Journal of Research in Reading (1995), 18(1), 10–23

Coloured overlays, visual discomfort, visual search and classroom reading

Ruth Tyrrell, Buckinghamshire; Keith Holland, Cheltenham; Douglas Dennis, Worcester; Arnold Wilkins, Cambridge

ABSTRACT

Forty-six children aged 12–16 were shown a page of meaningless text covered in random order by different plastic overlays, including seven that were various colours and one that was clear. By successive pairwise comparison each child selected the overlay that provided the greatest perceptual clarity of the text. The children with below-average reading ability were more likely to chose a coloured overlay, and they reported more perceptual difficulty on tasks devised by Irlen (1983). In separate sessions with and without the overlay of their choice, the children read for 15 minutes and performed a visual search task. The overlay had little effect on reading initially, but after about 10 minutes the children who chose a coloured overlay read more slowly without the overlay than with it. These children reported more symptoms of visual discomfort and showed signs of tiring when they read without the overlay. The visual search performance of the children who chose a coloured overlay was initially impaired but improved to normal levels when the overlay was used. Fourteen children aged 8–16 acted as chronological or reading age-matched controls, and undertook the reading and visual search tasks using a clear overlay which had no effect on performance.

RÉSUMÉ

Transparents colorés, inconfort visuel, recherche visuelle et lecture en classe

Soixante enfants de 8 à 16 ans ont participé à une étude relative aux effets de transparents de couleur sur les compétences en lecture et le comportement dans des écoles pratiquant l'intégration scolaire. On leur a montré une page de texte sans signification recouverte de différentes combinaisons produites par huit transparents de plastique différents, sept en couleur et un incolore. Au début, les transparents ont

ISSN 0141-0423 Published by Blackwell Publishers, 108 Cowley Road, Oxford OX4 1JF, UK and 238 Main Street, Cambridge, MA 02142, USA

été présentés un à un dans un ordre aléatoire, puis superposés suivant différentes combinaisons. En procédant à une comparaison par paires successives, chaque enfant a sélectionné le transparent ou la combinaison de transparents superposés lui procurant le maximum de clarté perceptive du texte. Quarante-six des enfants de 12 à 16 ans ont été divisés en groupes en fonction de leur savoir-lire. Les enfants peu performants en lecture ont été les plus enclins à choisir un transparent de couleur ou une combinaison de transparents de couleur, et ils ont manifesté davantage de difficultés perceptives dans les tâches élaborées par Irlen (1983).

Les enfants ont lu un livre pendant 15 minutes dans différentes sessions ordonnées de manière aléatoire, avec et sans le transparent (ou les transparents) de leur choix. Ils ont choisi un livre adapté à leur niveau de lecture et à leurs intérêts (on n'a pas utilisé de tests standardisés pour l'analyse de la lecture car la complexité de ce type de matériel augmente en fonction de la sémantique aussi bien que de la typographie). On a analysé la vitesse de lecture en comptant le nombre de syllabes. Au début, le transparent a eu peu d'effet sur la lecture, mais au bout de dix minutes, les enfants qui avaient choisi un transparent de couleur ont lu plus lentement quand ils n'avaient pas de transparent. Ils ont aussi davantage fait état de symptômes d'inconfort visuel et manifesté plus de signes de fatigue en lisant sans transparent.

Les enfants ont effectué également une tâche de recherche visuelle au cours de la même session. Cette tâche impliquait la recherche de lettres-cibles dans une page où les lettres étaient disposées de manière aléatoire, mais de façon à ressembler à une page de prose du point de vue de l'espace, de la longueur des suites de lettres, de la ponctuation, et de la position des lettres ayant des hampes vèrs le haut ou vers le bas. Les résultats en recherche visuelle des enfants ayant choisi un transparent de couleur ont été perturbés au départ, mais se sont améliorés et ont atteint un niveau normal quand le transparent a été utilisé.

Quatorze enfants de 8 à 16 ans, pris comme contrôles de l'âge chronologique ou de l'âge de lecture, ont effectué les tâches de lecture et de recherche visuelle en utilisant un transparent incolore, sans effet sur les résultats.

On a évalué sur le plan optométrique, grâce à un optométricien indépendant ignorant les niveaux de lecture ou le choix de transparent opéré, vingt-trois des soixante enfants, une sélection de bons et de mauvais lecteurs et ceux qui avaient choisi des transparents de couleur ou le transparent incolore. On a entrepris une série de tests pertinents pour la vision binoculaire qu'exige la lecture, y compris l'analyse des mouvements oculaires. Dans l'ensemble, la vision binoculaire s'est révélée pauvre chez tous les sujets ayant choisi un transparent de couleur ainsi que pour 60% de ceux ayant choisi un transparent incolore. Pour les sujets lisant en utilisant un transparent on a observé moins de fixations et de mouvements de régression.

Cette étude met l'accent sur le caractère individuel des difficultés perceptives de chaque enfant avec l'écrit et de leur réponse aux transparents de couleur. Les mécanismes des effets bénéfiques des transparents demeurent inconnus.

INTRODUCTION

When they look at printed text, certain individuals suffer perceptual distortions of the print which they may accept as quite normal. These include blurring, bending of

the lines, movement of the letters etc. The distortions may interfere with reading and are usually associated with discomfort. Helen Irlen, a psychologist, has drawn attention to these difficulties. She theorised that they were caused by an excessive sensitivity of the retina to specific frequencies of the light spectrum. She noted that the distortions were exacerbated when print had a high black–white contrast (Irlen, 1983, 1991), and that they were sometimes reduced when the text was covered by a particular colour, different for each individual. She has developed a system of coloured overlays and coloured lenses as treatment, available at the Irlen Institutes she has founded. The efficacy of this treatment remains controversial at present.

Anomalies of binocular vision have repeatedly been proposed as the cause of perceptual distortion, resulting in headaches and eye-strain (Holland, 1987; Schieman *et al.*, 1990). In addition, Wilkins *et al.* (1984) suggested that some of the perceptual distortions have a central origin. They proposed a neurological theory of visual discomfort that attributed the distortions to a cortical hyperexcitability. According to the theory, text provides a pattern that causes strong physiological excitation, sufficient to result in an inappropriate spread of excitation, particularly in individuals with a sensitivity to light. The sensitivity to light is related to headaches and eye-strain in various ways.

The following study was primarily concerned with the effect of selected coloured overlays on reading skills and general reading behaviour in school children. A secondary objective of the study was to explore the effects of coloured overlays on eye movements. A number of researchers have identified a relationship between eye movements and reading efficiency, although the relationship is not necessarily causal (Huey, 1908; Adler and Stark, 1978; Den Buurman, Rodersema and Gerrisen, 1981; Pavlidis, 1981).

METHOD

Selection of subjects

Sixty children, aged 8 to 16 years (33 boys and 27 girls), were selected from three comprehensive high schools, one middle school and one first school in Worcestershire. Forty of the children were new entrants to the comprehensive schools (i.e. aged 12+ to 14 years), who had a score greater than 97 on the non-verbal scale of the *Cognitive Abilities Test* (National Foundation for Educational Research, 1974), and had been tested on the Group Reading Test of *The Standard Reading Tests* (Daniels and Diack, 1977). These data were already available from the schools as a result of the regular local education authority screening programme.

Three groups were identified on the basis of the individual differences between chronological age and reading age, as measured by the Group Reading Test: 10 above-average readers (reading age more than one year above chronological age); 18 average readers (reading age within one year of chronological age); 12 below-average readers (reading age more than one year below chronological age). In addition, a group of six well-below average readers (reading age three to five years below chronological age) was selected from among the 14- to 16-year-olds in the comprehensive schools, by their teachers. A control group of eight pupils, with average reading for their age and with ages similar to the reading ages of the well-below-average readers, was selected from among the eight- to 12-year-old children

attending the first and middle schools (reading age (RA) control group). A further control group of six average and above-average readers matched by chronological age with the group of well-below-average readers was selected from the comprehensive high schools (chronological age (CA) control group). The control subjects received the same reading test as the experimental group. The same experimenter (RT) conducted all the testing in an order that was randomly counterbalanced.

Procedure

Subjects were tested on three occasions. The first two sessions, which concerned the use of coloured overlays, were held three weeks apart at a similar time of day and day of the week, during school hours. The third session involved optometric assessment and will be reported in detail (by KH) in a later publication.

In the first session subjects were interviewed concerning their attitudes to reading, choice of reading material and symptoms with which reading was usually associated. Then followed three proprietary tests, taken from Irlen's (1983) *Scotopic Sensitivity Syndrome (SSS) Screening Manual.* (The use of this material is limited to trained 'Screeners'. The first author was trained two years before the present study began.) The first test from the manual involved the subject in describing the extent of clear vision around the centre of gaze. This test was not included in the study because it became obvious that subjects were not adopting a stable criterion.

The remaining two tests used from the Manual involved the description of perceptual distortions in music manuscript and in a figure composed of symbols. A standardised set of questions was asked with each of these tests. Using the scoring system advocated by Irlen, subjects were divided into three groups on the basis of their total scores: those with low scores (0–3), those with moderate (4–6) and those with high (7 and over).

Coloured overlays, consisting of seven plastic sheets (333mm × 228mm) (Turquoise; Blue; Green; Yellow; Peach; Rose; Gold) were obtained from the Irlen Institute. The overlays had a matte finish on one side. An additional clear plastic sheet of similar size was added to the set. Subjects selected overlays on both of the first two sessions according to the methods laid down in the SSS Screening Manual: pairs of overlays were presented side by side on a page of text. The text was written in an unfamiliar language similar to Dutch using a serif font. The body of text was right justified, and set in a single paragraph 196mm high and 166mm wide. The text had an x-height of 1.5mm, an interlinear spacing of 3.6mm, with an average of about 1.5mm between words. When the overlays were placed upon the page subjects were asked to describe the appearance of the text, choosing the overlay that gave the clearest perception. The selected overlays were then superimposed in turn one upon another until, by a process of successive elimination, the subject had selected an overlay or combination of overlays that provided the clearest perception. Those subjects who chose a coloured overlay or overlays on the first session comprised the Coloured Overlay Group.

The subjects were then invited to read from a book of their own choosing. Staff who had administered the *Group Reading Test* guided subjects in the Poor Reader group by providing several books from which each subject chose one. Passages of a length sufficient to provide about 15 minutes of reading were photocopied. The photocopies were actual size, except for two books which had large, spaced text. For

these books the text was reduced by about 10% and concatenated to provide a continuous passage on each page. Subjects were audio- and video-taped.

After reading aloud for 15 minutes, subjects performed a visual search task. The stimulus material consisted of two pages of random letters presented to resemble conventional text. The punctuation and text layout corresponded to two passages from *Charlie and the Chocolate Factory* (Roald Dahl, 1983). The letters within the passage were replaced at random by other letters; those with ascending or descending strokes being replaced by other letters with ascenders or descenders. The passage was laser-printed (300 dpi), using Page Maker® on an Apple Macintosh®, choosing a serif font with size, word spacing and letter spacing so that the text best approximated that of the original passage from Dahl. The passages were left-justified, about 95mm wide and 130mm high, with an x-height of 1.9mm, an inter-linear spacing of 4.3mm, and about 1.2mm between the words. Each passage contained 55 x's in 32 lines. The subjects were instructed to look for the letter 'x' as quickly as possible, and to call out the name of the letter that followed it. Any letter reversals were accepted as correct. The subjects were audio-taped for later analysis and scoring.

The second session repeated the overlays testing, and the reading and visual search tasks. For one of the two sessions, first or second, selected at random, the photocopied text was covered by an overlay, or combination of overlays. The overlays used were those chosen by that subject at the beginning of the first session. (The results of the overlays testing in the second session were not used for the allocation of subjects to experimental groups. Inconsistencies in the choice of overlays on the two sessions occurred in 21% of subjects, but mainly in cases where several overlays were selected with similar colours.) No overlay was used for reading or visual search in the other session. Subjects in both the reading-age and the chronological-age control groups read using a clear overlay, irrespective of original preferences.

At the end of the reading task all subjects were asked the following questions: How do your eyes feel? Did you have any difficulties with the print? Did you have any difficulties with the light? Is there anything you would like to add?

The third session consisted of an optometric assessment, carried out on 23 of the 60 subjects by an independent optometrist (KH). The sample of 23 subjects included those using clear overlays as well as those using coloured: all subjects in the 'below-average' and 'well-below-average' reading ability groups for whom parental permission was available (i.e. all but three in the former group and all but one in the latter). Three subjects from the 'above-average' category were also selected from amongst those who chose clear overlays. To complete the sample, seven subjects from the 'average' category were included if they had shown an improvement on the visual search task using coloured overlays.

The optometrist examined the subjects without prior knowledge of their reading ability, or of their preferred overlay colour, if any. The following tests were carried out without filters: (1) visual acuity (6m Snellen chart); (2) static retinoscopy; (3) subjective refraction at 6m; (4) objective cover test (distance and near); (5) near point of convergence (push-up test); (6) pursuit eye movements at 0.4m (clinical observation); (7) colour vision (*City University Test*, 2nd ed.); (8) ophthalmoscopy. Additional tests were conducted (i) with the preferred colour overlay; (ii) with an overlay selected at random by the experimenter; and (iii) without any overlay. These additional tests were: (1) accommodative amplitude (the closest point of focus on an

A5 card bearing a paragraph of N6 sans serif text); (2) accommodative facility (the number of times in one minute that the eyes can be brought into focus on the above stimulus when viewing through a +2.00D or a −2.00D lens presented alternately); (3) near dissociated phoria (Howell Card technique: a card bearing a pointer and a row of numbers is viewed with a prism over one eye that displaces its image vertically; the subject judges the relative position of the images from the two eyes); (4) binocular eye movement recording using infra-red scleral reflection when three passages of text were read. Those subjects who had no preferred colour used two sets of randomly chosen coloured overlays. The subjects were advised not to comment on their performance when using any overlay. The reading passages were taken from *The Magician's Nephew* (C.S. Lewis, 1983), and set with typographic parameters similar to those of the passages used for the visual search test. They were matched for readability (Fry, 1977). One hundred words in each passage were marked out and the numbers of syllables and sentences counted. These values were then applied to the Fry readability graph. Prior to the reading exercise, subjects were shown words such as 'Narnia' and 'Shasta' which might be unfamiliar because of their specificity to the story. The passages were read under each of the three conditions described above in an order counterbalanced across subjects.

RESULTS

In Tables 1 and 2 are shown the preferences for a coloured overlay or the clear overlay obtained at the beginning of the first test session. The trend towards more frequent choice of coloured overlays among the poorer readers is significant (Page's $L = 2317$, $z = 2.47$, $p = 0.012$, 2-tail).

Table 1. Overlays chosen as improving the clarity of text by the Coloured Overlay Group. The chromaticities of each filter are given by Wilkins (1994)

Overlay	Chosen on its own	Chosen in combination with other overlays
Rose	5	3
Peach	1	2
Gold	5	2
Yellow	2	1
Green	1	6
Turquoise	3	8
Blue	0	4

The scoring of perceptual difficulties using Irlen's (1983) tests is shown in Tables 3 and 4; higher scores corresponded to greater difficulties. Table 3 shows that below-average readers tended to obtain high scores on the perceptual difficulties tasks. For the purpose of statistical analysis the cell sizes were increased by collapsing the two groups with above-average and average reading ability, and the two with below-average, and the groups with moderate or low perceptual difficulty. The resulting

Table 2. Number of subjects (and percentage of reading ability group) who chose a coloured overlay or the clear overlay

Reading ability	Number of subjects	Chose coloured n(%)	Chose clear n(%)
Above average	10	4 (40%)	6 (60%)
Average	18	10 (56%)	8 (44%)
Below average	12	9 (75%)	3 (25%)
Well-below average	6	6 (100%)	0 (0%)
Total	46	29 (63%)	17 (37%)

Table 3. Number of subjects (and percentage of reading ability group) with low, moderate or high scores on Irlen's (1983) tests of perceptual difficulty

Reading ability	Perceptual difficulty		
	Low	Moderate	High
Above average	2 (16%)	10 (76%)	1 (8%)
Average	10 (34%)	10 (34%)	9 (31%)
Below average	3 (25%)	3 (25%)	6 (50%)
Well-below average	0 (0%)	0 (0%)	6 (100%)

Table 4. Number of subjects (and percentage of perceptual difficulty groups) who chose a coloured overlay or the clear overlay

Perceptual difficulty	Chose coloured	Chose clear	Given clear
Low (n = 15)	2 (13%)	6 (40%)	7 (46%)
Moderate (n = 18)	7 (39%)	6 (33%)	5 (28%)
High (n = 24)	20 (83%)	2 (8%)	2 (8%)

Subjects in the control groups who were given a clear overlay are also shown for comparison.

2 × 2 contingency table had 32, 10, 6 and 12 subjects per cell and yielded a chi-square of 9.96 ($p = 0.0016$). Table 4 shows that subjects obtaining high scores on the perceptual difficulties tasks tended to choose coloured overlays. For analysis the groups with low and moderate perceptual difficulty were collapsed, and the control groups excluded. Fisher's exact probability for the resulting 2 × 2 contingency table with 9, 12, 20 and 2 subjects per cell was 0.0009.

Two children were not available for testing at the second session, and a third child was later found to be suppressing one eye. These children were excluded from subsequent analyses.

When subjects were questioned at the end of the reading task they reported the problems shown in Table 5. As might be expected from the above associations

Table 5. Incidence of symptoms after reading for 15 minutes with and without an overlay

	Chose coloured (n = 29)		Chose clear (n = 14)		Given clear (n = 14)	
	with	without	with	without	with	without
Symptoms						
Print blurring	4	20	4	3	3	4
Print moving	2	9	1	1	4	5
Print disappearing	1	5	1	0	0	1
Print closing up/shrinking in size	0	0	0	0	1	0
Losing place in text	0	8	2	4	1	0
Parts of word seen	0	3	0	0	0	0
Colours on page	0	4	0	0	0	0
Black/white shapes on page	0	2	0	0	0	0
Glare	0	3	1	2	0	2
Eyes stinging, watering, sore	8	18	6	5	1	2
Tiredness	2	10	3	3	2	1
Total symptoms	*17*	*82*	*18*	*18*	*12*	*15*
Signs						
Yawning	1	4	3	5	0	1
Finger tracking	0	1	1	1	1	1

Subjects who chose a coloured overlay or the clear overlay read with and without the overlay of their choice. Subjects in the control groups who were given a clear overlay are also shown for comparison.

between reading difficulties and choice of overlay, perceptual distortions and visual discomfort were more commonly reported by children who chose a coloured overlay when they were required to read without it. There was a significant but small correlation between the mean score on Irlen's tests of perceptual difficulty and the reports of perceptual difficulties after reading without the overlay ($r_s = 0.32$, $p < 0.05$). The mean score was significantly higher among subjects who showed signs of tiredness ($t(34) = 2.06$, $p < 0.05$, 2-tail). The number of perceptual distortions reported by each subject when they read with the overlay and when they read without it was subjected to an analysis of variance with choice of overlay (chose coloured, chose clear) as a between-subject variable and use of overlay as a within-subject variable. The analysis yielded a significant interaction term ($F(1,26) = 23.6$, $p < 0.0001$) due to the larger reduction in perceptual distortions for the group choosing a coloured overlay when they read using it ($t(13) = 6.2$, $p < 0.001$, 2-tail). The clear overlay had no effect ($t(13) = 0.27$, $p > 0.7$, 2-tail).

The first five minutes and the last five minutes of the 15-minute reading task were assessed by examination of three one-minute segments during each period. The mean numbers of syllables read in one minute are shown in Table 6.

A two-way analysis of variance with time of assessment (initial or final five minutes) and use of overlay as within-subject factors was performed separately for the group choosing coloured overlays and the group choosing clear. For the former

Table 6. Reading rate (in syllables per minute) with and without an overlay

	Chose coloured		Chose clear		Given clear RA controls		Given clear CA controls	
	with	without	with	without	with	without	with	without
Initial 5 min.	131.3	130.9	177.1	173.3	150.4	151.3	189.6	190.3
Final 5 min.	133.7	123.0	175.6	175.1	152.6	156.1	185.7	185.1
% difference	2%	−6%	−1%	1%	1%	3%	−2%	−3%

Subjects who chose a coloured overlay and those who chose the clear overlay read with and without the overlay of their choice. The control subjects read with and without a clear overlay.

group there was a significant main effect of use of overlay ($F(1,28) = 6.29$, $p = 0.018$) and a significant interaction term ($F(1,28) = 9.89$, $p = 0.004$). Peritz post hoc comparisons (Toothaker, 1991) indicated that the overlay significantly improved reading only in the final five minutes. The analysis of variance for the subjects choosing clear overlays yielded no significant main effects or interactions.

The reading rate during the last five minutes was decreased by 6% relative to that during the first five minutes when subjects who chose overlays read without them. There was no such decrease when the same subjects read using the overlays. The reading rate of subjects who did not choose coloured overlays showed no significant change over time with or without overlays. There was no significant correlation between the change in reading rate and the reports of perceptual distortion or the scores on Irlen's tests of perceptual difficulty.

Table 7. Mean (and standard deviation) of the number of targets detected in the visual search task with and without overlays

	Chose coloured		Chose clear		Given clear RA controls		Given clear CA controls	
	with	without	with	without	with	without	with	without
mean no. targets detected	26.0 (27.0)	24.2 (19.7)	27.6	27.4	21.8	22.5	30.5	30.3
SD	4.4 (4.7)	9.3 (13.0)	4.4	4.4	4.4	4.3	3.1	3.0

Subjects who chose a coloured overlay and those who chose the clear overlay read with and without the overlay of their choice. The control subjects read with and without a clear overlay. The group who chose coloured overlay includes the six well-below average readers, and the scores for this subgroup are shown separately in parentheses.

The visual search performance is shown in Table 7. For the children who chose a coloured overlay, letter detection was significantly improved by the use of the overlays ($t(28) = 2.98$, $p < 0.01$, 2-tail). For children who preferred a clear overlay the use of this overlay did not have any significant effect ($t(27) = 0.12$, $p > 0.90$, 2-tail). The children in the control groups matched for reading age and chronological age with the six well-below-average readers were given a clear overlay, and showed no advantage from its use.

The subjects who used the overlays in the first testing session were compared with those who used them in the second session. There was no significant effect of order of testing for the reading or the visual search tasks.

Statistical analysis of the optometric results was carried out separately and will be presented in detail elsewhere (by K.H.). The findings can be summarised as follows:

(1) The use of either filter (control or specific) produced a significant improvement in accommodative amplitude, but with no significant difference between the two filter conditions.
(2) As with accommodative amplitude, there was a significant improvement in accommodative facility of more than four cycles per minute.
(3) The average number of fixations and regressions occurring per line amongst subjects expressing a preference for a filter and amongst other subjects is shown in Table 8. Analysis of variance showed a trend towards the preferred overlay reducing both the number of fixations per line and the number of regressions. No significant change was seen with the randomly assigned overlay.
(4) Of the children seen for optometric assessment, overall binocular performance was judged to be below generally accepted clinical levels (described by Rosner, 1982) in all children showing a preference for an overlay, and also in 60% of the controls.

Table 8. Mean number of fixations and regressions per line of text for subjects with and without a preference for a coloured overlay

		Mean number of fixations per line	Mean number of regressions per line
Subjects preferring an overlay	chosen overlay	20.2	4.69
	random overlay	22.2	5.45
	no overlay	23.2	5.76
Other subjects	mean of both overlays	15.4	3.98
	no overlay	14.1	2.90

DISCUSSION

The group averages show modest but significant improvements in reading skills using overlays of the child's selection. These group statistics may mask the large improvements sometimes apparent in individual subjects, but without an independent means of discriminating these subjects from the remainder it is not possible to be sure.

The use of selected overlays resulted in improvements in ocular motor control when reading. These improvements might be related to the increases in reading rate and visual search performance which were also observed.

Experimenter effects and more conventional placebo effects may have contributed to the results obtained, but given the within-subject and between-subject controls, and the emergence of differences in reading speed only after 10–15 minutes, it seems unlikely that they provide a sufficient explanation.

The choice of overlay colours was varied and highly individual. The majority of subjects who found a particular overlay or combination of overlays helpful also found one or more colours unhelpful, even aversive. Similarly, those choosing a clear overlay often commented on specific colours that caused distortion or discomfort. Colours found to be helpful were not always considered acceptable by the individual subject, for example, one boy demonstrated beneficial results with a 'peach' overlay but commented that he would not use that colour even though it did help. This suggests that, in his case at least, coloured overlays were chosen for benefit and not for appearance. Some subjects selected a triple combination of overlays but the benefit they derived from the resultant colour was partly offset by the reduced light reaching the page and reflected from it. Thus not all subjects felt that they had received the optimum colour combination. This may also be partly due to the restricted number of overlay colours being used.

Subjects had no opportunity to practise with their selected overlays. It might well be the case that a lengthy period of usage is required before benefits can reliably be assessed.

The screening of the subjects using Irlen's tasks (Tables 3 and 4) showed that inefficient reading was positively related to the incidence of perceptual difficulties reported when undertaking these tasks. This appeared to be the case in some individuals in the groups of above-average and average readers who may have devised for themselves a set of coping strategies. Reading behaviours such as head turning, dysfluent reading, repetition, and loss of place were not confined to subjects with below-average reading ability.

The material used in the visual search task was specifically designed to resemble closely a page of prose with respect to word shape and length, individual letter forms and punctuation. The task involved the use of peripheral cues to guide the movements of the eyes, and central cues to identify the target objects (Haber and Hershenson, 1973, p. 215). Winter (1987) using less realistic tasks, failed to find differences when using a coloured filter of the subject's choice, one chosen at random, or none at all. As has been noted in a recent review, the studies that have shown beneficial effects of filters have been those by researchers connected with the Irlen Institute; the research by independent investigators has generally failed to show benefits (Solan and Richman, 1990). It is easy to dismiss this picture as reflecting experimenter bias and a lack of research sophistication. It is also possible, however, that the demonstration of beneficial effects requires an appreciation of (1) just how precise a selection of colour may be necessary; (2) just how subtle the effects on reading may be, as shown here; and (3) the fact that some good readers may benefit from a reduction in discomfort and distortion as much as those with reading difficulty, a point with relevance to the selection of control groups.

The selection of coloured overlay was undertaken in both the first and second sessions. Subjects choosing a coloured overlay were usually consistent in their choice of colour in the two sessions. Differences in lighting and the greater density when several overlays were combined may account for the cases of inconsistent selection. The scores of subjects when using coloured overlays were consistently superior irrespective of whether the overlay was used in the first or second session. One might have expected a slight improvement on the second session due simply to the subjects knowing what was expected of them.

Reading rate was measured by a syllabic count due to the variability of the texts being assessed. Other studies have used standardised reading analysis for estimating reading rate and have failed to show a significant increase (O'Connor, Sofo, Kendall and Olesen, 1990). In such reading tests the complexity of material increases both with respect to semantics and typography. A revised test that dissociates the semantic complexity from that of the typography may be preferable for assessing children who suffer perceptual dysfunction that is related to the visual aspects of the print itself. There are tests for assessing auditory decoding difficulties, but little to assess the level of visuo-perceptual skills pertinent to reading. It may well be the case that perceptual difficulties manifest themselves only when a child is confronted by stressful stimuli such as text, particularly if that text has specific spatial characteristics (Wilkins, 1993).

The mean percentage improvements in the visual search and reading rate across the groups was similar in subjects whose reading was 'above-average' and 'well-below-average'. These findings are consistent with the large number of factors that contribute to both reading and visuo-perceptual difficulties.

Comments from subjects after reading, and particularly after reading without coloured overlays, included: print moving; print blurring; colours or shapes (white or black) on the page; and various complaints of eye strain. After reading with the chosen coloured overlay there were comparatively few of these comments in answer to identical questions. There was a reduction in the amount of yawning and fidgeting observed when subjects read with the coloured overlays. By comparison, subjects using clear overlays showed little change. The subjective assessment of perceptual distortions and visual discomfort supplements the objective data to give a consistent picture suggesting that reading performance may be affected adversely, especially in the longer term.

The theoretical basis for the effects of colour on reading is at present largely a matter for conjecture, and many different mechanisms may be involved. K.H. (second author) suggests that the optometric findings point to a link between Scotopic Sensitivity Syndrome (also called Irlen syndrome) and unstable binocular vision (cf Alwes, Frisby and Lasher, 1990; Evans and Drasdo, 1991; Garzia, 1993). The link may not be causal, but the close parallels between the symptoms of the Irlen syndrome and those of binocular vision dysfunction may suggest a common physiological mechanism underlying both, or even a common dysfunction. Such a viewpoint is compatible with a parsimonious explanation for the discomfort and distortions on which the coloured overlays appear to have their primary effect. As Wilkins (1993) points out, visual stimuli that provoke maximal discomfort and distortions resemble text and are similar to the stimuli that induce seizures in patients with photosensitive epilepsy, seizures which can arise from a very localised hyperexcitability of the visual cortex. Wilkins advances the hypothesis that the distortions are a reflection of a minimal hyperexcitability of cortical neurones and that by changing the pattern of excitation in the cortex the colour reduces the excitation in hyperexcitable regions, preventing the anomalous spread of excitation responsible for the distortions. Such a disturbance might be expected to have effects on binocular control. The above interpretations are only a few among many, and they remain contentious.

The effects of colour on reading appear to be secondary to the effects of colour on discomfort and/or distortions. The latter are usually present after the page has been

observed only briefly, whereas the change in reading rate is often observable only after prolonged reading, as in this study. In some children the perceptual distortions result in a confusion of letters that interferes with reading; in others glare from the page makes reading uncomfortable. There would seem to be little effect of colour on reading unless discomfort and distortions are reported.

The results of our study indicate that, for some individuals, there is a role for coloured overlays in the classroom. The overlays can be used to reduce perceptual distortion and stabilise print while educational (and optometric if required) remediatory measures are undertaken.

The location of the present study in schools allowed the teachers in those schools to monitor the activities of the investigation, and the effects on the subjects in class following the completion of the research work. The subsequent involvement of a much larger number of teachers in this project after the initial feedback of results to the schools led to the development of guidelines for the classroom management of pupils who experience visual perceptual difficulties. Such a development would have been unlikely had a clinical design been adopted.

Note that the results reported in this article were obtained using Irlen coloured overlays and cannot necessarily be generalised to other filters.

Acknowledgements

The authors gratefully acknowledge the generous co-operation of the schools, parents and children, and of Worcestershire Education Authority. The research was supported by the Paul Hamlyn Foundation, the Irlen Institute, and the Medical Research Council.

DISCLOSURE OF INTEREST

None of the authors has a financial interest in the Irlen Institute. Although the first author was trained as an Irlen screener, she was not working for the Irlen Institute at the time the study was conducted. The last author is a member of the staff of the Medical Research Council Applied Psychology Unit. The Medical Research Council owns the rights to the Intuitive Colorimeter and the Intuitive Overlays.

REFERENCES

ADLER, G. and STARK, L. (1978) Eye movements, scan paths and dyslexia. *Journal of Ophthalmology*, 55, 557–570.

ALWES, W.H., FRISBY, S.M. and LASHER, D. (1990) *The Efficacy of using Coloured Filters to Improve Reading Ease and Efficiency*. Thesis for Doctorate in Optometry, School of Optometry, University of California, Berkeley.

DANIELS, J.C. and DIACK, H. (1977) *The Standard Reading Tests*. St. Albans: Hart-Davis Educational.

DEN BUURMAN, R., RODERSEMA, T. and GERRISSEN, J. (1981) Eye movements and the perceptual span in reading. *Reading Research Quarterly*, 16, 227–235.

EVANS, B.J.W. and DRASDO, N. (1991) Tinted lenses and related therapies for learning disabilities – a review. *Ophthalmic and Physiological Optics*, 11, 206–217.

FRY, E. (1977) Fry's readability graph: clarification, validity and extension to level 17. *Journal of Reading*, 20, 242–252.

GARZIA, R.P. (1993) Optometric factors in reading disability. In D.M. Willows, R.S. Kruk and E. Corcoss (eds) *Visual Processes in Reading and Reading Disabilities*. New Jersey: Erlbaum Associates, 419–434.

HABER, R.N. and HERSHENSON, M. (1973) *The Psychology of Visual Perception*. London: Holt, Reinhart and Winston Inc.

HOLLAND, K. (1987) A look at the reading process; investigating dynamic vision, parts 1–3. *Optician*, July 3, 10, 17.

HOLLAND, K. (1987) The treatment of dynamic visual problems. *Optician*, July 24.

HUEY, E.B. (1968) *The Psychology and Pedagogy of Reading*. Cambridge, Mass.: MIT Press. (first edition 1908)

IRLEN, H. (1983) *Successful Treatment of Learning Disabilities*. Unpublished Paper presented at First Annual Convention of American Psychological Association, Anaheim, Ca.

IRLEN, H. (1991) *Reading by the Colors*. New York: Avery Publishing Group Inc.

O'CONNOR, P.D., SOFO, F., KENDALL, L.S. and OLESEN, G. (1990) Reading disabilities and the effects of coloured filters. *Journal of Learning Disabilities*, 23, 597–603.

PAVLIDIS, G. (1981) Do eye movements hold the key to dyslexia? *Neuropsychologia*, 19, 57–64.

ROCK-FAUCHEUX, A., LECLUYSE, K. and WILLIAMS, M. (1993) The effects of wavelength on visual processing and reading: performance in normal and disabled readers. In S.F. Wright and R. Groner (eds) *Facets of Dyslexia and its Remediation*. Amsterdam: North-Holland.

ROSNER, J. (1982) *Paediatric Optometry*. London: Butterworths.

SCHIEMAN, M., BLASKEY, P., GALLAWAY, M., CINCER, E. and PARISI, M. (1990) Visual characteristics of adult Irlen filter candidates: case studies. *Journal of Behavioural Optometry*, 1, 174–178.

SOLAN, H.A. and RICHMAN, J. (1990) Irlen lenses: a critical appraisal. *Journal of the American Optometric Association*, 61, 789–796.

TOOTHAKER, L. (1991) *Multiple Comparisons for Researchers*. California: Sage Publications.

WILKINS, A.J. (1993) Reading and visual discomfort. In D. Willows, R. Kruk and E. Corcos (eds) *Visual Processes in Reading and Reading Disabilities*. New Jersey: Erlbaum Associates, 435–456.

WILKINS, A.J., NIMMO-SMITH, M.I., TAIT, A., MCMANUS, C., DELLA SALA, S., TILLEY, A., ARNOLD, K., BARRIE, M. and SCOTT, S. (1984) A neurological basis for visual discomfort. *Brain*, 107, 989–1017.

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

WINTER, S. (1987) Irlen Lenses: an appraisal. *Australian Educational and Developmental Psychologist*, 4, 1–5.

Address for Correspondence: RUTH TYRRELL, 11 Highlands Court, Chalfont St Peter, Buckinghamshire SL9 0DR, UK.