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REVIEW ARTICLE

Coloured overlays and their effects on reading speed: a review

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Abstract

Coloured overlays can reduce symptoms of visual stress and improve reading speed. These benefits are reliable and are not attributable simply to placebo effects. Five percent of children in mainstream education read at least 25% more quickly with an overlay, provided they have chosen the colour. The suboptimal design of children's text and the high level of classroom lighting may be partly responsible.

Keywords: coloured overlays, Meares–Irlen syndrome, prevalence, reading speed

What are coloured overlays?

Coloured overlays are sheets of coloured plastic designed to be placed over a page of text. They colour the page beneath without interfering unduly with the clarity of the text. They can reduce the symptoms of visual stress, including headaches from reading, and can improve reading speed. When claims for the benefit of coloured filters were made by Helen Irlen (1991), they were met with scepticism, justified at the time by the lack of scientific evidence to substantiate the claims. There are several reviews of the early literature, much of which was unpublished and of poor scientific design (see Evans and Drasdo, 1991). Over the years the evidence has gradually accumulated. Alternative explanations in terms of placebo effects have been eroded, and overlays are fast becoming an accepted reading aid. There are now several packs of overlays on the market.[1] The *Intuitive Overlays* (Wilkins, 1994) have been fully specified and have been used in the most research studies. They are described below. The Assessment Pack includes nine differently coloured overlays and one Grey overlay.

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[1]The Intuitive Overlays are sold by I.O.O. Marketing, 56-62 Newington Causeway, London SE1 6DS. The Cerium Overlays are sold by Cerium Visual Technologies, Appledore Road, Tenterden TN30 7DE.

The design of the *Intuitive Overlays* was based on two simple assumptions: (1) that there are certain colours that are effective in improving reading speed, and (2) these differ from one individual to the next. These assumptions were based on preliminary observations, but have subsequently been borne out by scientific evidence. The physiological mechanisms for the increase in reading speed were unclear (and to some extent remain so), and it was therefore inappropriate to guide the design of the overlays on the basis of any assumptions about mechanism. Given these constraints and the simplifying assumptions above, it was important to be able to sample colours systematically and comprehensively in order to optimise the selection of colour. The Commission Internationale de l'Eclairage 1976 uniform chromaticity scale (CIE UCS) diagram represents colours in such a way that equal distances on the diagram represent approximately equal differences between colours. The overlays were therefore designed to sample the CIE UCS diagram systematically and as comprehensively as practical.

The overlays have colours represented by the points on the CIE UCS diagram shown in *Figure 1*. The inner ring of solid squares shows the chromaticities of the nine coloured overlays. The outer ring shows the chromaticities of double overlays: two overlays, one superimposed upon another. The resulting colours are darker and stronger (more saturated). It is possible to place one overlay on top of any other – but in order to sample colours systematically it is only necessary to combine the overlays with others of similar or identical colour, as shown in the outer ring of *Figure 1*. The open squares in the outer ring show the chromaticities formed by two

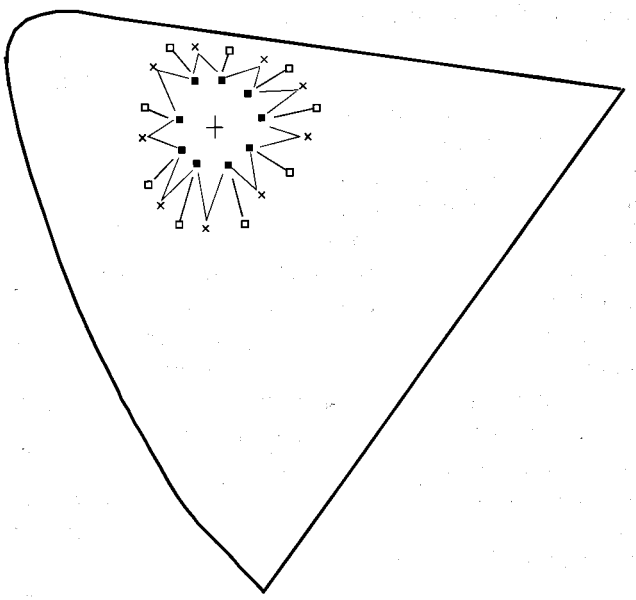

Figure 1. CIE 1976 UCS diagram showing the chromaticities of the nine colour *Intuitive Overlays*, solid squares, inner ring of points and Grey overlay (central cross). The chromaticities of double overlays formed by placing one overlay on top of another are shown by the outer ring of points. The open squares are the chromaticites of two overlays of identical colour. The crosses between them are chromaticities of two overlays of neighbouring colours. The lines connect the chromaticities of the double overlays with those of constituent single overlays.

identical overlays superimposed. The open squares are connected by single lines to the solid squares indicating the overlays that were superimposed in order to obtain this colour. The crosses show the chromaticity of double overlays formed from overlays of different, but neighbouring chromaticity. The crosses are connected by lines to two solid squares indicating the component overlays. Stronger (more saturated) colours outside the outer ring are available, but only by adding three or more overlays together. In practice this results in combinations that are dark. Some people can tolerate or even benefit from such overlays, but if a strong saturation is required, and overlays are too dark, it may be worth considering coloured lamps because these can provide a bright strongly saturated colour.

The overlays have a matte coating on one side and are glossy on the other. The matte surface reduces reflections of light sources from the surface of the overlay, but it has the disadvantage that it reduces the clarity of the text beneath slightly. The clarity is improved when the gloss surface is uppermost and the matte surface is in contact with the page, but this is practical only if surface reflections of room lights and windows can be sufficiently reduced. In practice this is possible when the room has few luminaries and windows and the light from them comes in one direction. If surface reflections can be avoided, the reduction of contrast is a matter of a few percent and the colour does not vary much with the angle of viewing.

Note that because of the matte surface, the overlays must be used in contact with the page. They cannot be held close to the eyes or used away from the page. This is an important aspect of design. When filters are used close to the eyes (as coloured spectacles) the optimal colour differs (Lightstone *et al.*, 1999).

Do coloured overlays work?

Tyrrell *et al.* (1995) examined 46 children aged 8–16 in a mainstream school. They measured the speed with which each child read a passage photocopied from a book chosen by the child from the school library. On separate days a week apart the reading was undertaken with or without an overlay the child had selected as optimal. The order of testing with or without the overlay was random. About half the children chose a clear overlay, included as a control, and the remainder chose one of the coloured Irlen overlays (the only overlays then available). The reading continued for 15 min, and initially there was no difference in speed between the two conditions. Differences emerged only after the children had been reading for 10 min and had begun to tire. The children who had chosen a coloured overlay slowed down when they were reading without it, and reported symptoms of eye-strain; the children who had chosen a clear overlay reported fewer symptoms, did not slow down, and showed no benefit from use of the overlay.

Jeanes *et al.* (1997) used the *Intuitive Overlays* in several small-scale studies in county primary schools. They presented each of the colours in turn and allowed children to choose the one that best improved the clarity of text. About 50% of children reported beneficial perceptual effects with one or more of the overlays. These children were all given their best overlay to use if they wished to do so, and 3 months later nearly half the children who were given overlays were still using them, that is, about 20% of the entire sample of normal school children. As in the study by Tyrrell *et al.* (1995), these children were slightly poorer at reading, on average.

In the research by Tyrrell *et al.* (1995) the effects of overlays on reading speed were observable only after 10 min continuous reading when the child had begun to tire. It has subsequently proved possible to demonstrate the benefits of overlays in a 1-min visually intensive test, the Rate of Reading Test (Wilkins *et al.*, 1996). The test consists of a passage of text that is read aloud as quickly as possible for 1 min. The score is the number of words correctly read. The passage consists of 10 lines each comprising the same 15 common words in a different random order. The words are familiar to poor readers who are therefore prepared to undertake the challenge of reading. The random order ensures that no word can

be guessed from the context; each word must be seen to be read. The absence of any meaning has the advantage that children are often unaware of their errors of omission and transposition of words. The text is printed in a small typeface, closely spaced, in order to increase the visual difficulty.

The simple task of reading randomly ordered common words would appear to provide a sensitive measure of the visual skills involved in reading. If the test is given twice, once with the chosen overlay and once without, the average rate of reading with the overlay can be compared with that without, and is greater in the children who will subsequently use the overlay voluntarily in the long term (Wilkins *et al.*, 1996, 2001; Jeanes *et al.*, 1997). In general, if children read more quickly with an overlay, they also read more accurately (Wilkins *et al.*, 1996). Recent versions of the test have included a greater number of lines so that fast readers do not finish the passage within the minute.

Placebo effects

The increase in reading speed with a coloured overlay is unlikely to be simply because of motivation or other placebo effects. Wilkins and Lewis (1999) used the Rate of Reading Test and included a placebo control. Reading rate was compared with no overlay, the chosen overlay, a Grey overlay and a Grey overlay that was identical except that it carried the label 'scientific prototype'. To generate high levels of motivation the children were told that the prototype was new, that it combined all the colours, that they were one of the first children to use it, and that they were expected to do as well as they could. Performance with this Grey overlay did not differ from that with the other Grey overlay, although reading with the chosen coloured overlay was superior. Bouldoukian had earlier used a similar research design, with similar results (Bouldoukian *et al.*, 2002).

In one of the experiments reported by Jeanes *et al.* (1997), the Rate of Reading Test was given without an overlay, with a clear (transparent) overlay, with the Grey overlay from the set of *Intuitive Overlays*, and with two coloured overlays from the same set, one of the chosen colour and one of a colour complementary to that chosen. The five conditions were presented in random order. With the overlay of the chosen colour the reading rate was superior to that with no overlay, that with a clear overlay and that with the Grey overlay. The reading rate with the overlay of complementary colour did not differ significantly from the rate in the other conditions.

In an earlier study by Wilkins and Lewis (1999) children undertook the Rate of Reading Test with no overlay, an overlay that was reported as having least benefit, the Grey overlay, and the chosen overlay. The four conditions were presented in random order. The reading rate increased in the order in which the conditions are listed above, although the only statistical difference was in the performance with the chosen overlay compared with the other conditions.

Wilkins *et al.* (2001) showed that children who chose the Grey overlay did not continue to use it, and the Grey overlay had no effect on reading speed.

The above studies are therefore consistent in finding (1) that coloured overlays are superior to clear overlays (a placebo control) and to Grey overlays that reduce the contrast and luminance by a similar amount; (2) that quite different colours can be beneficial, although; (3) the chosen colour appears to give the greatest benefit; (4) a complementary or aversive overlay colour gives relatively little benefit, but does not reduce reading speed and (5) the rate of reading is little affected by motivational instructions.

Repeatability and consistency

In further studies (Wilkins *et al.*, 2001), a year group of children in a middle school were examined. First, the children were tested as a group and were asked about symptoms of distortion and discomfort when viewing the text. All the children were then examined individually by different examiners using different methods in two sessions no more than 3 days apart. The same number of children, 78 (87%), chose a coloured overlay on both test sessions. The rate of reading with and without the overlay on session 1 was strongly correlated with the rate of reading with and without the overlay on session 2. The improvement in reading speed because of the overlay was measured as the ratio of reading speed with the overlay divided by that without. Overall there was an 11% improvement in reading speed with the chosen overlay. The ratio obtained in session 1 was strongly correlated with that obtained in session 2, notwithstanding the occasional choice of different overlays. Despite the differences in assessment method, 47% of children selected the same colour on both occasions and a further 21% chose an overlay of similar colour (neighbouring chromaticity). The consistency demonstrated by the children was very considerably above that expected on the basis of chance alone, but could, of course, have reflected memory for the colour previously chosen. Nevertheless, the children who chose the same colour consistently on the two testing sessions showed a greater improvement in reading speed with that colour than those who chose a similar colour, and these children in turn showed a greater improvement in speed than those who chose a different colour on each test session.

In a second study in the same report (Wilkins *et al.*, 2001) all the 378 children in a middle school in Norwich

were examined individually with overlays. They were then given an overlay of a randomly chosen colour for a few months before being given the chosen overlay. The overlay was used longer among the children who, by chance, received an overlay of the colour they had chosen. The length of time the overlay was used decreased with the difference between its colour and the colour chosen.

Symptoms

In the studies by Wilkins *et al.* (2001) the children were told to look at the text of the Rate of Reading Test (on this occasion printed in a 12pt sans serif font) and asked: 'Do the letters stay still or do they move?'; 'Are they clear or are they blurred (fuzzy, difficult to see)?'; 'Are the words too close together or far enough apart?'; 'Does it hurt your eyes to look at the page or is it OK?'

The symptoms reported during an initial testing of classes as a group were similar to those reported when the children were later examined individually. This suggests that the individual differences in the symptoms reported are consistent. There were more symptoms reported by the children who need overlays.

Reading strategy

Phonologically regular words can be read from a knowledge of the component grapheme–phoneme conversion rules, whereas irregularly spelled words require a knowledge of the word itself. In the study by Wilkins *et al.* (2001) children aged 8–12 were asked to read a set of regular and irregularly spelled words in order to infer the phonological reading strategy the children were using. There was nothing to suggest that the children who used overlays differed from those who did not with respect to phonological reading strategy.

Prevalence

All the children in year 3 in 12 Norfolk schools were examined with the *Intuitive Overlays* (Wilkins *et al.*, 2001). Initially 60% of the 426 children reported a reduction of visual distortions, or improved comfort with one or more coloured overlays. These children were issued their chosen colour free of charge. In the summer term, about 8 months later, 52% of these children (i.e. 31% of the total sample) were still using the overlay. The percentage of children using the overlay varied from one school to another with a mean of 30% and S.D. of 15% between schools. The prevalence is similar to that obtained in other studies of normal school children (Tyrrell *et al.*, 1995; Jeanes *et al.*, 1997; Wilkins and Lewis, 1999; Scott *et al.*, 2002). Recently, Kriss (2002) found a prevalence that was only slightly higher (37.5%) in children with diagnosed dyslexia compared with a prevalence (25%) in children with normal reading skills. In a further recent study (A. Grounds and A. J. Wilkins, in preparation), the prevalence was broadly similar in children with dyslexia, those without dyslexia but with similar chronological age, or similar reading age, or with both similar chronological and reading age but with general intellectual impairment. The prevalence of benefits in the adult population may be similar to that in children (Evans and Joseph, in press).

In the large-scale study by Wilkins *et al.* (2001), the children who were still using their overlays in the summer term were more likely to be those who in the previous autumn term read faster with their overlays than without on the Rate of Reading Test. Overall, 5% of children read more than 25% faster with their overlay.

Colour choice

The choice of colour was widely distributed among those available. The most frequently chosen colours, rose and aqua, were chosen by less than 10% of the sample of children. There was no statistical difference in the frequencies with which the various colours were chosen by children who continued to use their overlays and those who ceased to use them. Thirty-three children chose the Grey overlay. These children did not show a significant increase in reading rate with the overlay. Neither the children who chose the Grey overlay or the children who were given one having chosen a different colour continued to use the Grey overlay. There was no relationship between the colour children regarded as their 'favourite colour' and the colour they chose in an overlay.

In more recent work Scott *et al.* (2002) reported a relationship between the colour chosen and the ocular accommodation. The children who chose overlays which reflected predominantly longer wavelengths (rose, orange and yellow) tended to show greater accommodation (duochrome effect). The relationship was, however, statistically very weak and is not likely to account from the benefit from filters in the majority of cases.

Reading rate and reading skill

Scores on a standardized reading test (Young's Reading Test, average 100, S.D. 15) were available for 427 children in the study by Wilkins *et al.* (2001). The 133 children who used overlays had an average reading quotient of 98.7, compared with 102.2 for the remaining 294 who did not use overlays or did not choose them. As

might be expected, the good readers were generally the faster readers, as assessed by the Rate of Reading Test. Nevertheless, there were good readers (reading quotient more than 120) who read only 40 words per minute on the Rate of Reading Test. There were others with similar reading attainment who read more than *three* times as fast. These very large differences in reading speed among children with similar reading ability are curious, particularly because scores on the Rate of Reading test are highly reliable from test to re-test (Wilkins *et al.*, 1996). It is possible that some of the differences are attributable to visual factors, rather than more general aspects of reading ability. Support for this position comes from the large number of individuals who report improved clarity with overlays and also from the following observations concerning the design of text in children's reading books.

Suboptimal design of children's text

Hughes and Wilkins (2000) investigated whether the typography in children's reading schemes was suitable for the intended reading age. Versions of the Rate of Reading Test were constructed with text size and layout that closely resembled the text at four reading stages in each of two popular reading schemes. In this way the effects of typeface and spacing could be examined independently of the linguistic difficulty of the material. The reading speed of children aged 5–8 decreased as the text size decreased: in particular, these children read fastest the text designed for 5- and 6-year olds. Older children aged 9–10 were neither assisted nor disadvantaged by text size over the range examined. Children of all ages, particularly those who reported illusions in a visual stress pattern, were found to make more errors on the smaller than on the larger text. The authors concluded that the reading development of some children might benefit from a larger text size and spacing than is currently the norm, and that no children would be disadvantaged by such a change. It is possible that the benefit from overlays is partly attributable to the poor design of printed material for children. Teachers need to be able to choose from reading schemes that include at least one in which the linguistic content becomes more complex without an associated decrease in type size and spacing, and no such schemes are currently available.

Hughes and Wilkins (2002) investigated the size of text in children's Big Books (the large scale books that are used to introduce reading to small groups). They found that the text was too small and too closely spaced. In some books the text was too small even to be seen at the maximum reading distance! They recommended a maximum reading distance of 3 m (half the current recommended maximum).

Reading silently for comprehension

The Rate of Reading Test uses meaningless material that the individual is required to read aloud. The reading involved therefore differs from normal reading both with respect to comprehension and concurrent articulation. Lewis and Wilkins (unpublished data) therefore measured the improvement in reading speed with overlays using the Rate of Reading Test and compared the improvement with that on a test that required silent reading for comprehension. The latter test (the Baddeley Silly Sentences Test, 1992) required children to read a series of simple sentences, such as 'fruits grow on trees' and 'we eat shoes' and place a tick or cross beside each, as appropriate. Both tests were given to 29 children with reading difficulties, aged 8–16, referred to the Norfolk Sensory Support Service. The tests were given with and without an overlay in random order. The overlay covered the textual material but left the right margin uncovered for the children to enter their responses. The rate of reading was significantly correlated with the rate of sentence verification ($\rho = 0.69$, $p < 0.01$ without an overlay, and 0.81, $p < 0.01$ with). The percentage improvement in reading speed and comprehension with an overlay was also significantly correlated ($\rho = 0.55$, $p < 0.01$, see *Figure 2*). When the testing was repeated with 35 unselected children (aged 9–10) who showed an average increase in rate of reading only one-fourth that in the above sample the correlation was not significant. This is to be expected, given that reading rate on the Silly Sentences Test is more variable than that on the Rate of Reading Test, being influenced not only by reading speed but also by speed of comprehension. Taken together these findings indicate that the Rate of Reading Test is suitable for predicting the improvement in speed to be expected from overlays in natural reading tasks, at least when the increase is marked.

Luminance

The lighting levels recommended for non-residential buildings have shown an increase over time from 1930 to 1970 followed by stabilization or decline. The current recommendations for general lighting in schools show a two to threefold variation from one country to another but are on average close to the European recommendation of 300 lux, i.e. such that the luminance of a white sheet of paper is about 100 cd m^{-2} (Mills and Borg, 1999). Classrooms are usually well lit by daylight and lighting levels are sometimes more than four times this recommended figure (author's observations). Under these conditions patients may be more likely to find darker overlays, including double overlays, of use. In the studies of

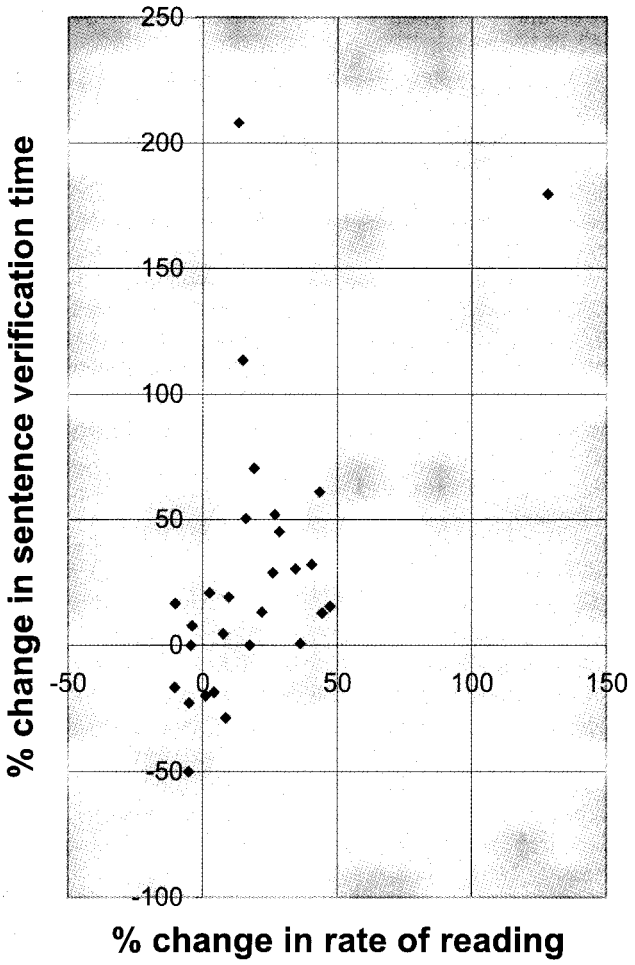

Figure 2. The percent change in sentence verification time resulting from overlay use for 29 children with reading difficulty, shown as a function of the per cent change in rate of reading.

school children reviewed above, approximately half chose double overlays. If children are examined under the lighting conditions typical of a optometry examination room far fewer children are likely to choose double overlays. It is therefore important for an examination with overlays to be conducted under lighting conditions that resemble those in the patient's classroom or workplace.

Coloured glasses

This review has concerned coloured overlays, but would be incomplete without mention of coloured glasses. Many individuals who report benefit from coloured overlays report greater benefit when they wear coloured glasses. The glasses can be used for writing and for distance vision (e.g. board work in the classroom). Apart from these practical considerations, the range and precision of colour available in lenses is greater than in overlays, and recent studies have documented just how precise the colour has to be for optimal effect (A. J. Wilkins, N. Sihra and A. Myers, in preparation). The colour optimal for use in lenses differs from that optimal in overlays, for reasons that may concern colour adaptation (Lightstone *et al.*, 1999), but are presently unclear. Lightstone and Evans (1995) have proposed a clinical protocol and this has been evaluated in open trials (Evans *et al.*, 1999). The efficacy of coloured lenses in reducing symptoms has been demonstrated in two trials that were clearly double-masked (Wilkins *et al.*, 1994, 2001). The efficacy in improving reading in the long term has also been demonstrated (Robinson and Foreman, 1999). Unfortunately this last study used lenses for the evaluation of patients for inclusion in the trial, so it is not possible to be sure the mask was maintained.

Conclusion

Overlays provide a low-cost treatment option that has scientific support. They increase reading speed substantially in at least 5% of the school population. A similar proportion of adults may benefit. There are many issues that remain to be resolved. These include whether the benefit from overlays provides an appropriate indication of a patient's likely benefit from coloured lenses. Overlays not only colour the text they cover, they reduce its contrast, and for a few patients this may perhaps be an important component of the benefit derived (Williams *et al.*, 1995). For the majority, however, the colour is the important component and most report greater benefit with coloured lenses than from overlays. This is despite the fact that the colour appropriate for lenses is not the same as that appropriate for overlays, for reasons that are discussed by Lightstone *et al.* (1999). The mechanisms for the increase in reading speed are under exploration and, to date, the most likely candidates appear to be central (Wilkins, 1995) rather than peripheral (Simmers *et al.*, 2001).

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