

Predicting the continued use of overlays in school children – a comparison of the Developmental Eye Movement test and the Rate of Reading test

Nadia Northway

Department of Vision Sciences, Glasgow Caledonian University, Cowcaddens, Glasgow G4 0BA, UK

Abstract

Coloured overlays have been advocated to enhance reading speed and ability in children with reading difficulty or dyslexia. Assessing the efficacy of overlays has to date been largely subjective. Objective assessment is presently carried out with the Rate of Reading test (RRT), where an increase in reading speed of more than 5% is considered to indicate a positive prognosis for continued use of the overlay. The Developmental Eye Movement (DEM) test is used to assess horizontal scanning behaviour in a number naming task. In this study both tests were utilised to determine whether coloured overlays could enhance reading performance or scanning. This article shows that for some children rate of reading is not improved with coloured overlays although performance on the DEM test does improve. Improvements to the DEM scores occurred in 88% of children who continued to use overlays for more than 3 months. This compared with 60% sensitivity in the RRT. The possible reasons for this phenomenon and the clinical implications are discussed.

Keywords: coloured overlays, Developmental Eye Movement test, dyslexia, Meares–Irlen syndrome, Rate of Reading test, reading

Introduction

Reading difficulty or dyslexia is characterised by a reading/spelling attainment below that expected, on the basis of the child's age, IQ and access to education. The exact role of visual anomalies in reading disabled or dyslexic children remains unclear. Pavlides (1981), Fischer and Weber (1993) and Biscaldi *et al.* (1998) have suggested that eye movement deficits might be central in contributing to reading difficulty. Stein *et al.* (1989) have highlighted binocular instability. Evans *et al.* (1996) have also reported weaknesses of binocular vision in dyslexic children and adults.

Several treatment modalities have been suggested to address visual anomalies associated with dyslexia such

as monocular occlusion (Stein *et al.*, 2000), saccadic training (Fischer and Hartnegg, 2000) and orthoptic treatment. Additional treatment has been described, which includes the use of coloured overlays or lenses. Helen Irlen (Irlen and Lass, 1989), a psychologist in the USA, first suggested the use of coloured overlays and tinted lenses in the treatment of reading difficulty but her work remains controversial. It was however the observation of Meares (1980), who noted that dyslexic readers frequently complain of visual distortions when reading. The presence of visual distortions that improve with the use of colour is known as Meares–Irlen syndrome (MIS), Scotopic Sensitivity syndrome or visual stress. There are many symptoms of MIS such as movement and flicker of the print, merging of background and text, and pattern effects within the print. Certain groups of patients may be more susceptible to MIS and links with dyslexia, migraine (Good *et al.*, 1991) and epilepsy (Wilkins *et al.*, 2002) have been noted. Wilkins *et al.* (1994) have shown in a double masked placebo trial that visual symptoms for reading are significantly fewer when a precision tint is used when

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Correspondence and reprint requests to: Nadia Northway.

E-mail address: n.northway@gcal.ac.uk

compared with a control tint of similar colour. There are however conflicting views expressed by Menacker *et al.* (1993) and Iovino *et al.* (1998) who have expressed doubt about the efficacy of coloured filters for reading and the need for individual colours. More recent attempts by Simmers *et al.* (2001a) to investigate visual function in these subjects have failed to reveal any obvious deficit in visual processing or evidence that colour specificity is necessary (Simmers *et al.*, 2001b).

The controversy surrounding this treatment is heightened by the lack of an objective means of assessing the effects of colour on reading. Wilkins *et al.* (1996) developed the Rate of Reading test (RRT) to address this problem. The RRT consists of short non-contextual passages of 150 simple words. The words are arranged in 10 lines with 15 words on each line and the words used are easily recognised by young children (*Figure 1*). The non-contextual nature of the test removes the complication of understanding the text and also prevents guessing as each word must be fixated and cannot be derived from meaning. An improvement in reading speed of more than 5% is considered to indicate that benefit is derived from the overlay and that continued use is likely (Wilkins *et al.*, 1996).

The Developmental Eye Movement test (DEM) (*Figure 2a,b*) is used to detect anomalies of horizontal scanning behaviour in a number-naming task, and normative scores have been provided for children between 6 and 13 years of age (Garzia *et al.*, 1990). It provides information about the child's ability to scan in both a horizontal and vertical task and takes into consideration his or her ability to read out loud (automaticity skills). The results can be compared with normative values for children for each task for the appropriate age group, and by analysing the relationship between the horizontal and vertical task one can determine if there is a tracking problem and/or automaticity difficulty. Tracking difficulties are evident when the child has difficulty keeping the place and finds

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

Figure 1. Example of the Rate of Reading test.

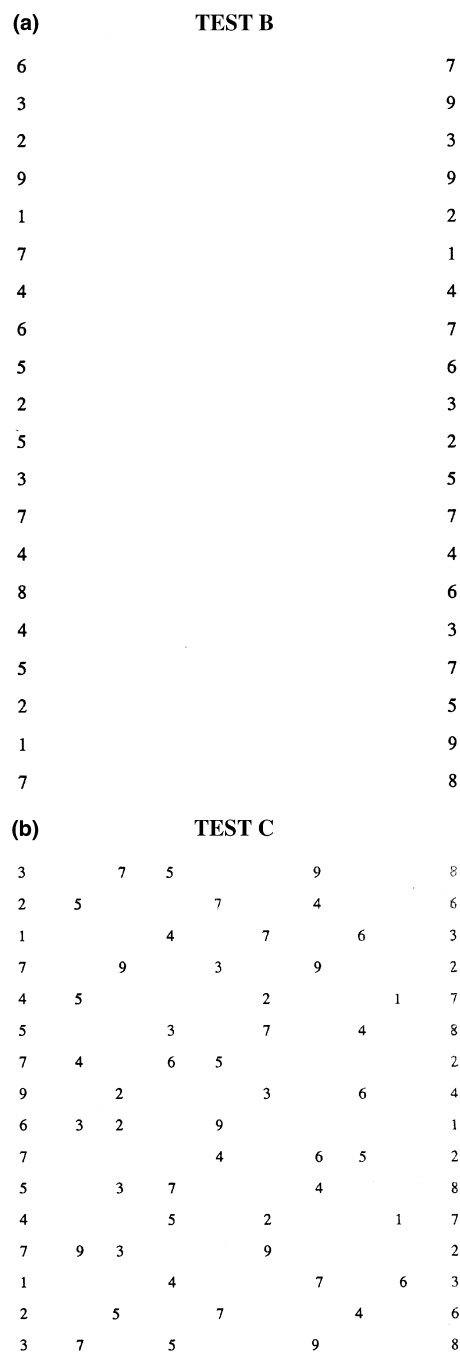


Figure 2. (a) Vertical task of Developmental Eye Movement test. (b) Horizontal task.

copying difficult. The DEM test can be used to assess children presenting to the clinician with a history of difficulty with reading in school in a quick and non-invasive way, and in particular allows an assessment of the child's performance in relation to age matched normal values.

The RRT and DEM test were carried out on children presenting to the reading difficulty clinic to investigate

possible visual factors contributing to their reading problems. A retrospective study was conducted to see if the RRT and the DEM test results at first visit were of benefit to the clinician and if these tests could be used to predict continued overlay use.

Method

Sixty-four children who had attended the eye clinic over a period of 6 months were given a full visual assessment in addition to assessment of reading speed using the RRT, scanning/tracking assessment using the DEM, and intuitive overlay assessment. Only children who had been formally diagnosed with dyslexia by an educational psychologist, had normal vision with or without correction, and had no orthoptic abnormality were included in the study. The presence of amblyopia, a history of poor convergence, low accommodation amplitude, or strabismus prevented inclusion in the study. Overlay assessment was carried out using the Institute of Optometry intuitive overlay test set. The children were asked to view the visual material provided in the test, which consists of non-words of 12 point font size. The children viewed the text and were asked about any perceptual abnormalities noted when viewing the text. The questions used to ascertain the presence of perceptual abnormalities are detailed in *Table 1*. The child was shown the visual material with half of the text covered by the overlay and asked if perceptual abnormalities were better or worse on the text with colour or on the uncovered white text. Overlays which were preferred to the uncovered text were then compared with each other and the child asked to chose the one they felt was better. A process of elimination was continued until one colour was selected. The colour of overlay chosen at this stage was then used to test reading speed using the RRT and performance on the DEM. If the child did not chose an

overlay then the RRT and the DEM were carried out using a randomly chosen overlay.

The DEM test was carried out as recommended (Garzia *et al.*, 1990) in order to determine scanning/tracking ability. The child was asked to read the vertical column of numbers in test A and B. The time taken to complete tests A and B was added together to determine the total vertical time. Time to complete the horizontal task was recorded and adjusted if errors had occurred. This was carried out both with and without coloured overlays. The ratio was calculated by dividing the adjusted horizontal time by the adjusted vertical time. The ratio was then compared with the mean value for the child's age to determine whether scanning problems, automaticity problems or both were present.

The results from the test can be interpreted in four categories.

- (1) Category I = normal horizontal time, vertical time and ratio values for age.
- (2) Category II = normal vertical time with increase in horizontal time and high ratio indicative of horizontal scanning problems.
- (3) Category III = increase in horizontal and vertical time but normal ratio indicative of automaticity problems.
- (4) Category IV = increase in horizontal and vertical time with high ratio: combination of II and III indicative of scanning problems and automaticity difficulty.

The RRT was carried out by asking the child to read the passage as quickly as possible. The examiner recorded any errors made and instructed the child to stop reading after 1 min. Deductions were made for errors. The RRT was carried out four times. The order of testing is organised to balance the effects of practice and fatigue by carrying out the test with overlays, without overlays, again without and finally with overlays

Table 1. Questions as asked about symptoms. Choice always given to child in order to reduce examiner affecting answers given. Numbers represent the total number of children giving abnormal response when perceiving text. (Abnormal responses are underlined)

Question about symptoms	Number of children with symptom
1. Do you get headaches? If yes do you get them in the morning, afternoon, or evening?	12
2. When reading does the print appear clear or <u>fuzzy</u> ?	29
3. When reading does the print appear to be single or <u>double</u> ?	3
4. Do the words appear to <u>move</u> or do they sit still?	24
5. Do the words sit in straight lines or do the <u>lines seem jumbled or in patterns</u> ?	17
6. Is the page just black and white or are there <u>colours in the writing</u> ?	4
7. Do the words sit flat on the page or do <u>they appear to jump off the page</u> ?	21
8. Do the words appear <u>to flicker or wobble</u> when reading?	22
9. Does the page appear <u>to be too light or too dark</u> or is it alright?	11
10. Do your eyes feel sore or tired and if so when does this happen?	9

(Wilkins *et al.*, 1996). A similar strategy was used when carrying out the DEM.

Results

Effect of overlays on RRT and DEM performance

The performance of all 64 subjects on both the RRT and the DEM test when using overlays were analysed. The 14 subjects who did not subjectively pick an overlay were given a random overlay to use. The remaining 50 subjects were assessed using the overlay they had subjectively chosen. Any change in performance when using the overlay was calculated using the following equation:

$$(\text{Without overlays} - \text{with overlays}) / \text{without overlays} \times 100.$$

The clinical standard adopted for the RRT was also used for the DEM, i.e. an improvement in performance of more than 5% was considered to indicate objective evidence of a change in performance to substantiate the subjective claims of improvement by the patient. These results are shown graphically in *Figure 3*. Different symbols are used to depict whether the child did or did not choose an overlay. It became apparent that there were four possible outcomes from *Figure 3*. There were those who showed an improvement in the DEM horizontal task, and showed an improvement on the RRT. There were children who showed an improvement in the horizontal DEM only and there were children who showed no appreciable difference in the DEM or

RRT when using coloured overlays. There were four children who showed an improved performance in the RRT only with overlays.

Fifty of the children had chosen an overlay at first visit and fourteen had not chosen an overlay. Of the 50 children who had chosen an overlay 40 continued to use the overlay after 12 weeks. Ten of the children had stopped using the overlays. Analysis was carried out to determine if the RRT and DEM results were altered by overlays in the children. The children were grouped according to overlay outcome at the second visit. Group 1 consisted of children ($n = 14$) who had not chosen overlays at the first visit. Group 2 consisted of children ($n = 10$) who had chosen an overlay at the first visit but had not continued to use it. Group 3 consisted of children ($n = 40$) who continued to use overlays repeatedly and subjectively reported continued benefit for 12 weeks. The mean performances of the RRT and the DEM at first visit are shown for the three groups in *Table 2*.

Subjects who did not chose an overlay and subjects who stopped using overlays

The children comprising group 1 and 2, performed slightly better on all tests when compared with the children in group 3 but this was not statistically significant (ANOVA, $p = 0.06$). There was a significant reduction in performance on the RRT when using overlays for the children in group 1 and 2 (Paired *t*-test, $p < 0.01$). There was a small but insignificant difference in horizontal DEM time for these groups when using overlays (Paired *t*-test, $p > 0.05$).

Performance of subjects continuing to use overlays

The children in this group had lower rates of reading and poorer times to complete the DEM test however this was not statistically significant when compared with the other groups (ANOVA, $p = 0.06$). There was a significant improvement in RRT score and DEM score when using overlays for the children in this group (Paired *t*-test, $p < 0.01$).

The mean age of the three groups was not statistically different (ANOVA $p = 0.24$)

Prognostic value of the RRT and DEM test

The children who did not chose overlays at the first visit and the children who discontinued use of the overlay showed little change in performance on either test when using overlays.

Of the 40 children who had persistently used overlays for more than 12 weeks, the RRT was significantly improved in 24 of the 40 children. The DEM time was significantly improved in 35 of the 40 children with only

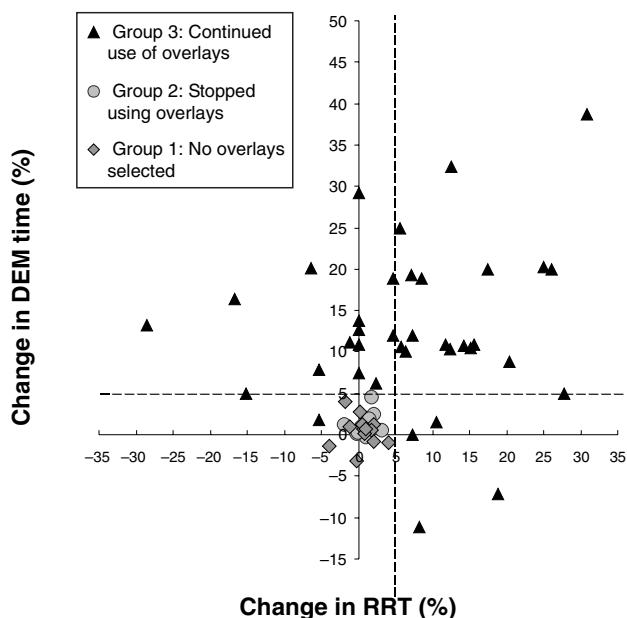


Figure 3. Change in performance on Developmental Eye Movement test and Rate of Reading test, dotted lines represent 5% difference in performance. Each symbol represents one patient.

Table 2. Mean (\pm S.D.) test results at first visit for all children in the study. Children are grouped according to overlay outcomes

Group name	Overlay outcomes	Mean age of group in years	Mean RRT \pm S.D. in words per minute	Mean horizontal DEM time in seconds \pm S.D.	Mean change in RRT (%) using overlay	Mean change in DEM (%) horizontal
1 ($n = 14$)	No overlay chosen	8.9 \pm 3	77 \pm 15	59 \pm 17	-2.4 \pm 4	0.4 \pm 3.7
2 ($n = 10$)	Overlay chosen and not continued after 12 weeks	9.2 \pm 2	76 \pm 21	62 \pm 19	-4.4 \pm 9	1.15 \pm 0.8
3 ($n = 40$)	Overlay continued to be used	9.4 \pm 2.5	63 \pm 27	76 \pm 25	10.1 \pm 13	13.3 \pm 8

RRT, Rate of Reading test; DEM, Developmental Eye Movement test.

Table 3. Mean (\pm S.E.M.) rate of reading for children. Group 3A had significantly higher rates of reading than group 3B (unpaired t -test, $p < 0.01$)

Group	Mean \pm S.E.M. RRT words per minute without overlay	Mean \pm S.E.M. RRT words per minute with overlay	Statistical change in RRT with overlays (paired t -test)
3A	68 \pm 21	79 \pm 20	$p < 0.0001$
3B	55 \pm 17	57 \pm 18	$p = 0.62$

RRT, Rate of Reading test; DEM, Developmental Eye Movement test.

five children failing to show more than 5% improvement. Of these five children, two showed an actual decrease in performance and the other two showed mild improvements. One child did not show a significant improvement in either test. Four children showed an improvement in the RRT only.

From the above results it is apparent that the DEM test had shown an improved performance in 88% of the children who continued to subjectively prefer overlays. This compared with only 60% of children continuing to use overlays showing an improved performance on the RRT.

Further analysis was carried out to determine if the children who showed an improvement in both tests varied in quality of performance from those who showed only an improvement in the DEM and if the number of symptoms reported by subjects was different in each group.

The children were divided into two groups based on whether they showed an improvement in both tests or an improvement in the DEM only. The subject who had shown no improvement on either test but had continued using overlays was excluded from analysis as were the four children who had shown an improvement in the RRT only because of the small number size.

Group 3A ($n = 20$) consisted of children who showed an improvement in the RRT and the DEM.

Group 3B consisted of children ($n = 15$) who showed a significant increase in performance in the DEM only.

Rate of Reading test

Rate of reading was significantly faster for group 3A when using overlays (Paired t -test, $p < 0.01$). There was

no significant increase in rate of reading using overlays for group 3B (Paired t -test, $p = 0.23$).

The mean rate of reading is significantly better for group 3A than group 3B (Unpaired t -test, $p = 0.04$) when using overlays. These results are shown in *Table 3*.

Developmental Eye Movement test

Table 4 shows the average time for the two groups to complete the horizontal task with and without overlay.

Time to complete the horizontal test was significantly faster for both groups with overlays than without. Group 3A were statistically faster at performing the DEM task than group 3B (unpaired t -test, $p < 0.05$).

Perceptual distortions/visual symptoms

Analysis was carried out to determine if there were differences in the number of visual symptoms reported by the children in group 3A and 3B. In addition the number of perceptual distortions was calculated for the children in groups 1 and 2 who had failed to show continued benefit from the overlays. They are represented in group C ($n = 24$). There was no significant difference in the average number of symptoms reported by group 3A (4.1) or group 3B (3.2) ($p = 0.09$, t -test). Children who had not chosen overlays or who had subsequently stopped using overlays had significantly fewer perceptual distortions/symptoms when compared with the children who had continued to use overlays (ANOVA, $p < 0.05$) These results are shown graphically in *Figure 4*.

Table 4. Showing average time to complete horizontal DEM task for children continuing to use overlays. A significant improvement in time is seen for both groups when overlays are used. There is a significantly poorer performance by the children in group 3B when compared with group 3A, taking significantly longer to complete the Developmental Eye Movement task (unpaired *t*-test, $p < 0.05$)

Group	Mean ± S.D. horizontal DEM time without overlay	Mean ± S.D. horizontal DEM time with overlay	Percentage change in DEM time	Statistical change (paired <i>t</i> -test)
3A	72 ± 24	64 ± 18	11% Improvement	Horizontal task ($p < 0.001$)
3B	88 ± 21	74 ± 23	15% Improvement	Horizontal task ($p < 0.001$)

RRT, Rate of Reading test; DEM, Developmental Eye Movement.

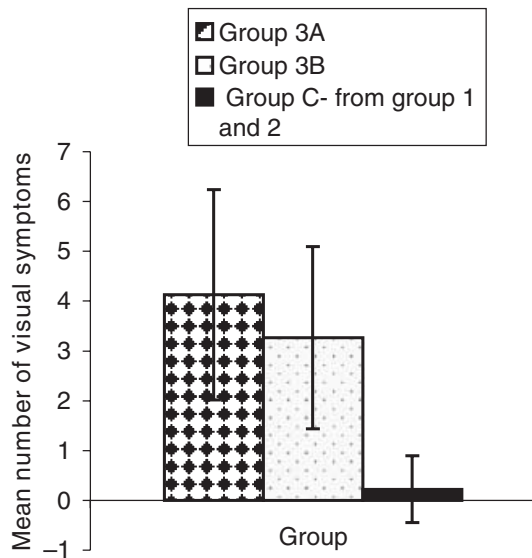


Figure 4. Average number of visual perceptual distortions/ symptoms ± S.D. experienced before use of overlays by children. Group 3A represents children who showed an improvement in both tests. Group 3B represents children who showed an improvement in the Developmental Eye Movement test only. Group C represents the children who did not find overlays of benefit.

Comparability of RRT and DEM

Correlation analysis was carried out between the results from the DEM and the RRT for all subjects. Subjects found to have a lower RRT took longer on the horizontal task on DEM. A similar trend was found with overlays (Pearson correlation coefficient $R^2 = 0.59$, $p < 0.001$) and without (Pearson correlation coefficient $R^2 = 0.58$, $p < 0.001$). These can be seen in *Figure 5(a,b)* for all subjects.

Discussion

Children who are visually symptomatic did in general find a coloured overlay of benefit. For those who had no visual symptoms on questioning, overlays were not chosen or were subsequently discarded during the 12 week screening period. This is a useful finding and providing the practitioner asks about perceptual distortions and visual symptoms in a reliable way, this information may be used when deciding whether to prescribe an overlay or not.

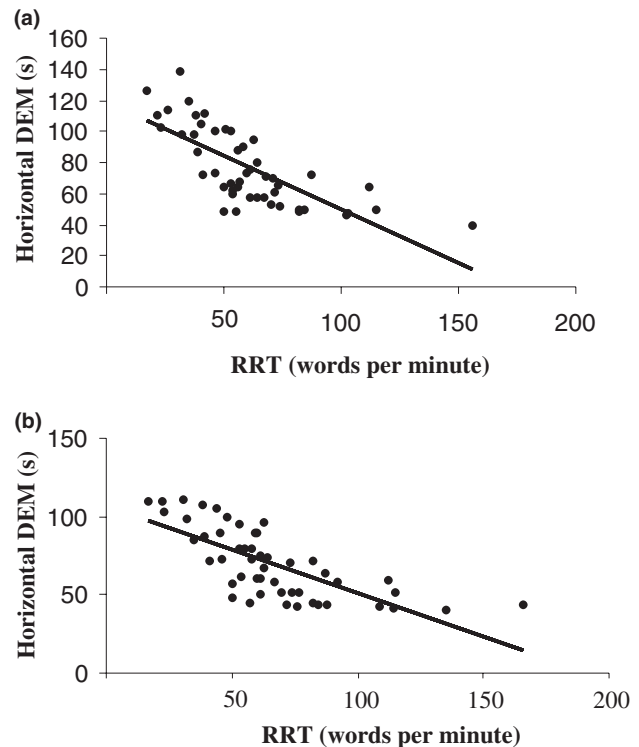


Figure 5. (a) The correlation of performance on the Rate of Reading test (RRT) and Developmental Eye Movement (DEM) test for subjects without overlays. (b) The correlation of performance on the RRT and DEM for subjects with overlays.

The DEM is designed to assess horizontal and vertical scanning or tracking behaviour using numbers. The results have shown that performance on the DEM is enhanced when using overlays in the majority of the children who continued to use overlays. The RRT identified considerably fewer children who would continue to use overlays. Despite the fact the children did not show any increase in reading speed, they continued to prefer to use the overlay than to be without it. This presents the clinician with a dilemma, in that the current clinical recommendations (an increase of RRT by more than 5%) would fail to provide objective support for the

subjective preference displayed by many of the children using overlays.

The question arises as to why some of the children do not show an increase in reading speed but can perform more quickly on the DEM. The reasons for these differences may be because of the different visual presentations used in the tests and/or the differences in cognitive effort required for each test. Many of the children who failed to show an improvement in RRT had considerable automaticity difficulties (as revealed by the DEM when compared with children of a similar age). It may be the case that the visual perceptual problems experienced by these children are only a small contributory factor compared with the greater problems with cognitive processing. The small visual benefits from the overlay may not be able to manifest themselves in the presence of greater difficulty in reading out loud. Robinson and Conway (1990) also found that rate of reading was not enhanced in their study but that comprehension and accuracy were improved when using overlays. The RRT does not measure comprehension but it is possible that an improvement in comprehension may lie beneath the children's persistent use of the overlay rather than an improvement in speed. Alternatively, the fact that the DEM uses single numbers instead of words may result in this test being cognitively less demanding and small improvements in visual perception are more readily seen.

Another causal factor for the differences may be the presentation of the numbers on the DEM. The numbers are irregularly spaced and this may result in a reduction in lateral masking. Geiger and Lettvin (1987) have shown that dyslexic readers mask letters and words in the foveal area and demonstrate reduced lateral masking effect in the visual periphery when compared with non-dyslexics. It is possible that the children who fail to show an improvement in RRT may be more susceptible to the effects of lateral masking and the effects of the coloured overlay are minimised in the visually crowded RRT. Given that there is wide spacing between the numbers in the DEM, there is thus less lateral masking than in the RRT, possibly resulting in easier identification of the numbers for many of the subjects in this study.

Spacing of text can be critical and has been shown to influence reading speed and eye movement control. Vitu *et al.* (1990) has shown that there is an optimal landing (location of fixation on new word) position when reading which helps with processing and execution of saccadic eye movements in reading. More recent reports by Rayner *et al.* (1998) have shown that unspaced text can interfere with reading speed and eye movement control. The RRT was devised to be visually crowded, simulating the striped effect which is known to cause pattern glare in order to maximise visual discomfort. Perceptual distortions experienced by people when

viewing black and white contrast patterns around three cycles per degree are known as pattern glare (Wilkins *et al.*, 1984). To achieve this effect visual discomfort is maximised by 'reducing the spacing between words' (Wilkins *et al.*, 1996) and as such this may affect performance in some children. There were in fact many of the children who did not show an increase in reading speed who demonstrated scanning difficulties. The crowded textual appearance in the RRT may be a significant and more difficult obstacle in the presence of poor eye movement control in those children found to have poor scanning technique in the DEM, and the benefits of overlays are less obvious. It is possible that the spacing of the numbers in the DEM allows a more accurate landing position to be found or is easier because of less lateral masking. How coloured overlays may be influencing this behaviour is beyond the scope of this study and clearly requires further investigation.

In addition, given that there was little difference in the type and number of visual symptoms experienced by the children who showed an increase in reading speed and those who did not, it seems likely that it is the nature and presentation of the task which accounts for the greater degree of sensitivity found in the DEM. At the current time the prescription of overlays is used to screen for MIS. Improving identification of children with possible MIS is important if we want to intervene at an early age. Having a better objective assessment of overlay effects can only aid detection and treatment of the visual perceptual distortions that hinder reading progress in these children. It is possible that the closely spaced wording in the RRT which is designed to maximise visual discomfort, interferes with word identification to a greater extent in those with greater automaticity difficulties and thus hides some of the benefit the child may be deriving from the overlay. Thus the DEM may be cognitively and visually easier for some of these children and as such the DEM may be a more useful test to the clinician when evaluating the possible long-term benefits on reading from the use of overlays.

Despite the difference in the visual presentations of the two tasks involved, the DEM test and the RRT correlate well. Those with lower rates of reading are found to take longer to complete the horizontal task in the DEM, but it would appear that reading speed may not be an efficient way to monitor changes in visual perception for some of the children in this study.

This study has found that in comparison with the DEM, the RRT demonstrates poorer sensitivity when determining if children will continue to use overlays. It would appear that the DEM is a useful addition to the clinical assessment of children choosing overlays, detecting 88% of the children who would subsequently continue to use overlays. This is in comparison to only

60% of the children who have been identified by the RRT. This may be because the DEM is cognitively less demanding than the RRT or it might be the case that the RRT is visually too complex for some children.

In conclusion, careful questioning is required during clinical examination in order to determine the presence and degree of visual perceptual difficulties. The absence of visual perceptual distortions may indicate that an overlay is unlikely to be of benefit however one must be careful to test with overlays. Some children answer unreliably during questioning (because of lack of understanding of the questions or because of the fact that they do not realise the distortions are abnormal), and therefore full assessment is still indicated.

In addition the use of both the RRT and the DEM can allow the clinician to determine whether coloured overlays benefit reading even in those with poorer automaticity skills. This may be important given that the optometrist/orthoptist testing the child may not have psychological reports to determine the child's cognitive status. This will allow the clinician a better insight into the mechanics of the reading behaviour and the effects of colour on reading, enabling him to make informed decisions about the use of coloured overlays for reading and to whom to prescribe them.

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