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Randomised controlled trial of the effect of coloured overlays on the rate of reading of people with specific learning difficulties

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Abstract

A randomised controlled trial has demonstrated that, for selected children with reading difficulties, individually prescribed coloured filters reduce symptoms of asthenopia. In the present study, we investigate the effect of individually prescribed coloured overlays on the rate of reading. Subjects were 33 children and adults who: had consulted a specific learning difficulties clinic; had received treatment to normalise any conventional optometric and orthoptic anomalies; and subsequently reported symptomatic relief from coloured filters. These subjects carried out the Wilkins Rate of Reading Test (which assesses visual rather than linguistic factors) under two conditions: with their chosen coloured overlay and with a control filter. Steps were taken to ensure that a strong placebo effect was associated with the control overlay and, when asked which they preferred, subjects were not significantly more likely to prefer their coloured overlay than the control filter ($p = 0.11$). Nonetheless, the rate of reading was significantly faster with the coloured overlay than with the control ($p = 0.0019$). Further analyses support the conclusion that individually prescribed coloured filters can improve reading performance for reasons that cannot be solely attributed to conventional optometric factors or to placebo effects.

Keywords: coloured overlays, dyslexia, Meares–Irlen Syndrome, scotopic sensitivity syndrome, specific learning difficulties, tints

Introduction

Some people with reading difficulties report symptoms of asthenopia and visual perceptual distortions, which may remain even after any refractive or orthoptic anomalies have been treated (Robinson, 1994; Evans *et al*., 1995; Evans, 2001). Meares (1980) clearly defined these symptoms and Irlen (1983) developed a treatment regimen using coloured filters. Despite numerous open trials, it was more than 10 years until the first randomised double-masked placebo-controlled trial of the use of coloured filters for reading difficulties was published (Wilkins *et al*., 1994). This showed that individually prescribed coloured filters significantly reduce symptoms of eyestrain and headaches compared with control filters.

The aim of the present study was to extend these findings and to determine, with a placebo-controlled design, whether individually prescribed coloured filters had a significant effect on reading performance.

Reading tests for use in education are generally designed to assess high level linguistic aspects of reading. Typically, these tests use large text and widely spaced lines so that visual problems may have relatively little effect on performance. The present study used a new test of the rate of reading which had been specifically designed to be influenced by visual anomalies (Wilkins *et al*., 1996).

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Methods

Subjects

The subjects were 33 patients who met the following sequential criteria: (1) attended the Institute of Optometry because of suspected or diagnosed specific learning difficulties; (2) any clinically significant refractive, binocular or accommodative problems had been corrected (see below); (3) still complained of symptoms of asthenopia and/or perceptual distortions whilst reading and (4) reported a reduction in these symptoms when using a coloured plastic sheet (overlay) placed over a page of text.

All the subjects were attending the Institute of Optometry Specific Learning Difficulties Clinic because of suspected or diagnosed specific learning difficulties. Subjects were not evaluated by an educational or child psychologist as part of the research, but questionnaire data were available in which subjects were asked whether they had received such an assessment and if so what the diagnosis had been. This revealed that 20 of the subjects had received a diagnosis of dyslexia following assessment by an educational psychologist and three others had received a diagnosis of other specific learning difficulties.

Four of the subjects were adults (ages 18, 19, 30 and 40 years) and 29 were children (mean age 11 years 4 months, range 7 years 10 months to 14 years 11 months); and 70% were male. A refractive correction was used during the research by those patients who reported habitually (>50% of the time) using this when reading. Three subjects wore myopic corrections (range, –1.00 to –3.00), eight subjects wore hyperopic corrections (range, +1.00 to +2.75) and two subjects had astigmatism over 0.50 D (both of these were hyperopes with astigmatism of –3.00 and –2.50 in their worst eyes). There were no cases of anisometropia over 1.00 D. All the subjects could binocularly resolve N5 or smaller.

Optometric examination

Subjects underwent a detailed optometric assessment including the tests in *Table 1*.

Cycloplegic refractions were carried out where indicated (Evans, 2002) and any clinically significant refractive errors were corrected (Rabbetts, 2000). Similarly, any ocular motor (binocular or accommodative) anomalies that were either likely to be causing symptoms or might deteriorate if not corrected were treated (Evans *et al*., 1999; Evans, 2002). Ocular motor anomalies were most commonly treated using orthoptic exercises but, where appropriate, refractive or prismatic corrections were also used (Evans, 2002).

Table 1. Summary of clinical eye examination of subjects

Symptoms (questionnaire and direct questioning)
History (questionnaire and direct questioning)
Visual acuity
Ocular motility
Cover test at distance and near
Retinoscopy and subjective refraction
Aligning prism at distance and near (Mallett Unit) assessing compensation of phoria and binocular stability
Stereoscopic acuity (Randot Circles Test)
Accommodative lag (objective and subjective)
Accommodative facility (flippers)
Near point of convergence
Fusional reserves at near
Pupillary reflexes and ophthalmoscopy

The coloured overlays evaluation was considered if the child was still reporting asthenopia and/or visual distortion after any refractive and ocular motor anomalies had been corrected (Lightstone and Evans, 1995). One-third of the subjects in the study received orthoptic exercises before being prescribed coloured filters. The literature supports the finding in the present study that, although correcting ocular motor anomalies sometimes eliminates asthenopic symptoms, this is not always the case. Sometimes, symptoms are still present in people with specific learning difficulties whose ocular motor function is within normal limits (Evans *et al*., 1999; Evans, 2001).

Independent variable: the interventions

Each subject used two interventions: coloured overlay and control filter. Subjects had been tested with the Intuitive Overlays,[1] as detailed in the test instructions and outlined by Wilkins (1994). Briefly, a series of coloured transparent sheets are placed consecutively over a passage of jumbled text. The subject selects any colour(s) which improve(s) their perception of text. If more than one colour is selected then the chosen colours are compared pairwise to find the patient's 'optimal' colour.

The overlays have been described by Wilkins (1994) and the repeatability of the colour choice was evaluated by Jeanes *et al*. (1997). When placed over a page of white paper the reflectance of the paper through the overlays varies little with the angles of incident and reflected light, provided specular reflections are avoided. It is most appropriate to describe the spectral properties of the overlays in terms of the reflectance of white paper through the overlay and this is illustrated in *Figure 1*. The overlays have chromaticities disposed approximately evenly around the circumference of a circle in the CIE 1976 UCS diagram, centred on white (*Figure 1*).

[1]Supplied by I.O.O. Marketing, London, UK; 0207 378 0330.

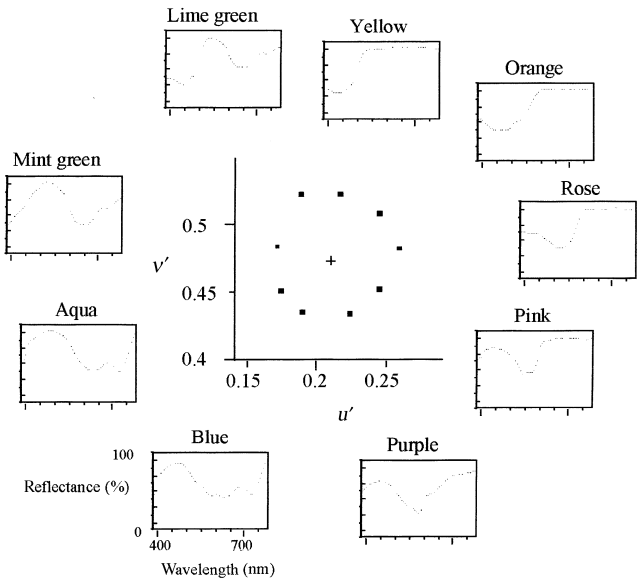

Figure 1. Centre: CIE 1975 UCS ($u'v'$) diagram showing the chromaticity coordinates (under the equal energy illuminant) of the nine coloured overlays (■) and that of equal energy white (+). Perimeter: panels show the reflectance (0–100% of each overlay as a function of wavelength (30–780 nm). The panels are disposed in a manner similar to that of the corresponding chromaticity coordinate. Reprinted with permission from Wilkins *et al.* (1994).

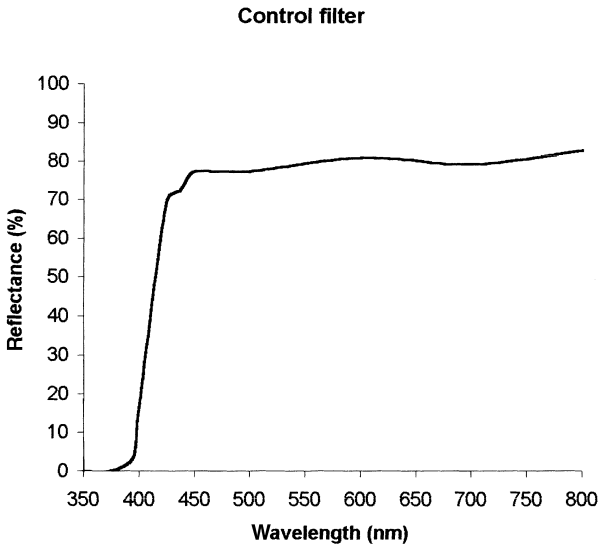

Figure 2. Spectral transmittance of control filter. Reproduced by permission of Lee Filters, Andover, Hampshire, UK.

The hue angle, h_{uv}, between neighbours averages 40° with a standard deviation (S.D.) of 7.7°; the saturation, s_{uv}, averages 0.52 (S.D. 0.19). The photopic reflectance (when the overlay was placed upon a halon standard) averages 65% (S.D. 13%). The overlays provided nine colours and a grey (reflectance 47%) when used singly. They were also used in pairs, one on top of another. The pairs were either of the same colour or of neighbouring chromaticity and provide a further 19 colours having greater saturation (s_{uv} average 1.1, S.D. 0.13) with a hue angle between neighbours averaging 20°(4.8°). The overlays therefore sample colours systematically and comprehensively. They have a matt coating and this reduces the contrast of the text beneath. With diffuse illumination and avoiding specular reflection, which were the conditions during the research, the reduction in contrast is generally less than 5%.

An ultraviolet blocking filter[2] was used as a control. This filter has a pale yellow colour (*Figure 2*) and it was assumed that the minimal spectral absorption of this filter would have a negligible effect on subjects' performance. Several steps were taken to convince the subjects that the control filter was as 'special' as the coloured filter they had chosen and to enhance the associated placebo effect (Richardson, 1995, p. 39): the control filter was mounted in a white cardboard frame; the following Letraset text was inscribed onto the frame 'Research Model A16 Anti UV/IR Filter. Made in USA'; and this filter was described to subjects using a cover story that it was a new filter from the United States where it was thought to be 'a wonderful discovery to help patients with reading difficulties'. It was further explained that the aim of the research was to compare their reading rate using a coloured overlay to that with this new filter. When measured under the lighting conditions used during the research, the control filter had a negligible effect on luminance and the reduction in contrast was less than 5%.

Dependent variable: the Rate of Reading Test

The dependent variable was performance as assessed by the Wilkins Rate of Reading Test[1] (Wilkins *et al.*, 1996). In this test, the subject reads a passage of text made up of 15 repeated words, which were selected as being commonly encountered by young readers (*Figure 3*). These words are repeated in random order and the subject is asked to read them out loud as quickly as possible while maintaining accuracy. The number of words correctly read in a minute is calculated. The text is small and closely spaced, so as to exaggerate the effect of any visual problems. Because the test requires little comprehension and only very basic word reading skills, performance is independent of language skills in the age group under test.

The Rate of Reading Test is produced in four parallel versions, with the same words but in different order. Two of the versions were read using the coloured overlay and the other two with the control filter, using

[2]Filter 226, supplied by Lee Filters, Andover, Hampshire, UK; 01264 366245.

come see the play look up is cat not my and dog for you to
the cat up dog and is play come you see for not to look my
you for the and not see my play come is look dog cat to up
dog to you and play cat up is my not come for the look see
play come see cat not look dog is my up the for to and you
to not cat for look is my and up come play you see the dog
my play see to for you is the look up cat not dog come and
look to for my come play the dog see you not cat up and is
up come look for the not dog cat you to see is and my play
is you dog for not cat my look come and up to play see the

Figure 3. Example of text in Wilkins Rate of Reading Test.

an ABBA design to control for practice effects. Half the subjects read first with the control filter (i.e. control filter was condition A) and the other half read first with their preferred coloured overlay (for these, the coloured overlay was condition A). The mean rate of reading for each subject in each condition was calculated as the number of words correctly read per minute from averaging the two trials. The examiners were not masked and knew the identity of the patient and of the overlays that were being used.

Further analyses

After they had completed the Rate of Reading Test all four times, subjects were asked which filter they preferred for reading, the coloured overlay or UV-blocking filter. Some of the subjects had undergone the overlay testing and been issued with an overlay of their preferred colour several weeks before participating in the research and had demonstrated a sustained voluntary use of the overlay. Other subjects were first tested with overlays on the same day as they participated in the research, and had thus only reported an immediate benefit. For further analyses, subjects were therefore divided into two groups: those showing a *sustained benefit* (more than 6 weeks) and those who showed only an *immediate benefit* (same day) from the coloured overlay.

Results

The experimental design controlled for order effects in two ways: by using an ABBA design and by having half the subjects start with the overlay and half with the control filter. The interaction between these factors is illustrated in *Figure 4*. The top line illustrates the subjects who read with the control filter first (A = control, B = overlay). These subjects increased their rate of reading at the second attempt, with the coloured overlay. This improvement, from first A to first B, was marked, as one would expect from a combined treatment and practice effect. On their second attempt with the coloured overlay there was a less marked improvement, as would be expected from only a practice effect. Their final result was the second attempt with the control filter, which was worse than either of their attempts with the coloured overlay. As one would expect from practice, this final attempt with the control filter was better than their initial result with the control.

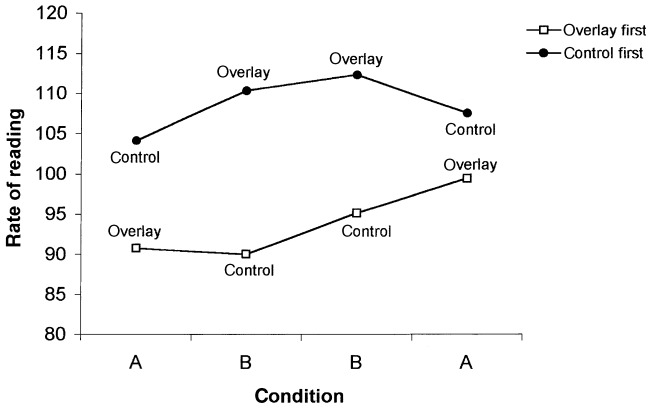

Figure 4. The rate of reading test results, separated to illustrate the effects of order and of condition. See text for more details.

The lower line in *Figure 4* represents the half of the sample who read first with their coloured overlay (A = overlay, B = control). The second condition for these subjects was with the control filter, with which they had a slightly lower rate of reading. This is as expected: the removal of a treatment effect just outweighed a practice effect. Their third attempt was again with the control filter, and they performed better than on the previous attempt with the control filter, as would be expected from a practice effect. Their final attempt was the second with the coloured overlay and this was their best result, as expected from combined treatment and practice effects.

Figure 4 reveals that, despite randomly allocating subjects to the groups who read first with the overlay or first with the control filter, those who read first with the control tended to have a faster rate of reading than those who read first with the overlay. The significance of this was tested by calculating the mean rate of reading on all four attempts for all subjects in each of these groups. This mean aggregated result was not significantly different in those who read first with the overlay compared with those who read first with control filter (unpaired two-tailed t-test, $t = 1.32$, d.f. $= 31$, $p = 0.20$).

As half the subjects read first with the overlay and half with the control filter, order effects will cancel out. Therefore, the data for all subjects were pooled for the main analyses of the effect of the filters on the rate of reading. *Figure 5* shows, for each subject, the mean rate of reading with the coloured overlay vs the mean rate of reading with the control filter. It can be seen that nearly

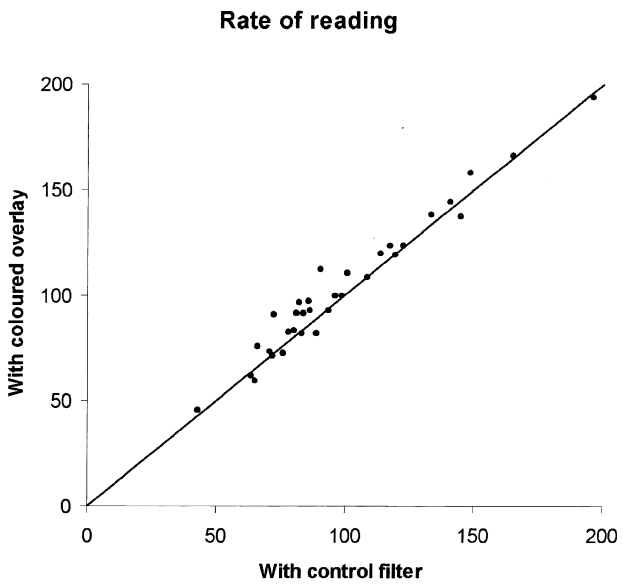

Figure 5. Scatterplot showing, for each subject, the mean rate of reading with the coloured overlay plotted against the mean rate of reading with the control filter. Points above the diagonal line indicate a faster rate of reading with the coloured overlay.

all of the subjects read faster with the coloured overlay than with the control filter.

On average, the mean rate of reading was 4% faster with the coloured overlay (103.0 words min^{-1} ± S.E. 5.6) than with the control filter (99.0 ± 5.7). The fairly large standard errors reflect the marked individual differences *between* subjects in reading speed. These differences do not contribute to the *within* subject comparison of performance with and without the overlay. The repeated-measures design means that the paired *t*-test is the appropriate statistic for comparing the means and with this test the performance was significantly faster with the coloured overlay than with the control (two-tailed, $t = -3.38$, d.f. $= 32$, $p = 0.002$).

When asked whether they preferred their coloured overlay or the 'anti-UV/IR' filter, one subject refused to choose and 66% of the remaining subjects preferred their coloured overlay (sign test, $Z = 1.59$, two-tailed $p = 0.11$).

We also analysed the data by dividing the subjects into two groups, those who expressed a preference for the coloured overlay and those who preferred the control filter. The 21 subjects who preferred the coloured overlay read 5% faster with this than with the control (paired *t*-test, two-tailed, $t = 3.69$, $p = 0.0014$). The smaller group of 11 subjects who preferred the control overlay read only 1.7% faster with the coloured overlay than with the control (paired *t*-test, two-tailed, $t = 0.78$, $p = 0.45$).

We then studied the effect of duration of use of overlay. Of the 33 subjects, 16 had reported a *sustained benefit* and 17 had only demonstrated an *immediate benefit* from their overlay. In the *sustained benefit* group 81% of subjects performed better with their coloured overlay than with the control filter, compared with only 59% in the *immediate benefit* group. However, a 2×2 contingency table showed that the difference between these two ratios was not statistically significant (chi-square, $p = 0.16$).

Discussion

When assessing the impact of interventions it is important to control for the placebo effect (Evans, 1997). Two aspects of our data suggest that the placebo effect associated with the use of colour was adequately controlled in the study.

First, subjects' subjective preference was not significantly more likely to be for the coloured overlay. Although the significance of this result will depend on sample size, this finding suggests that the control filter was a fairly effective placebo.

Second, the data on duration of use provide some information on placebo effects. If children continue to use a coloured overlay for a sustained period, then this suggests that they are more likely to be receiving a 'genuine' benefit, in addition to any placebo. A group of children who have only stated an immediate, initial, preference for an overlay might be expected to include a greater proportion of 'just placebo' cases than a group who had been using an overlay for longer. The results show that, unlike the *immediate benefit* group, the subjects who had been using their coloured overlay for a sustained period were indeed much more likely to demonstrate a faster rate of reading with this than with the control filter.

Although the present study did not set out to investigate the aetiology of Meares–Irlen Syndrome, this issue has been addressed by other recent publications. The term patterned (or pattern) glare (Wilkins and Nimmo-Smith, 1984) has been used to describe symptoms of asthenopia and visual perceptual distortions when viewing striped patterns that have certain spatial parameters (Wilkins *et al.*, 1984). Lines of text have spatial properties that can cause pattern glare (Wilkins and Nimmo-Smith, 1984, 1987). Pattern glare is a strong correlate of Mearles–Irlen syndrome (Wilkins and Neary, 1991; Evans *et al.*, 1992, 1995, 1996; Conlon *et al.*, 1998) and is also correlated with migraine (Wilkins *et al.*, 1984; Chronicle, 1993) and epilepsy (Wilkins *et al.*, 1984).

Individually prescribed coloured filters are an effective treatment for some forms of visually precipitated migraine (Evans *et al.*, in press) and epilepsy (Wilkins *et al.*, 1999). Pattern glare is likely to result from hyperexcitability of the visual cortex (Wilkins, 1995).

Some cortical neurones are tuned for wavelength or for colour appearance and coloured filters may have a beneficial effect through changing the pattern of excitation in the cortical network (Wilkins, 1995).

Our results support the conclusion of Wilkins *et al*. (1996) that, in some people, Intuitive Overlays significantly improve the rate of reading. Our data further demonstrate that this improvement in performance cannot be attributed to conventional optometric anomalies nor to placebo effects. We conclude that, in appropriately selected patients, individually prescribed coloured filters can have a beneficial effect not only on symptoms (Wilkins *et al*., 1994) but also on immediate reading performance. This supports the finding of a recent study by Robinson and Foreman (1999) who assessed the long-term effect of coloured lenses on conventional measures of reading performance.

Declaration of interest

The Medical Research Council (MRC) owns the rights to the Intuitive Overlays and Rate of Reading Test. Arnold Wilkins receives an 'Award to Inventors' from the MRC. These products are available from I.O.O. Marketing Ltd which raises funds for the Institute of Optometry, a registered charity.

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