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Rate of Reading Test® : its reliability, and its validity in the assessment of the effects of coloured overlays

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Summary

A simple reading test that can be undertaken by disabled readers is described. The test is suitable for use in the optometric clinic, taking less than 2 minutes to administer per passage. Test–retest scores are acceptably reliable. The test reveals increases in the speed of reading when coloured overlays are used both (1) in children who have made long-term use of coloured overlays for reading, and (2) in children who will subsequently do so. Copyright © 1996 The College of Optometrists. Published by Elsevier Science Ltd.

Introduction

Passages of text are widely used by optometrists for routine tasks such as assessing the effects of an additional refractive power for reading. Most passages are suitable only for fluent adult readers, although the McClure reading passages (Clement Clarke International) provide visual material suitable for the qualitative assessment of reading in young children. Quantitative assessment is possible using the Bailey–Lovie chart which comprises a set of random words of decreasing size (Bailey and Lovey, 1980), but these are not suitable for children. Reading speed can be assessed by the MNREAD test (Ahn and Legge, 1995; Legge *et al.*, 1989), which is available on printed cards (Ahn *et al.*, 1995). The test provides a standard set of simple sentences with equal numbers of lines and characters, and with equal contextual difficulty. It can be used to determine the smallest print size that yields maximum reading speed, and is of particular use in patients with low vision. Both the MNREAD and the Bailey–Lovie tests have been validated in optometric settings, but neither is suitable for use with children who have a very limited reading vocabulary.

Recently there has been much media attention given to the effects of coloured overlays and coloured lenses in children with reading difficulty. Some studies have found effects on reading (Hannell *et al.*, 1991; Robinson, 1990, 1994; Robinson and Conway, 1994; Whiting *et al.*, 1994) whereas others have failed to do so (Blaskey *et al.*, 1990; Cotton and Evans, 1990a,b; Martin *et al.*, 1993; Menacker *et al.*, 1993; Solan, 1990). The field is controversial (Evans and Drasdo, 1991; Hoyt, 1990; Parker, 1990; Scheiman *et al.*, 1991; Silver, 1995; Ward, 1991; Solan and Richman, 1990) although a recent double-blind cross-over study shows clinical benefits that cannot be attributed to placebo effects (Wilkins *et al.*, 1994). There is a need for a quantitative assessment of reading that reveals reliably any beneficial effects of colour that there may be. To date, the measures that have been most commonly used in such assessments have been conventional reading tests, such as the Neale Analysis (Neale, 1989).

Conventional reading tests are designed for educational use and are not suitable for assessing the effects of any optometric intervention (whether refractive or chromatic). This is because: (1) the tests assess the linguistic and semantic aspects of reading at least as much as the visual; (2) the test items typically increase in complexity until the reader fails, and the visual complexity of the material usually covaries with linguistic complexity; (3) performance is usually limited by a reader's vocabulary, and adults therefore score at or near the test ceiling; (4) children with poor reading ability are aware of their failures and are often embarrassed by them. It seems there is a place for a simple test that minimises the linguistic and semantic aspects of reading and maximises the visual difficulties.

Many visual difficulties with reading seem to emerge when

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the test is presented in a long paragraph with closely spaced lines and letters. The theory of visual stress proposed by Wilkins (1995) provides one possible explanation as to why. The theory is based on the fact that certain patterns of stripes can induce seizures in patients with photosensitive epilepsy (Wilkins *et al.*, 1980), photophobia in patients with migraine (Wilkins *et al.*, 1984), and perceptual distortions in children with reading difficulty, many of whom have migraine in the family (Wilkins *et al.*, 1991; McLaughlan *et al.*, 1993). The arrangement of words on the page can sometimes resemble stripes, and when it does, the text can be stressful to read, inducing eye-strain and headache (Wilkins and Nimmo-Smith 1985). The theory predicts the spatial parameters of text that render reading visually stressful.

The present paper describes a simple reading test (the Rate of Reading Test®) that maximises visual stress of this kind, while minimising the linguistic and semantic aspects of reading. The test takes less than two minutes to administer and yet is sufficiently sensitive to reveal reliably the improvement in reading fluency that results from the use of coloured overlays. The test is suitable for use in the clinic with a wide variety of patients, both those who are skilled readers and those who are dyslexic. Alternative versions of the test are simple to provide.

Design

In the Rate of Reading Test® subjects are simply required to read aloud a passage of randomly ordered words as rapidly as possible. Their reading is timed and errors are noted.

The passage is designed to be visually stressful, according to Wilkins' (1995) theory. The text is made to resemble stripes by reducing the horizontal spacing between words. Because the text is printed in a small typeface the 'stripes' thus created have spatial parameters close to those optimal for perceptual distortion. In other respects the appearance of the text is conventional. The test is printed in 'Times' fount, 9 point, set 'single spaced', with a '4 point' (0.36 mm) horizontal spacing between words using Microsoft Word 5.0® on an Apple Machintosh® computer with a 300 dpi Laser printer. The text is set as a paragraph 72.5 mm wide, 33.4 mm high, with an interline space of 3.15 mm. The letters have an x-height of 1.6 mm and a width that averages 1.53 mm. Although Times is an 'adult' serif fount, none of the several hundred children we have tested so far has had the slightest difficulty identifying the letters and reading isolated words.

To reduce the variability in reading speed due to linguistic factors (*cf* the MNREAD test), the syntactic and semantic properties of the text are minimised by the use of randomly ordered words. The same 15 common words are used in each line, in a different random order. All the words used in the test are selected from the 110 most frequent words in a count of words in children's reading books (undertaken by ML and PDP). The passage can therefore be tackled both by adults and by children who have only a modest reading vocabulary. This is an important requirement in the assessment of children who use overlays because many find reading difficult.

The test is designed to compare an individual's performance under one set of visual conditions with that under another. Multiple equivalent versions of the test are available by rearranging the word order. The reading of equivalent passages can therefore be assessed under different visual conditions, and the effects of practice balanced over time. *Figure 1* shows two sample passages from the test. Note that, although one word in the passage may cue another neighbouring word with which it is commonly associated (e.g. cat–dog), this association is random and will be similar overall from one version of the test to another. Note that the test is unlike other tests of reading in that it is not designed to compare one individual subject with others of the same age or ability.

The theoretical basis of this test derives from extensive recent research into the nature of reading development. Accurate and rapid decoding of text to sound is important in early reading, and it is essential for the development of the automaticity of text information processing that characterises the competent reader (Adams, 1990; Pumfrey *et al.*, 1992). From a more practical perspective, reading aloud is a familiar task for school children, and it has the further advantage that the omission of a word or a line is immediately obvious to the examiner.

Administration

All the 15 words used in the passage are printed in large type at the front of the test. The test should only be given

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

Figure 1. Two passages from the Rate of Reading Test®.

to subjects who can correctly read these words (and this will include all but the most disabled readers). The test is scored by noting the errors on a score sheet comprising an enlarged version of the text, and by measuring the total time taken to read the passage. The reading speed is assessed by noting the total number of words in the passage correctly read and calculating the average number correctly read per minute. Errors typically consist of omissions, substitutions and reversals. It is useful to tape record the subject in case it is necessary to check the errors subsequently. The reading speed is usually the best single measure of performance because most errors tend to decrease the speed either by reducing the number of words correctly read or by increasing the time taken to read the passage.

Reliability and validity

The reliability and validity of the test were assessed in the following studies. In the first study the test was administered to primary school children aged 8–11 at the beginning and again at the end of the summer term. The test proved to be acceptably reliable. It also showed predictive validity: performance on the test with and without an overlay at the beginning of the term predicted the children who continued to use the overlay throughout the term.

Study

Subjects

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

Procedure

All the children were tested individually using the Intuitive Overlays® (Wilkins, 1994) following the recommended procedure. In brief, the ten overlays can be superimposed, one on top of another of similar colour, to give nineteen admissible combinations of the 10 overlays, providing a total of 29 colours. A clear overlay was added as a control, making a total of thirty possible overlays or combinations thereof. A page bearing random letters (12 pt Apple Macintosh® Times set solid, x-height 2.1 mm, interline spacing 4.2 mm) arranged to resemble words in a paragraph of text (132 mm wide by 70 mm high) was partially covered by each overlay combination in turn. The child was asked to say which of the two sides (covered or uncovered) made the text 'look most clear and comfortable to see'. Any overlays that the child reported to improve clarity were then compared side by side until the best overlay or combination of overlays was obtained by a process of elimination. The children were not forced to choose a coloured or a clear overlay; some children consistently preferred the uncovered page. As far as possible, the examiner tried to avoid implying that an improvement in the clarity of text might result from a coloured overlay.

The Rate of Reading Test® was then administered, following the procedure described above. All the children tested were able to read the isolated words successfully, and were therefore able to pass on to the second part of the test, namely the reading passages. Two test passages were administered in random order. The passages were identical except with respect to word order. One of the passages, chosen at random, was used with the chosen overlay (or combination of overlays) and the other passage without, in random order. Children who preferred the uncovered page were tested with and without a clear (transparent) overlay. The children were asked to read each passage out loud quickly and clearly, trying to make as few mistakes as possible. The reading was tape-recorded and timed, and any mistakes were noted. Scoring was based on the number of words correctly read and the time taken to read them. A word was scored as correct if it was read in the correct sequence relative to at least one of its neighbours.

The testing took place in a school, at the beginning of the summer term, 1995. The room was lit by a mixture of daylight and fluorescent lighting, and the illuminance of the work surface therefore varied about a mean of approximately 500 lux. The reflectance of the overlays has been described elsewhere (Wilkins, 1995).

Three weeks after the testing, the children who had reported improved clarity with a particular colour were issued (free of charge) with that colour (as provided by an overlay or pair of superimposed overlays). The children were encouraged to try out the overlay (or pair of overlays), but to persist only if they found it helpful to do so. They were not led to expect any long-term benefit.

At the end of the summer term, the children who had been issued with an overlay were again assessed using the Rate of Reading test®, both with and without their preferred overlay combination.

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

Results

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

The 38 children who were issued with an overlay were tested with and without the overlay combination at the beginning and again at the end of the summer term, about 8 weeks later. The Pearson product moment correlation between the reading speed *without* the overlay combination on the first test and *without* the overlay on the second test about 8 weeks later was 0.83. *Figure 2* shows a scatterplot of the data. The 39 children who preferred the uncovered page were tested with and without a clear overlay in immediate succession in random order. The correlation between the reading speed with and without the clear overlay was 0.92.

Unsurprisingly, there was a significant effect of practice. Overall, the second test was performed 2.9% faster than the first ($P = 0.005$, paired t-test). The second presentation was faster not only within a test session, but also when similar conditions were compared about 8 weeks apart. In *Figure 2*, the effects of practice can be assessed by the extent to which the points lie above the diagonal. As can be seen the effects of practice were small in comparison to the large differences between individuals.

At the end of the summer term 15 of the 38 children who were given an overlay combination (40%) were still using their chosen overlay(s) frequently for most activities involving reading.

Table 1 shows the speed of reading (words per minute) with and without the overlay, separately for the children who were given the overlay and those who were not. The former group is divided into the children who subsequently continued to use their overlay frequently and those who did not. The children who used their overlay for most reading tasks showed a highly significant increase in reading speed (averaging 7.2%) with their overlay ($P = 0.0012$, paired t-test). The children who subsequently used their overlay infrequently or not at all showed no significant increase in reading speed at the first assessment ($P = 0.30$, $P = 0.16$, respectively). *Figure 3* shows the scores at the *first* testing session with and without the overlay(s). The scores for children who subsequently used their overlay(s) (filled points) are shown separately from those who subsequently made little or no use of the overlay(s) (open points). Scores above the diagonal show the children who read more quickly with their overlay(s). As can be seen, all but three of the 15 children who subsequently used their overlays

Table 1. Reading speed (words per minute) for children who chose a coloured overlay and those who did not. The former group are subdivided into those who subsequently used their overlay frequently, those who used it infrequently, and those who did not use it at all. The latter group were tested with and without a clear overlay. The statistical significance of this comparison with and without overlays is shown.

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

ns, Not significant; **, $P < 0.01$; $P < 0.001$.

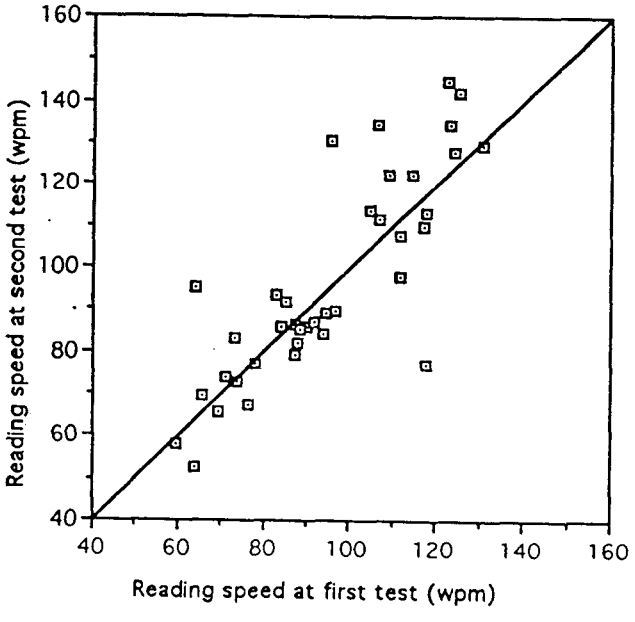

Figure 2. Reading speed in words per minute with and without an overlay, at first and second testing session, about 8 weeks apart.

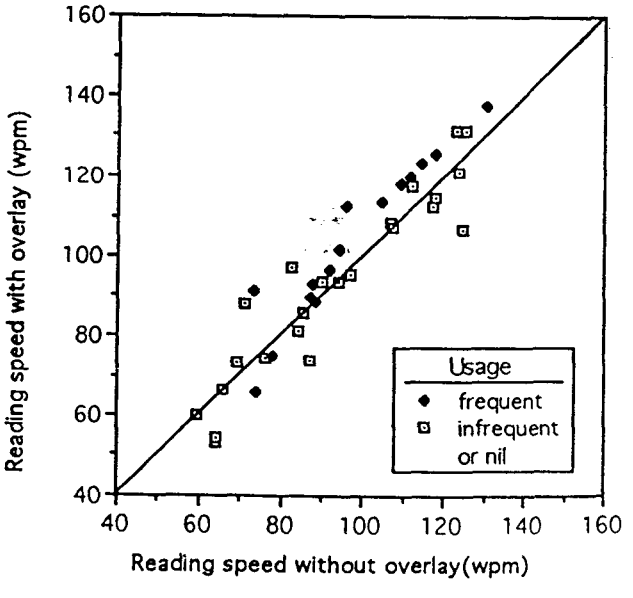

Figure 3. Reading speed in words per minute at the first testing session, with and without overlays. The children who subsequently used their overlay frequently are shown separately from those who did not.

frequently read more quickly using them at the initial testing session. This was the case in only eight of the 23 children who made little or no use of the overlays. At the first test an improvement in reading speed (with overlay relative to without) of more than 5% was associated with continued use of the overlay in 11 of the 15 cases (73%) of children showing an improvement with the overlay. This was true in only six of the 23 cases (26%) of children who did not show such an improvement. On the other hand, some variability in these figures is to be expected: 17 of the 39 children (44%) who did not choose a coloured overlays, and who were tested with a clear overlay, showed an improvement of more than 5%. Of these 17, nine were tested with the overlay second, suggesting that practice was not responsible for the improvement.

At the second assessment the advantage from the overlay was even more pronounced in the children who were now using it frequently ($P = 0.0008$). There was no significant speed advantage in the case of children who had been given an overlay but who did not now use it frequently ($P < 0.07$).

As can be seen from *Figures 2* and *3*, there was a large range in reading performance across the subjects. The minimum score and maximum scores differed by a factor of more than three. Despite this range, there was no significant correlation between the reading speed without the overlay and the age of the child (Pearson product moment correlation = 0.20).

Errors

Errors were classified into categories of omissions (whole lines, single words etc.) and categories of commissions (intra- and extra-vocabulary intrusions, reversals of order). A detailed analysis will be published elsewhere (Jeanes *et al.*, submitted). Suffice it to say here that (1) in general errors of omission and commission tended to co-occur; and (2), more importantly, there was a *negative* correlation between speed and errors for all groups. In other words, there was no evidence of a speed/accuracy trade-off; the use of overlays did not result in an improved reading speed because of a less accurate reading strategy.

Discussion

Usefulness

The Rate of Reading® test is both reliable and valid. It is useful in assessing the benefit from coloured overlays, particularly in predicting the individuals who, when offered a coloured overlay, will continue to use it. (Continued usage is one operational measure of benefit, and is less likely than some others to be due to placebo effects.)

Speed and sensitivity

Using conventional reading material the effects of coloured overlays on reading speed have hitherto been measurable in most children only after 10 minutes of continuous reading, when the children have begun to tire (Tyrrell *et al.*, 1995). In contrast, the Rate of Reading Test® takes no more than about two minutes per passage with a slow reader but is nevertheless sensitive enough to reveal the effects of coloured overlays and interestingly to do so, as here, in an unselected group of children.

Optometric factors

The question arises as to what extent the improvements in reading speed are the result of the effects of colour on untreated refractive errors or anomalies of binocular vision. Although some of the poor performance in the above study may have been attributable to conventional visual defects, these are unlikely to provide a sufficient explanation for all the benefits of colour. The double-masked study mentioned above (Wilkins *et al.*, 1994; Evans *et al.*, 1996) demonstrated that coloured filters could relieve symptoms that were not attributable to conventional errors of refraction or binocular vision anomalies.

A study by Bouldoukian (1995) has demonstrated that coloured overlays improve reading speed in individuals who have normal vision. The Rate of Reading Test® was administered with the chosen overlay and also with an ultra-violet blocking filter (called a 'New anti-UV/IR' overlay) used as a control for placebo effects. The subjects had all been correctly refracted and were screened for any disorders of binocular vision. When asked whether they preferred their coloured overlay or the 'anti-UV/IR' overlay, the subjects were not significantly more likely to choose one over the other (66% preferred their coloured overlay; sign test $P = 0.11$). This may suggest that the cover story concerning the 'New' filter had the desired result of creating a placebo effect which may have been greater than that associated with the coloured overlay. Despite the absence of a preference for the coloured overlay, however, the speed of reading of the group was significantly quicker with their coloured overlay than with the control ($P < 0.002$). Evidently preference can be dissociated from reading performance.

The range of scores amongst children aged 8–11 is large, and only weakly related to age (and thus to other reading skills that might be expected to improve over this age range). The findings therefore suggest the possibility of a large contribution of visual/visuo-perceptual factors to test performance. If visual/visuo-perceptual factors play a dominant role, the improvement in performance with overlays among individuals who have been optometrically screened is of particular interest. It suggests that colour has its effects independently of conventional optometric factors, and of anomalies of binocular vision, as suggested by Evans *et al.* (1996).

Visual stress?

In the study by Tyrrell *et al.* (1995) which used the Irlen overlays, the speed of reading conventional text was not initially affected by the use of an overlay. It was only after 10 minutes' continuous reading when the patient had begun to tire that the overlay had a modest but beneficial effect on speed. In the present study, the overlays had a larger effect on reading speed, and did so immediately. There are several possible reasons: (1) the Intuitive Overlays® used in the present study may have been more effective than those of Irlen; (2) the study by Tyrrell *et al.* used conventional children's reading books, so the comprehension of the story-line may have increased the variability of the measurement of speed; (3) the text used in the present study was smaller and more closely spaced than in the study by Tyrrell *et al.* which used conventional children's reading books (mean interline spacing 4.46 mm, S.D. 0.60, mean x-height 1.85 mm, S.D. 0.16): the text of the Rate of Reading Test® was designed to be more stressful and may therefore have exaggerated the effects of the overlay. Of these three possibilities, the latter two seem to be the most worthy of future attention, partly because they justify the design of the Rate of Reading Test®. The design was conceived on the basis of a theory of visual stress, and further work will be necessary to justify this theory. Regardless of the theoretical justification for the design of the test or, indeed, the theoretical rationale for the present findings, the test is clearly of practical use, and we offer it on this basis.

Prevalence

The above findings are surprising with respect to the high proportion of children in a county primary school selecting coloured overlays, and in the high proportion continuing to use them without prompting. These findings are, however, quite consistent with other work. Jeanes *et al.* (submitted) individually examined all the 93 children in years 2, 3 and 4 in a primary school and 59 in the first year intake of a secondary school, offering the use of a coloured overlay free of charge to all the children who reported an improved perception of text with a particular colour (combination of overlays). Fifty-three per cent of the children were given overlays, 22% of whom continued to use them for 10 months of their own volition. These children then demonstrated a mean improvement of 14% in reading speed with their overlay ($P < 0.02$). The improvement was not seen in the children who had failed to persist in using the overlay. The present findings extend this work by showing that the Rate of Reading Test® predicts the children who *subsequently* will use their overlay, and does so before they have become acquainted with its use.

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End notes

The Rate of Reading Test® is available with instructions and scoring sheets from IOO Marketing, Institute of Optometry, 56–62 Newington Causeway, London SE1 6DS, UK. The Medical Research Council owns the rights.

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