed refractive correction, we would not necessarily expect an immediate effect on comprehension because comprehension is strongly influenced by many non-visual factors. Given the methods by which comprehension was measured in the study by Henderson et al. (2013), any effect of the overlay is likely to have been lost in the variability associated with comprehension, memory for the text and visual search of the passage.

The many studies that have found that overlays improve reading speed include those with single-masked design and placebo controls, but none was double-masked (indeed, it is difficult, if not impossible, to mask the choice of overlays). It is possible that the masking used in the study by Richie et al. (2011) reduced the effect of the overlays. It is also possible that the identification of individuals with Irlen syndrome was inappropriate, possibly overinclusive: 77% of individuals selected by their teachers as 'below-average' readers were identified with Irlen syndrome. This is nearly twice the conventional estimates of the prevalence of visual stress in individuals with dyslexia and would have meant that many children did not have visual stress. Another possible explanation for the absence of any effect of overlays is that the study used the Irlen overlays.

There are position statements from the American Academy of Pediatrics, Council for Children with Disabilities, American Academy of Ophthalmology, American Association for Pediatric Ophthalmology and Strabismus, the Board of Certified Orthoptists and the Royal College of Ophthalmologists, all of which take the view that the evidence for the use of coloured filters to treat dyslexia is inadequate. The use of coloured filters to treat visual stress is also a controversial issue. It is worth noting that none of the above statements appears to be based on a comprehensive review of the literature. None of them has distinguished between the methods used by Irlen and those advocated in the intuitive colorimeter system, which are designed for optimal precision tinting, and take colour adaptation into account. An independent review that includes recent literature (Uccula et al. 2014) ends with the statement that it is premature to conclude that coloured filters have little benefit. A large-scale multicentre trial of precision tints in children who use coloured overlays is overdue.

Best practice

This area of optometry practice is challenging for a number of reasons, which include: variation in the definitions and criteria for diagnosis of dyslexia that are employed in practice; difficulty in distinguishing between the effects of visual stress and other conditions that give rise to similar symptoms; the fact that visual stress itself cannot be directly measured; a widespread assumption that visual stress and dyslexia are strongly associated or even that occurrence of visual stress indicates dyslexia; ongoing controversy over the benefits of coloured filters in alleviating visual stress and the role that this form of intervention plays in helping to alleviate difficulties with reading. With these points in mind, our recommendations for best practice in optometry are as follows:

[2] Benefit to reading speed, expressed as a proportion of the benefit with a tint of optimal colour.

- Optometrists should be aware, and if necessary inform patients, that visual stress and dyslexia are not the same thing. A visual stress assessment is not a dyslexia assessment. Assessment for visual stress can tell us nothing about whether a patient is likely to be dyslexic. Likewise, knowing that a patient is dyslexic can tell us little about whether visual stress or any other vision-related problem will be a factor in that person's reading difficulty.
- Assessment of visual stress should take account of the patient's day-to-day symptoms, and also the patient's response to viewing a high-contrast grating pattern (the Pattern Glare Test) – these two together are the principal indicators of visual stress. A measurement of reading speed (using WRRT) should also be obtained, particularly when the patient's complaint relates to difficulty with reading text, but note that reading speed varies widely between individuals and slow reading speed is not in itself an indication of visual stress.
- Assessment of visual stress should always be undertaken as part of a more comprehensive investigation that includes assessment of refractive and binocular (accommodation and vergence) status. Some symptoms that have become associated with visual stress (eg headaches, blurred vision, words moving around) are typical of the effects of uncorrected refractive error and accommodation-vergence anomalies. Optometrists should be in a position to address any vision-related problem that causes discomfort and interferes with reading, and advise patients accordingly.
- Treatment of visual stress, involving selection and use of coloured filters, should be undertaken systematically as described above and in the literature cited. The aim of treatment should be to achieve a sustained reduction in visual discomfort and disturbance and, in the context of reading, to reduce aversion to text and enable a possible increase in reading speed.
- Finally, it must be remembered that, although treatment of visual stress may reduce aversion to text and support an increase in reading speed, it would not be expected to reduce any reading difficulties that stem from poor phonological and linguistic processing, ie the difficulties that are considered to define developmental dyslexia.

Summary

Many optometrists now use overlays in the assessment of visual stress in patients with reading difficulties, and some use the Pattern Glare Test and the Wilkins Rate of Reading Test as components of the assessment. We consider some of the issues that surround such an assessment.

Disclosure of interest

None of the authors has a financial interest in coloured overlays or tinted lenses. AJW receives emoluments based on sales of the Pattern Glare Test, the Wilkins Rate of Reading Test and the intuitive colorimeter.

References

Adjamian P, Holliday I, Barnes G et al. (2004) Induced visual illusions and gamma oscillations in human primary visual cortex. *Eur J Neurosci* **20**, 587–92

Allen PM, Evans BJW, Wilkins AJ (2009) *Vision and Reading Difficulties*. London: Ten Alps Creative

Bellocchi S (2013) Developmental dyslexia, visual crowding and eye movements. In: Stewart LC (ed.) *Eye Movement: Developmental Perspectives, Dysfunctions and Disorders in Humans*. New York: Nova Science

Chouinard B, Zhou C, Hrybouski S et al. (2012) A functional neuroimaging case study of Meares–Irlen syndrome/visual stress (MISViS). *Brain Topogr* **25**, 293–307

Chronicle E, Wilkins AJ (1991) Colour and visual discomfort in migraineurs. *Lancet* **338**(890)

Conlon E, Lovegrove W, Barker S et al. (2001) Visual discomfort: the influence of spatial frequency. *Perception* **30**, 571–81

Coutts LV, Cooper CE, Elwell CE et al. (2012) Time course of the haemodynamic response to visual stimulation in migraine, measured using near-infrared spectroscopy. *Cephalalgia* **32**, 621–9

D'Ath PJ, Thomson WD, Wilkins AJ (2006) Memory for the colour of non-monochromatic lights. *Color Res Appn* **32**, 11–15

Elliott JG, Grigorenko EL (2014) *The Dyslexia Debate*. Cambridge: Cambridge University Press

Evans BJW, Joseph F (2002) The effect of coloured filters on the rate of reading in an adult student population. *Ophthal Physiol Opt* **22**, 535–45

Evans BJW, Stevenson SJ (2008) The pattern glare test: a review and determination of normative values. *Ophthal Physiol Opt* **28**, 295–309

Evans BJW, Cook A, Richards IL et al. (1994) Effect of pattern glare and coloured overlays on a simulated reading task in dyslexics and normal readers. *Optom Vis Sci* **71**, 619–28

Evans BJW, Busby A, Jeanes R et al. (1995) Optometric correlates of Meares–Irlen syndrome: a matched group study. *Ophthal Physiol Opt* **15**, 481–87

Henderson L-M, Tsogka N, Snowling M (2013) Questioning the benefits the coloured overlays can have for reading in students with and without dyslexia. *J Res Special Ed Needs* **13**, 57–65

Hollis J, Allen PM (2006) Screening for Meares–Irlen sensitivity in adults: can assessment methods predict changes in reading speed? *Ophthal Physiol Opt* **26**, 566–71

Huang J, Cooper TG, Satana D et al. (2003) Visual distortion provoked by a stimulus in migraine associated with hyperneuronal activity. *Headache* **43**, 664–71

Huang J, Zong X, Wilkins A et al. (2011) fMRI evidence that precision ophthalmic tints reduce cortical hyperactivation in migraine. *Cephalalgia* **31**, 925–36

Hunt RWG (1991) *Measuring Colour* (2nd edn). Chichester: Ellis Horwood

- Jeanes R, Busby A, Martin J et al. (1997) Prolonged use of coloured overlays for classroom reading. *Br J Psychol* **88**, 531–48
- Kriss I, Evans BJW (2005) The relationship between dyslexia and Meares–Irlen syndrome. *J Res Reading* **28**, 350–64
- Lightstone A, Lightstone T, Wilkins A (1999) Both coloured overlays and coloured lenses can improve reading fluency, but their optimal chromaticities differ. *Ophthal Physiol Opt* **19**, 279–85
- Monger LJ, Wilkins A, Allen PM (2015) Identifying visual stress during a routine eye examination. *J Optom* **8**, 140–5
- Monger LJ, Shah D, Wilkins AJ et al. (2016) The effect of viewing distance on response to the pattern glare test. *Clin Exp Optom* **99**, 47–50
- Newman Wright A, Wilkins A, Zoukos Y (2007) Spectral filters can improve reading and visual search in patients with multiple sclerosis. *J Neurol* **254**, 1729–35
- Richie S, Della Sala S, McIntosh R (2011) Irlen colored overlays do not alleviate reading difficulties. *Pediatrics* **128**, e932–8
- Rose J (2009) *Identifying and Teaching Children and Young People with Dyslexia and Literacy Difficulties. An Independent Report to the Secretary of State for Children, Schools and Families*. Available online at: http://webarchive.nationalarchives.gov.uk/20130401151715/http://www.education.gov.uk/publications/eOrderingDownload/00659-2009DOM-EN.pdf (accessed 10 September 2015)
- Scott L, McWhinnie H, Taylor L et al. (2002) Coloured overlays in schools: orthoptic and optometric findings. *Ophthal Physiol Opt* **22**, 156–65
- Singleton C, Henderson L-M (2007) Computerised screening for visual stress in children with dyslexia. *Dyslexia* **13**, 130–51
- Tyrrell R, Holland K, Dennis D et al. (1995) Coloured overlays, visual discomfort, visual search and classroom reading. *J Res Reading* **181**, 10–23
- Uccula A, Enna M, Mulatti C (2014) Colors, colored overlays and reading skills. *Front Psychol* **5**, 833
- Wilkins AJ (1994) Overlays for classroom and optometric use. *Ophthal Physiol Opt* **14**, 97–9
- Wilkins AJ (1995) *Visual Stress*. Oxford: Oxford University Press
- Wilkins AJ (2002) Coloured overlays and their effects on reading speed: a review. *Ophthal Physiol Opt* **22**, 448–54
- Wilkins AJ (2003) *Reading Through Colour*. Chichester: John Wiley
- Wilkins AJ, Hibbard PB (2014) *Discomfort and Hypermetabolism*. Paper presented at the 50th Anniversary convention of AISB, London
- Wilkins A, Neary C (1991) Some visual, optometric and perceptual effects of coloured glasses. *Ophthal Physiol Opt* **11**, 163–71
- Wilkins AJ, Darby CE, Binnie CD (1979) Neurophysiological aspects of pattern-sensitive epilepsy. *Brain* **102**, 1–25
- Wilkins AJ, Nimmo-Smith MI, Tait A et al. (1984) A neurological basis for visual discomfort. *Brain* **107**, 989–1017
- Wilkins A, Milroy R, Nimmo-Smith I et al. (1992a) Preliminary observations concerning treatment of visual discomfort and associated perceptual distortion. *Ophthal Physiol Opt* **12**, 257–63
- Wilkins A, Nimmo-Smith MI, Jansons J (1992b) A colorimeter for the intuitive manipulation of hue and saturation and its application in the study of perceptual distortion. *Ophthal Physiol Opt* **12**, 381–5
- Wilkins AJ, Evans BJW, Brown JA et al. (1994) Double-masked placebo-controlled trial of precision spectral filters in children who use coloured overlays. *Ophthal Physiol Opt* **144**, 365–70
- Wilkins AJ, Jeanes RJ, Pumfrey PD et al. (1996) Rate of reading test: its reliability, and its validity in the assessment of the effects of coloured overlays. *Ophthal Physiol Opt* **16**, 491–7
- Wilkins AJ, Lewis E, Smith F et al. (2001) Coloured overlays and their benefits for reading. *J Res Reading* **181**, 10–23
- Wilkins A, Sihra N, Myers A (2005a) Increasing reading speed using colours: issues concerning reliability and specificity, and their theoretical and practical implications. *Perception* **34**, 109–20
- Wilkins A, Sihra N, Nimmo-Smith I (2005b) How precise do precision tints have to be and how many are necessary? *Ophthal Physiol Opt* **25**, 269–76
- Wilkins AJ, Evans BJW, Allen PM (2009) Coloured filters – do they work? *Optom Today* 22 May, 30–8

CET multiple choice questions

This article has been approved for one non-interactive point under the GOC's Enhanced CET Scheme. The reference and relevant competencies are stated at the head of the article. To gain your point visit the College's website www.college-optometrists.org/oip and complete the multiple choice questions online. The deadline for completion is 31 July 2017. Please note that the answers that you will find online are not presented in the same order as in the questions below, to comply with GOC requirements.

1. What increase in reading speed is considered clinically significant when measured by the Wilkins Rate of Reading Test?

- 5%
- 10%
- 15%
- 20%

2. Which of the following statements is correct?

- Visual stress is the same as dyslexia
- Visual stress is a risk factor for dyslexia
- Dyslexia is a risk factor for visual stress
- Visual stress is not the same as dyslexia

3. Which pattern is most effective at detecting visual stress in the Pattern Glare Test?

- Pattern 1: 0.5 cycles per degree
- Pattern 2: 3 cycles per degree

- Pattern 3: 12 cycles per degree
- Pattern 4: 16 cycles per degree

4. Which of the following statements is correct?

- An eye examination is used to diagnose visual stress
- An eye examination is used to diagnose dyslexia
- An eye examination is used to rule out refractive and oculomotor visual problems
- An eye examination can be used for all of the above

5. Under which light source are precision tints thought to be most effective?

- Daylight
- Incandescent
- White fluorescent
- LED

6. What approximately is the considered efficacy of a tinting system with 30 lenses?

- 25%
- 50%
- 75%
- 95%

CPD exercise

After reading this article, can you identify areas in which your knowledge of visual stress and dyslexia has been enhanced?

How do you feel you can use this knowledge to offer better patient advice?

Are there any areas you still feel you need to study and how might you do this?

Which areas outlined in this article would you benefit from reading in more depth, and why?