British Journal of Psychology (1997), **88**, 531–548 *Printed in Great Britain*

Prolonged use of coloured overlays for classroom reading

Rebecca Jeanes
Medical Research Council Applied Psychology Unit, Cambridge, UK

Anne Busby
Upbury Manor School, Gillingham

Judith Martin
William Westley C.P. School, Whittlesford

Elizabeth Lewis
Norfolk Sensory Support Service

Nicola Stevenson
Medical Research Council Applied Psychology Unit, Cambridge

David Pointon
Norfolk Sensory Support Service

Arnold Wilkins*
Medical Research Council Applied Psychology Unit, 15 Chaucer Road, Cambridge CB2 2EF, UK

Ninety-three children in a primary school and 59 children in two first-year classes of a secondary school were asked individually to observe a paragraph of random letters arranged to resemble text, and to compare the perceptual effects on its clarity of coloured plastic sheets overlaid on the text. A total of 29 colours were compared using 10 coloured plastic sheets and 19 pairwise combinations of sheets, one superimposed on another. The resulting colours sampled CIE 1976 hue angle (h_{uv}) and saturation (s_{uv}) systematically and efficiently. All the children who reported beneficial perceptual effects (53 per cent) were given their preferred overlay or combination of overlays to use as and when they wished. When the children were examined three months later the children tended to choose a colour similar to one

* Requests for reprints.

they had chosen previously. Ten months later, 22 per cent of those offered the overlaps were still using them of their own volition. These children, but not those who had ceased to use their overlay(s), read randomly ordered simple words more quickly with their overlay than without. In a second independent group of children referred to the Norfolk Sensory Support Service, who used overlays routinely, the reading speed was similar with a grey or clear overlay; and slower than with the chosen coloured overlay, suggesting that reduction of contrast was not the critical factor. In a third independent group of children in a primary school in Kent, the increase in reading speed with the chosen overlay predicted the children who continued to use their overlay during the ensuing eight weeks.

The purpose of this paper is to describe a series of consecutive studies which examine the use of coloured overlays in the classroom. The first studies in the series address questions concerning the physical characteristics of overlays. Subsequent studies assess the possible benefits that accrue from the use of these overlays, and the way in which the children who are likely to benefit can best be identified.

Background

Olive Meares (1980) reported the perceptual distortions of text described by children who have difficulty reading. The perceptual distortions include blurring, fading, movement of the lines of text, transposition of the letters, illusory colours, etc. She used grey and coloured overlays to reduce these distortions. Irlen (1983) also reported benefit from colour. She founded 'Irlen Centres' that provide 'Irlen overlays', sheets of coloured plastic designed to be placed over a page of text, and 'Irlen filters', dyed plastic (CR39 resin) lenses, worn as glasses and incorporating any necessary refractive correction. The possible effects of colour on reading remain controversial, partly because of a lack of scientific evidence and partly because the Irlen Centres remain largely independent of conventional optometric, orthoptic and ophthalmic practice.

The perceptual distortions that the children describe are non-specific symptoms commonly associated with visual discomfort, with uncorrected refractive error, and with disorders of binocular vision. The latter tend to be associated with reading difficulty (Evans, Drasdo & Richards, 1994).

Treatment using colour

Wilkins *et al.* (1992) described a simple device they used to investigate the effects of colour on the perception of text. Called the *Intuitive Colorimeter*, it illuminates text with coloured light and allows the colour (CIE 1976 hue angle, h_{uv}) and depth of colour (CIE 1976 saturation, s_{uv}) to be varied separately without changing the brightness (luminance, V_λ). When the text has a particular hue and saturation, certain individuals report a decrease in the distortions to which they are usually subject (Wilkins *et al.*, 1992). Often the beneficial effects occur within a range of colours (gamut) that is small, stable and idiosyncratic; i.e. different observers benefit from different specific shades of colour (chromaticities). The colour chosen in the colorimeter can be reproduced when that individual wears coloured lenses that have been dyed using new techniques for precision tinting. These techniques are now available in optometric practice in the United Kingdom (Wilkins, 1995).[1] When coloured lenses are worn, eye-strain and headache are often reduced, and these benefits are retained in the long term (Maclachlan, Yale & Wilkins, 1993). Clinical trials with a double-masked placebo-controlled cross-over design (Wilkins *et al.*, 1994) have shown that the benefits are not attributable simply to placebo effects. The participants in these studies were selected on the basis that they had regularly used coloured overlays in the classroom, and had done so of their own volition, and claimed benefits. The participants were given two pairs of lenses to wear, each for four weeks. One pair matched the optimal *Colorimeter* setting, and the other a suboptimal setting. The incidence of episodes of headache and eye-strain was lower when the optimally tinted lenses were worn than when the other, control pair of coloured glasses was worn, even though the participants were unaware of which pair of glasses was which. The lenses differed in chromaticity by an average of only six times the difference in colour that is just noticeable. The double-masked study therefore lends credence to Irlen's (1991) claims that, to be optimally beneficial, a colour needs to be selected individually and with precision. For a recent review of the literature, see Wilkins (1996).

The colour of an overlay is not a good predictor of the colour of an optimal tint for spectacles (Wilkins *et al.*, 1994). The overlay provides one coloured surface in a visual field containing many differently coloured surfaces, and the eyes are adapted to white light. When coloured glasses are worn the entire visual field is coloured, the eyes adapt to the colour, and, partly as a result of that adaptation, the colour is discounted by mechanisms similar to those that underlie colour constancy. If the effects of the tint are central (cortical) rather than peripheral (ocular), as proposed by Wilkins (1995), one might very well expect differences in the colour chosen for overlays and for lenses.

Tyrrell, Holland, Dennis & Wilkins (1995) examined children's reading with and without overlays placed upon the text. The overlays included the seven then supplied by the Irlen Institute and also a clear (uncoloured) overlay for comparison. The children (from a state school in Wiltshire) were asked to select the overlay that made the text clear and comfortable to read, and the number of children rejecting a clear overlay in favour of a coloured one increased with the number of years the children were behind the reading level expected for their age. The proportion of children choosing a coloured overlay was high: more than 70 per cent of the poor readers and 40 per cent of the good readers. The children who chose a coloured overlay were generally slower at reading (as might be expected, given the association between reading failure and choice of overlay). These children were more likely than others to report symptoms of perceptual distortion and eye strain. The initial reading speed was unaffected by the use of the overlay. However, after 10 minutes of continuous reading without the overlay the reading speed declined, the children who had chosen a coloured overlay began to tire and report discomfort and distortions. The decline in reading speed was small, but did not occur when the overlay was used. There was no effect of the clear overlay amongst the children who chose it.

[1] For a list of practitioners, contact the Institute of Optometry, London.

Figure 1 shows the CIE 1976 Uniform Chromaticity Scale diagram in which the colours (chromaticities) of the Irlen filters have been plotted, together with the chromaticities of pairwise combinations of the filters (sometimes used in preference to single overlays). Clearly the Irlen filters used in the study by Tyrrell *et al.* (1995) did not sample colours systematically. The Irlen filters omitted purple hues (represented by the quadrant below and to the right of the cross, which shows equal energy white).[2]

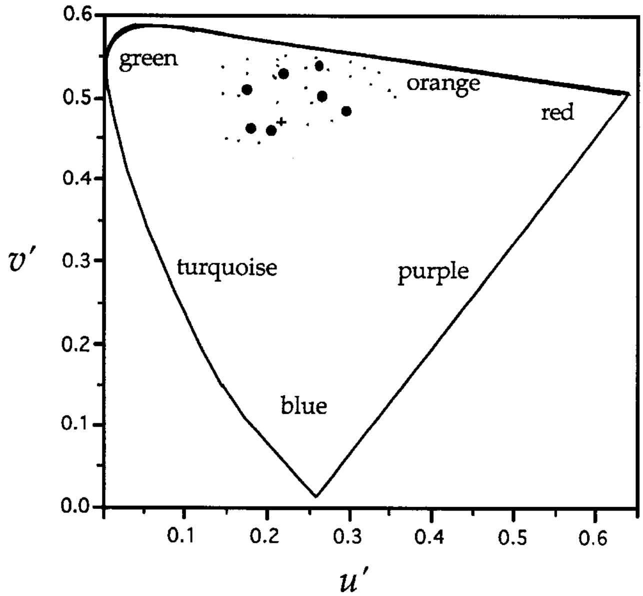

Figure 1. Chromaticity coordinates of the Irlen overlays in the CIE 1976 Uniform Chromaticity Scale Diagram. The large points represent the seven overlays and the small points the pairwise combinations of these overlays. The cross represents equal energy white.The names of the colours are for guidance only.

No systematic study has yet been undertaken to determine the range of colours optimal for overlays. Nevertheless, if children do indeed respond to colour in an idiosyncratic way, as indicated in the case of coloured lenses by the study of Wilkins *et al.* (1994), it might be preferable to choose overlays that sample colours systematically, so as to maximize the chances of closely approximating any colour optimal for a given individual.

An alternative set of 10 filters has therefore been developed (Wilkins, 1994), and the chromaticities of these filters are shown in Fig. 2. The colour of each filter is represented by a letter or letter pair, and the strength of colour (saturation, s_{uv}) is given by the distance of the symbols from the centre of the circular array of symbols (equal energy white). Figure 2 also gives the chromaticities of combinations formed by superimposing two overlays of the same colour, or two with neighbouring

[2] The Irlen Centres have subsequently added a purple and a grey to their range of overlays.

colours. As can be seen, the 10 overlays (nine coloured and one neutral grey) can be combined to sample the colour space evenly, systematically and efficiently. These filters are now available as the *Intuitive Overlays®*.[3]

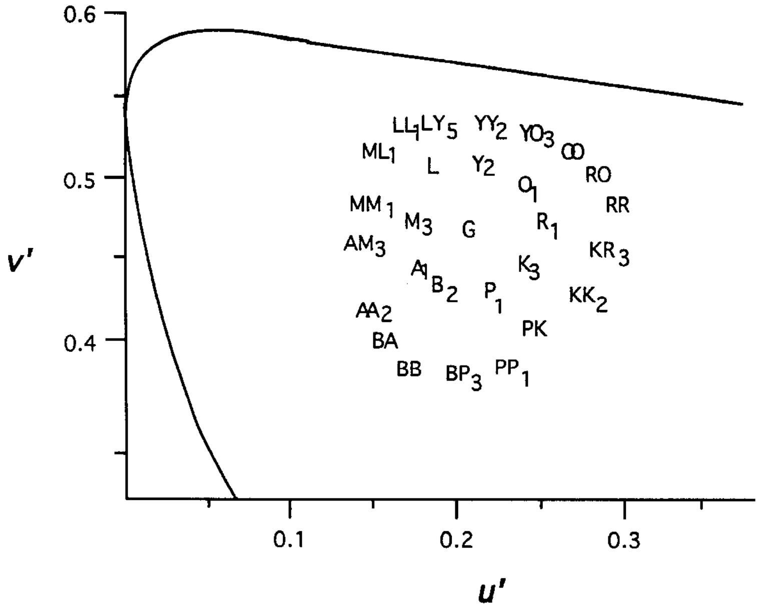

Figure 2. Chromaticity coordinates of the Intuitive Overlays in the CIE 1976 Uniform Chromaticity Scale Diagram. The positions of the single letters show the coordinates of **R**ose, **O**range, **Y**ellow, **L**ime green, **M**int green, **A**qua, **B**lue, **P**urple, pin**K** and **G**rey overlays, and those of the double letters the coordinates of combinations. (After Wilkins, 1994.) The numerical subscripts accompanying the letters indicate the number of participants who used an overlay of this colour in Study 2 (primary school); one participant who used a double grey overlay is not shown.

STUDY 1: INITIAL ASSESSMENT

Using the *Intuitive Overlays®* we examined 152 children individually, offering an overlay free of charge to all those children who claimed to find it helpful in improving the clarity and comfort of text.

Method

Participants

One sample of participants was provided by the 93 children aged five years five months–11 years two months (mean eight years seven months) who attended a primary school 10 miles from Cambridge. All the children in the primary school were examined with the exception of those in the first year infants. A second sample comprised 59 children, aged 11 years four months–12 years three months (mean 11 years nine months), attending two first-year classes in a secondary school in Kent. In two of the classes in the primary school, the teachers had previously used overlays.

[3] Obtainable from I.O.O. Marketing, 56–62 Newington Causeway, London SE1 6DS.

Procedure

The testing began with a questionnaire administered to each class as a group (described in a later section) and was followed by individual testing. All the children were tested individually using the *Intuitive Overlays*®, following the recommended procedure. In brief, each of the 10 overlays was placed in turn upon the test sheet supplied with the overlays (a page of random letters arranged to resemble text). The child was asked to assess whether each overlay made the text clearer and more comfortable to see, less clear and less comfortable, or had no effect. Pairwise combinations of overlays (shown in Fig. 2) were then assessed in a similar way.

Any overlays that the child reported to improve clarity were then compared side by side until the best one was obtained by a process of elimination. The children were not forced to choose a coloured overlay: some children consistently preferred the uncovered page.

The examinations were carried out towards the end of the autumn term 1993.

About two weeks after all the examinations had been completed, each child who reported beneficial effects from overlays was given, free of charge, the overlay or combination of overlays that he or she reported as maximally beneficial.

Results

Forty-seven of the children in the primary school (51 per cent) and 32 in the secondary school (54 per cent) reported improved perception with an overlay or combination of overlays. The proportion of children choosing overlays was no greater in the classes of two teachers who had previously used overlays than in the remaining class.

Thirty-four children chose a single overlay, and 45 chose a combination of two. For the single overlays the most popular choice was mint green (six children), the least popular being lime green (one child). The combination of overlays most frequently chosen was lime green and yellow (six children) and the combinations of rose with orange, orange with another orange, pink with purple and blue with aqua were never chosen.

STUDY 2: FOLLOW UP

The examiner returned to the schools three months later, at the end of the Easter term, and reassessed all the children who had received an overlay or overlay combination. The children were asked individually whether they had used the overlay and then whether they wished to keep it. Each child was then re-examined with the entire set of overlays using a procedure identical to that used previously.

Results

Proportion still using overlays

At the primary school, 42 of the 47 children who had received overlays (89 per cent) said they were still using them, and 33 (70 per cent) said they wished to keep the overlay(s). The colours of these overlays are shown in Fig. 2. At the secondary school 24 of the 32 children (75 per cent) said they were still using the overlays, and 21 (66 per cent) said they wished to keep their overlay.

Further analyses of the results of Studies 1 and 2

Reliability of colour choice

The preferences for coloured overlays expressed on the first and second occasions were compared statistically as follows. The difference in the colour selected on the first occasion and that selected on the second was estimated from the distance in the CIE 1976 UCS diagram. When identical colours were chosen the distance was zero, and in general, the smaller the distance in colour space, the greater the similarity in the choice of colour on the two occasions. Forty-six of the 47 children from the primary school who were given an overlay were tested twice. For these children the distance in colour space averaged 0.0761. The likelihood of such a colour difference occurring by chance was estimated by a randomization procedure. One participant's first preference was randomly paired with another participant's second preference until all the data had been randomly reallocated (without replacement). The average distance in colour space was obtained and the process repeated 10000 times. 9643 of the repetitions gave an average distance greater than that observed. The probability of obtaining the consistency between first and second choices on the basis of chance alone could therefore be estimated as .0357. (The 99 per cent confidence limits on this estimate were 0.0309 to 0.0405.) In a similar analysis of the data from 28 available children in the secondary school, 9923 of 10000 chance simulations were greater than the observed distance of .0613, giving a probability of chance occurrence of .0077 (with 99 per cent confidence limits of 0.00545 to 0.00995). The children's colour preferences were evidently more reliable than could reasonably be expected on the basis of chance alone.

Consistency of colour choice

The following analysis was undertaken to determine whether a preference for one colour would be associated with an aversion to a complementary colour. For each child the mean u' and mean v' chromaticity coordinate was obtained for the filters that were reported to improve perception. The corresponding means were obtained for the chromaticity coordinates of the filters that made the text less clear or comfortable. This was equivalent to finding the 'centre of mass' in colour space of all the 'good' colours (averaging 10.7 in number) and the centre of mass of all the 'bad' ones (12.6 on average). The greater the distance between the centres, the greater the tendency for 'good' colours to differ from 'bad'. The distance between the two centres of mass was obtained for each child (confining the analysis to the 74 children who expressed both a preference and an aversion. The average was 0.0358 with a standard deviation of 0.0198. The average distance obtained was compared with that obtained when the same number of pairs of 'good' and 'bad' overlays were chosen at random, by computer. The mean for 10000 such Monte Carlo trials was 0.020072 with a standard deviation of 0.000035. The distance in colour space between the 'good' and the 'bad' colours was very significantly greater than that expected from the Monte Carlo trials ($t(73) > 6$, $p < 10^{-8}$). The children's choice of overlays clearly demonstrated a tendency for preferred and adverse colours to differ. The tendency was weak, however. Had the choices been maximally consistent and complementary, the distance would have averaged between about 0.05 and about 0.08 (depending on the overlays chosen).

(In the above analyses, randomization procedures were used because of the difficulty in formulating a probabilistic model given the different frequencies with which the various colours were chosen.)

STUDY 3: LONG-TERM FOLLOW-UP

Ten months after the initial assessment, 34 of the primary school children were still in school, and of these 11 (32 per cent) were still using the overlay. Two were no longer using an overlay because they had received coloured glasses. At the secondary school, three of the 32 children (9 per cent) were still using the overlay. The above observations indicate that, if offered overlays of appropriate colour, many children in primary and secondary schools would elect to use them. The benefit claimed by the children who used overlays consistently was similar to that claimed when precision filters are worn as spectacles (Wilkins *et al.*, 1994), namely, headaches were reduced, the eyes were less tired, and the letters no longer 'misbehaved'. A quantitative assessment of these reports was not attempted because they can all too readily be attributed to placebo effects, particularly in a classroom setting where children compare themselves with their classmates. The reports are, however, consistent with those from a double-masked study using coloured lenses (Wilkins *et al.*, 1994), which suggests that such placebo effects are an insufficient explanation. Placebo effects are difficult to control where overlays are involved because the child knows the identity of their preferred overlay. Nevertheless, placebo effects usually decline over time. The fact that such a high proportion of children were still using the overlays 10 months after the initial assessment is therefore of interest.

Introduction to Studies 4, 5 and 6

It is important to know not only whether the filters are used without prompting, but also whether there are beneficial effects on reading, as has been claimed by Irlen (1991).

The effects of overlays on reading are difficult to examine. The literature, recently reviewed by Evans & Drasdo (1991), is inconsistent, and as Solan & Richman (1990) point out, protagonists of the Irlen method provide positive reports, and other researchers usually fail to show any effect of colour on reading. Wilkins & Neary (1991) and Tyrrell *et al.* (1995) showed an increase in the speed of visual search with tinted glasses and overlays respectively. They used passages of random letter strings arranged to resemble text and asked participants to report the letter that followed each occurrence of the letter *x*. Tyrrell *et al.* (1995) also showed an improvement in reading speed with normal prose (from children's reading books), but only after 10 minutes of continuous reading, when the children had begun to tire. The double-masked study by Wilkins *et al.* (1994) used the Neale Analysis of Reading which failed to show a difference between the optimally and suboptimally coloured lenses, although performance with lenses was superior to that without. The Neale Analysis may not show beneficial effects of colour on reading because it contains short passages of text that are clearly printed in a large typeface.

The typographic characteristics of text, particularly the spacing between words and lines, are known to affect visual discomfort (Wilkins, 1995, chapter 5). It is therefore possible that colour (whether from overlays or lenses) improves reading by reducing the discomfort and distortions which occur mainly with closely spaced text after a lengthy period of reading. In order to assess the effects of colour on reading in the short term it may therefore be necessary to use text that has typographic characteristics that stress the visual system. We therefore designed a reading passage with the appropriate characteristics. The passage measured 72.1 mm wide by 33.2 mm high and was set in 9pt Times (x-height 1.5 mm) with 3.5 mm line spacing and about 0.7 mm between successive words. The passage had 10 lines with 15 words per line, and an example is shown in Fig. 3.

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. A passage from the *Rate of Reading Test*®, reproduced actual size.

In order to measure any effects of visual stress on reading, it was important to minimize the variability from linguistic and semantic demands. This was achieved by using a meaningless passage of random words. The words were chosen from the 110 words most commonly used in children's readers (as assessed in a count undertaken by Professor Peter Pumfrey and Mr Mike Laskier at the University of Manchester), and should therefore have been familiar to poor readers. Each of the 10 lines consisted of the following words presented in a different random order: and, cat, come, dog, for, is, look, my, not, play, see, the, to, up, you. The test has been described in detail elsewhere (Wilkins *et al.*, 1996)[3] and is now available as the *Rate of Reading Test*®.

The participant was required to read the text aloud as rapidly as possible, and to do so with and without their preferred overlay, in an order randomized across participants. The participant was tape-recorded, and the reading timed and errors noted.

STUDY 4: RATE OF READING AND OVERLAY USAGE

All the children in Study 1 who were given an overlay and who were still at the school during the subsequent academic year were examined with the *Rate of Reading*

[3] See p. 535.

Test®. Thirty children were examined from the primary school, 11 of whom were still using overlays and 30 from the secondary school, three of whom were still using them.

The median time taken per line, averaged across all participants and expressed as a reading rate, was 99 words per minute without the overlay and 102 with. When the participants were divided into two groups, those who said they still used their overlays, and those who said they did not, the reading rates were as shown in Table 1.

Table 1. Reading speed (words per minute) with and without an overlay, expressed separately for children who were still using their overlay 10 months after they were first offered it, and children who had by that time ceased to use it

School	Still using?	*N*	Without overlay	With overlay
Primary	Yes	11	78.9	85.3
	No	19	95.7	95.1
Secondary	Yes	3	90.0	118.7
	No	27	115.1	116.5

In the case of the children in the primary school who were still using their overlays, the reading speed improved by an average of 8 per cent ($t(10) = 2.68, p = .011$, one-tail). There were too few children in the secondary school who were still using their overlay for such an analysis to be justified. Note that the improvement was obtained despite the test being short and simple.

Speed/accuracy trade-off

Errors in reading were classified into the mutually exclusive categories listed below in order of the percentage of participants committing each error at least once:

1. Intrusion of any word in the inappropriate context, excluding errors of word order but including word repetition (93 per cent).
2. Omission of a word, including those resulting from errors of word order (77 per cent).
3. Omission of an entire line (41 per cent).
4. Repetition of an entire line (2 per cent).

Chi-square analyses provided no indication whatever that the nature of the errors differed amongst children who made frequent as opposed to infrequent use of their overlays, regardless of whether they were reading with or without the overlay ($p > .3$ in every case).

To investigate the possibility of a speed/accuracy trade-off, the total number of words correctly read in the appropriate order was calculated separately for each individual participant without the overlay and with the overlay. The difference in the accuracy with and without the overlay was then correlated with the difference in reading speed with and without the overlay. The correlation was in every case positive (Pearson product moment correlation .37, $p < .05$ and .79, $p < .001$) for the primary and secondary school respectively), indicating that the increase in speed resulting from use of the overlay(s) was associated with an increase in accuracy (a decrease in errors). Both measures of performance were therefore consistent in showing improvements with the overlay, and there was no evidence for any speed/accuracy trade-off.

STUDY 5: PREDICTION OF USAGE

The children in the previous study may have read more rapidly with their overlay simply because they had used it and had therefore become familiar with its use. In Study 5 a completely different sample of children was used and the *Rate of Reading Test*® was administered at the outset of the study. This study has been reported in detail elsewhere (Wilkins *et al.*, 1996), and will therefore be only briefly reported here.

Method

Participants

All but three of the children in years 4, 5 and 6 (three classes) in a county primary school in Kent took part in the study. There were 47 boys and 30 girls, and their ages ranged from eight years eight months to 11 years nine months. The data from two children were incomplete and were rejected.

Procedure

All the children were tested individually using the *Intuitive Overlays*® as in Study 1, although on this occasion a clear acetate sheet was included among the overlays. As before, the children were not forced to choose an overlay: some children consistently preferred the uncovered page. The *Rate of Reading Test*® was then administered, following the procedure described above. Two equivalent test passages were administered in random order. One of the passages, chosen at random, was used with the chosen overlay (or combination of overlays) and the other passage without, in random order. Children who preferred the uncovered page were tested with and without a clear (transparent) overlay. The children were asked to read each passage out loud quickly and clearly, trying to make as few mistakes as possible. The reading was tape-recorded and timed, and any mistakes were noted. The scoring was, however, based simply on the number of words correctly read and the time taken to read them.

The testing took place at the beginning of the summer term 1995. Three weeks after the testing, the children who had reported improved clarity with a particular colour were issued (free of charge) with that colour (as provided by an overlay or pair of superimposed overlays). The children were encouraged to try out the overlay (or pair of overlays), but to persist in using the overlay(s) only if they found it helpful to do so.

At the end of the summer term, six weeks later, the children who had been issued with an overlay were again assessed using the *Rate of Reading Test*®, both with and without their preferred overlay or combination of overlays.

During the intervening period the children's usage of overlays was assessed by their teachers and by the children. Children using the overlay(s) on most occasions when they read were allocated to a frequent user group.

Results

Preference

Following the assessment with the overlays at the beginning of the summer term, 38 of the 77 children (49 per cent) reported improved clarity or comfort when viewing text with a particular colour (as provided by an overlay or pair of overlays superimposed). The remaining 39 preferred the uncovered page.

The 38 children who were issued with an overlay (or combination of overlays) were tested with and without the overlay(s) at the beginning and again at the end of the summer term, about eight weeks later.

Test–retest reliability

The Pearson product moment correlation between the reading rate *without* the overlay(s) on the first test and the second test about eight weeks later was .83. The 39 children who preferred the uncovered page were tested with and without a clear overlay in immediate succession in random order. The correlation between the reading rate with and without the clear overlay was .92.

Practice

The second presentation was faster within a test session, and also when similar conditions were compared eight weeks apart ($p < .000$). The effects of practice were small in comparison to the large differences between individuals.

Errors

The frequency of errors of each category were: intrusions (85 per cent), word omissions (77 per cent), line omissions (53 per cent), line repetitions (0 per cent). Again, chi-square analyses failed to give any indication of a relationship between the nature of the errors and the use of an overlay. Again the correlation between differences in speed and accuracy with and without the overlay was positive (.96, $p < .001$; .96, $p < .001$ at first and at second tests respectively).

Long-term usage

At the end of the summer term 15 of the 38 children (40 per cent) who were given an overlay (or combination of overlays) were found to still be using their chosen overlay(s) frequently for most activities involving reading.

Table 2 shows the rate of reading (words per minute) with and without the overlay, separately for the children who were given the overlay and those who were not. The former group is divided into the children who subsequently continued to use their overlay frequently and those who did not. The children who used their overlay for most reading tasks showed a highly significant increase in reading speed with their overlay ($p = .0012$, paired t test) on the first test occasion. The children who subsequently used their overlay infrequently or not at all showed no significant increase in reading speed at the first assessment ($p = .30$, $p = .16$, respectively).

Table 2. Reading speed (words per minute) for children who chose a coloured overlay and those who did not. The former group are subdivided into those who subsequently used their overlay frequently, those who used it infrequently, and those who did not use it at all. The statistical significance of the comparison with and without an overlay is shown

		First test			Second test		
	N	Without overlay	With overlay		Without overlay	With overlay	
Not given	39	99	101	n.s.			
Given	38						
No use	6	109	105	n.s.	107	110	n.s.
Infrequent use	17	88	89	n.s.	92	95	n.s.
Frequent use	15	97	104	**	97	108	***

**$p < .01$; ***$p < .001$; n.s. = not significant.

At the second assessment the advantage from the overlay was even more pronounced in the children who were now using it frequently ($p = .0008$). There was no significant speed advantage in the case of children who had been given an overlay but who did not now use it frequently ($p < .07$).

The minimum score and maximum scores differed by a factor of more than three across participants. Despite this range there was no significant correlation between the reading rate without the overlay and the age of the child (Pearson product moment correlation = .20).

Discussion of Studies 1–5

The five studies show a prevalent, consistent and long-standing preference among schoolchildren for the use of coloured overlays when reading. Studies 4 and 5 show that reading speed, as measured by a simple non-linguistic reading task, is improved by the use of an overlay, and that the preference children express for overlays is related to the increase in reading speed associated with the use of the overlay. The possible reasons that have been advanced for the beneficial effects of overlays include their effect in reducing contrast and luminance (Williams, May, Solman & Zhou, 1995). Study 6 was undertaken to determine the extent to which the reduction of luminance and contrast could explain the preference for coloured overlays.

STUDY 6: CONTRAST

Method

Participants

Thirteen boys and eight girls who had been referred to the Norfolk Sensory Support Service and assessed using the *Intuitive Overlays*® were examined as a consecutive series. The mean age was 10 years two months (range seven years three months–14 years seven months).

Procedure

Parallel versions of the *Rate of Reading Test*® were administered (1) with no overlay, (2) with a grey overlay (reflectance ~ 50 per cent), (3) with a clear acetate sheet, (4) with the preferred overlay, and (5) with an overlay of a colour complementary to this. The order of the conditions was randomized and counterbalanced. As before, the reading was tape-recorded and the number of words correctly read per unit time was abstracted.

Results

The mean rate of reading under the five conditions was as follows: no overlay–66.8 words per minute (wpm), (SD 19.2); clear overlay–65.8 wpm (SD 18.5); grey overlay–66.28 (SD 19.7); overlay of preferred colour–74.1 wpm (SD 22.2); overlay of complementary colour–69.7 wpm (SD 18.1). *Post hoc* pairwise comparisons using the Peritz procedure (Toothaker, 1991) demonstrated that the rate of reading with the coloured overlay was significantly greater than with the clear and grey overlay and with no overlay. There was no significant difference between the rate of reading with no overlay, a clear overlay, and a grey overlay. The difference between the rate of reading with the preferred overlay and with an overlay of complementary colour was not significant, but neither was the difference between the latter overlay and the remaining three overlays.

Discussion

In Study 6 overlays with the preferred colour improved reading speed, whereas grey and clear overlays did not. Few of the children in Studies 1–6 expressed a preference for a grey overlay. Since grey overlays reduced the contrast of the text by an amount equivalent to the coloured overlays, reduction in contrast *per se* does not appear to be a crucial mechanism for the beneficial effects of the overlays.

Evans *et al.* (personal communication) address the issue of binocular vision, and show that improvements in reading speed can be obtained using the *Rate of Reading Test*® described above in participants whose binocular function is quite normal. Of course, this is not to say that all the children in the present studies had normal binocular function. But further studies will be required before we know the proportion of children in whom a beneficial effect of an overlay can be attributed to ocular or binocular dysfunction. At present, it is clear only that peripheral ocular anomalies are an insufficient explanation of a benefit from overlays in many children.

STUDY 7: GROUP ASSESSMENT

Method

Procedure

One hundred and forty-seven of the 152 children in Study 1 who were examined individually had, at the outset of the study, been examined by a test administered to each class as a group. This test was designed in the hope of developing group testing methods to reduce the number of children who required individual assessment. A series of questions about perceptual distortions and headaches were printed on sheets distributed to the children. Each child was also provided with text printed on coloured paper. The questions were worded as follows: 'When you read or copy, do any of these happen?' (letters move; letters blur; page glares); 'When you read for a while, do you get headaches or tired eyes?' (Yes, headaches; Yes, tired eyes; No, neither); 'Does anyone in your family have headaches that are so bad they have to lie down?' (Yes; No); 'Have you been given glasses?' (Yes; No); 'On the following pages jumbled letters have been printed on white paper and on coloured paper: which is easiest to look at?' (white; green; blue; yellow; pink; purple). The questions were read aloud to the class, and interpreted by the class teacher on an individual basis, where necessary.

The reflectance of the five papers was measured relative to a halon standard (Monolite Ltd) and from the reflectance function the following CIE 1976 UCS chromaticities (u', v') were derived: white (0.208, 0.472); green (0.181, 0.500); blue (0.192, 0.469); yellow (0.217, 0.519); pink (0.262, 0.473); purple (0.219, 0.455). The photopic reflectance ranged from 82 per cent for the white to 44 per cent for the pink.

Results

Multiple regression analysis was undertaken on the data set from the primary school and the secondary school separately and also for the combined data set. The three analyses gave broadly similar findings and only the results for the combined set will be presented here. The responses to the first question were coded as reports of perceptual distortion (letters move, or letters blur) and reports of glare. The responses to the questions concerning headache, tired eyes, headaches in the family and glasses did not contribute appreciably to the variance and were therefore omitted. Multiple regression techniques were used to derive a regression equation to predict whether the child was given overlays. The equation was based on reports of perceptual distortion and glare, and on the choice of a coloured page rather than the white. The equation accounted for 20 per cent of the variance and correctly classified the responses of 104 of the 147 children. However, of the 43 incorrectly classified responses, 16 were false negatives, that is children who were not classified as requiring an overlay on the basis of the group test, but who were given an overlay when assessed individually. Of these 16, 14 continued to use their overlay for at least three months. In other words there were many children who persistently used their overlays who would not have been identified by the group test.

Although it is possible that further refinement of the group test might improve upon its predictive power, the improvement would have to be considerable for the test to be sufficiently sensitive and selective. It may well be better to test all children individually, given that the assessment time is usually about 10–15 minutes per child.

GENERAL DISCUSSION

The children's choice of overlays, though apparently haphazard, was more reliable than would be expected by chance, particularly for the older children. There was a tendency for preferred colours to be complementary to aversive colours. The tendency was weak and not sufficient to be used as a guide in selecting children who benefit; indeed the children who persisted in using their overlays showed less of a tendency towards complementarity than the others, though the difference was non-significant.

One half of the primary school children initially reported benefits from overlays and one third of all these children continued using overlays of their own volition for more than 10 months. Although it is possible that the overlays became part of a 'fad' in which children were happy to participate, the proportion of children choosing overlays was no greater in the classes of teachers who had previously used overlays, than in the classes of other teachers.

The children who persisted in using their overlays demonstrated an improvement in reading rate of about 8 per cent. The reading was assessed using a test that stressed the visual aspects of reading and minimized the contribution of linguistics and semantics. The change in the reading speed was obtained in a test taking about two minutes to administer, whereas in previous studies that have used more conventional reading material the improvement has been evident only after several minutes of reading when the child has begun to tire.

The mechanisms that underlie the benefits from overlays have not been the main focus of this study. The study was an attempt to document the prevalence of reports of beneficial effects, and to assess any effects on reading. This objective seemed a necessary prerequisite. Many mechanisms for beneficial effects are possible, the most obvious and contentious being the Hawthorn or placebo effect. It is not possible to obtain an effective placebo using overlays. (Children can easily recognize the colour of overlays they have chosen.) Issues regarding placebo effects are better left to research methodologies which allow specific colours to be chosen and then used without the participant's awareness. As mentioned earlier, such a research methodology was used in a study by Wilkins *et al.* (1994) which demonstrated beneficial effects of optimally tinted lenses relative to other lenses with sub-optimal tint. The lenses relieved eye-strain and headaches, and the relief could not be attributed to any placebo effect. This does not, of course, mean that placebo effects did not contribute to the selection and use of overlays in the present study. The length of time for which the overlays were used does, however, suggest that some other factors were probably involved. The overlays reduce the contrast of text by diffusion, and this reduction has been shown to benefit certain readers (Williams *et al.*, 1995). Study 6, however, showed improved reading with coloured overlays, and no such improvement with grey overlays, as compared with clear overlays. Moreover, grey overlays were rarely chosen in preference to coloured ones. Grey overlays reduce contrast and luminance by an amount similar to that of coloured overlays.

The division between magno- and parvocellular visual pathways elaborated by Livingstone & Hubel (1988) should be considered in the present context, owing to the selective deficits in magnocellular pathways and transient system function in individuals with dyslexia (e.g. Eden *et al.*, 1996; Lovegrove *et al.*, 1986). Although the individuals who used coloured overlays in the present studies clearly had a visual difficulty with reading, few were dyslexic according to customary definition. Even if the magnocellular deficits are more prevalent than is currently envisaged and are responsible for visual dysfunction in children who use coloured overlays, it is quite unclear at present how this dysfunction can be reduced by the use of the overlays, given that each individual appears to benefit from a different colour.

The absence of a strong effect of complementary colours is consistent with the model of visual stress advanced by Wilkins (1995). The model attributes the beneficial effects of colour to a redistribution of cortical excitation that avoids strong excitation in localized areas of cortical hyperexcitability. Interference with colour processing at the level of the visual cortex would not be expected to show any relation to the colour confusions seen with conventional cone pigment anomalies. Cortical lesions can result in a loss of colour perception (achromatopsia) in the presence of normal cone mechanisms, and can give a difficulty with hue naming in specific regions of colour space that show no relation to complementary colours or conventional axes of colour confusion (Kennard, Lawden, Morland & Ruddock, 1995). The lack of complementarity shown in the present data is therefore consistent with a cortical locus for the reported effects of colour on spatial perception.

Of course, we do not wish to suggest that any improvements from colour were invariably the result of central perceptual mechanisms. Indeed, some of the children ceased to use their overlay after they had been referred for a conventional optometric examination and had received adequate refraction or orthoptic exercises for binocular vision anomalies. For various reasons, not all the children in the present study received an optometric examination. Nevertheless, there remained children who continued to find colour helpful despite conventional optometric intervention. A more detailed study in which a routine optometric and orthoptic examination is provided for all participants is clearly necessary. Current estimates from the Institute of Optometry suggest that about 30 per cent of children find coloured overlays useful even after conventional treatment (Evans, personal communication).

Acknowledgements

We thank the children who took part, and their parents for giving permission. We also thank the staff of William Westley County Primary School, Whittlesford, Cambridge, Upbury Manor School, Gillingham, Kent, and Hadlow County Primary School, Kent, for their support.

Statement of interest

The *Intuitive Overlays*®, the *Rate of Reading Test*® and the *Intuitive Colorimeter*® were developed by one of the authors (A. W.), who is employed by the Medical Research Council. The Council owns the rights. The *Intuitive Overlays* and *Rate of Reading Test* are marketed under licence by the Institute of Optometry Marketing Ltd, 56–62 Newington Causeway, London SE1 6DS.

References

Eden, G. F., VanMeter, J. W., Rumsey, J. M., Maisog, J. M., Woods, R. P. & Zeffiro, T. A. (1996). Abnormal processing of visual motion in dyslexia revealed by functional brain imaging. *Nature*, **382**, 66–69.

Evans, B. J. W. & Drasdo, N. (1991). Tinted lenses and related therapies for learning disabilities—A review. *Ophthalmic and Physiological Optics*, **11**, 206–217.

Evans, B. J. W., Drasdo, N. & Richards, I. L. (1994). Investigation of accommodative and binocular function in dyslexia. *Ophthalmic and Physiological Optics*, **14**, 5–19.

Irlen, H. (1983). Successful treatment of learning difficulties. Paper presented at the First Annual Convention of the American Psychological Association, Anaheim, California, USA.

Irlen, H. (1991). *Reading by the Colours*. New York: Avery Publishing.

Kennard, C., Lawden, M., Morland, A. B. & Ruddock, K. H. (1995). Colour identification and colour constancy are impaired in a patient with incomplete achromatopsia associated with prestriate cortical lesions. *Proceedings of the Royal Society, Series B*, **260**, 169–175.

Livingstone, M. & Hubel, D. (1988). Segregation of form, color, movement, and depth: anatomy physiology and perception. *Science*, **240**, 740–749.

Lovegrove, W., Martin, F. & Slaghuis, W. (1986). A theoretical and experimental case for a residual deficit in specific reading disability. *Cognitive Neuropsychology*, **3**, 225–267.

Maclachlan, A., Yale, S. & Wilkins, A. J. (1993). Open trials of precision ophthalmic tinting: one-year follow-up of 55 patients. *Ophthalmic and Physiological Optics*, **13**, 175–178.

Meares, O. (1980). Figure/background, brightness/contrast and reading disabilities. *Visible Language*, **14**, 13–29.

Solan, H. A. & Richman, J. (1990). Irlen lenses: A critical appraisal. *Journal of the American Optical Association*, **61**, 789–796.

Toothaker, L. (1991). *Multiple Comparisons for Researchers*. Newbury Park, CA: Sage.

Tyrrell, R., Holland, K., Dennis, D. & Wilkins, A. (1995). Coloured overlays, visual discomfort and classroom reading. *Journal of Research in Reading*, **18**, 10–23.

Wilkins, A. J. (1994). Overlays for classroom and optometric use. *Ophthalmic and Physiological Optics*, **14**, 97–99.

Wilkins, A. J. (1995). *Visual Stress*. Oxford: Oxford University Press.

Wilkins, A. J. (1996). Helping reading with colour. *Dyslexia Review*, **7**, 4–7.

Wilkins, A. J., Evans, B. J. W., Brown, J. A., Busby, A. E., Wingfield, A. E., Jeanes, R. J. & Bald, J. (1994). Double-masked placebo-controlled trial of precision spectral filters in children who use coloured overlays. *Ophthalmic and Physiological Optics*, **14**, 365–370.

Wilkins, A. J., Jeanes, R. J., Pumfrey, P. D. & Laskier, M. (1996). Rate of reading test: Its reliability, and its assessment of the effects of coloured overlays. *Ophthalmic and Physiological Optics*, **16**, 491–497.

Wilkins, A. J., Milroy, R., Nimmo-Smith, I., Wright, A., Tyrrell, R., Holland, K., Martin, J., Bald, J., Yale, S., Miles, T. & Noakes, T. (1992). Preliminary observations concerning treatment of visual discomfort and associated perceptual distortion. *Ophthalmic and Physiological Optics*, **12**, 257–263.

Wilkins, A. J. & Neary, C. (1991). Some visual, optometric and perceptual effects of coloured glasses. *Ophthalmic and Physiological Optics*, **11**, 163–171.

Williams, M. C., May, J. G., Solman, R. & Zhou, H. (1995). The effects of spatial filtering and contrast reduction on visual search times in good and poor readers. *Vision Research*, **35**, 285–291.

Received 22 June 1995; revised version received 20 June 1996