

Questioning the benefits that coloured overlays can have for reading in students with and without dyslexia

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Visual stress (the experience of visual distortions and discomfort during prolonged reading) is frequently identified and alleviated with coloured overlays or lenses. Previous studies have associated visual stress with dyslexia and as a consequence, coloured overlays are widely distributed to children and adults with reading difficulty. However, this practice remains controversial. We investigated whether overlays have advantageous and reliable benefits for reading in undergraduate students with and without dyslexia. Both groups read jumbled text faster with a coloured overlay than without. The dyslexic group did not show greater gains than controls, despite reporting significantly more symptoms of visual stress. However, coloured overlays did not improve reading rate or comprehension of connected text. The improvement in reading speed with an overlay was not reliable and was significantly reduced at retesting for dyslexic students. These results question the value of coloured overlays as a tool for identifying visual stress and as a form of remediation for the reading difficulties associated with dyslexia.

A substantial proportion of people report unpleasant visual symptoms when reading for long periods (Evans and Joseph, 2002; Kriss and Evans, 2005; Wilkins, Lewis and Smith et al., 2001). These symptoms, referred to as ‘visual stress’ include visual-perceptual distortions (moving or blurring letters, illusions of colour) and visual discomfort (eye strain, glare from the page, migraine). Visual stress, also referred to as Meares-Irlen syndrome, Irlen syndrome, or scotopic sensitivity syndrome, is commonly defined, identified *and* treated by the use of coloured overlays or lenses (Allen, Gilchrist and Hollis, 2008; Wilkins, 1995; 2003; Wilkins, Huang and Cao, 2004). Thus, Kriss and Evans (2005, p. 1) define visual stress as a syndrome characterised by ‘symptoms of visual stress and visual perceptual distortions that are alleviated by using individually prescribed coloured filters’.

Visual stress can also be identified using symptom questionnaires that include questions such as ‘Does the print

seem to move when you read?’ Evans and Joseph (2002) screened 113 university students for visual stress using a symptom questionnaire that measured symptoms of eye-strain and headaches. More than one third of their sample reported symptoms of visual stress, and students who found an overlay to be helpful during reading were more likely to report perceptual distortions. However, the reliability of subjective report may be poor for some individuals (Singleton and Henderson, 2007a).

The prevalence of visual stress is reported to higher in individuals with dyslexia than non-dyslexic individuals (Irlen, 1991; Singleton and Henderson, 2007b; Singleton and Trotter, 2005). Consequently, measures of visual stress are sometimes included in screening batteries for dyslexia (Nichols, McLeod and Holder et al., 2009), and coloured overlays are frequently distributed to individuals with dyslexia as part of the remediation for reading difficulty. Since a number of investigators have argued that dyslexia and visual stress are separate conditions (Kriss and Evans, 2005; Kruk, Sumbler and Willows, 2008; Singleton and Henderson, 2007b), the rationale underlying this practice is unclear: in the absence of a causal theory, it is difficult to know whether the recommendation of overlays is aimed at increasing reading performance or at improving comfort during reading. Indeed, the mechanisms that underlie visual stress and the benefit from coloured filters remain unclear (Evans, 2001). One recent explanation for visual stress argues that strong sensory stimulation (e.g., from stripy text) may lead to a lack of inhibition in visual cortex and a spread of excitation that results in the inappropriate firing of cortical neurons and the perception of illusions/distortions (Huang, Cooper and Satana et al., 2003). Coloured filters are thought to redistribute this excitation (Wilkins and Evans, 2010) and hence alleviate visual distortions, improve text processing and reading rate, but evidence is lacking.

Coloured overlays are thin transparent coloured films that are placed over a page of text. They are designed to colour the page without affecting clarity of the text (Wilkins, 2002). The Intuitive Overlays (Wilkins, 2001) have been used in many empirical studies (Evans and Joseph, 2002; Jeanes, Busby and Martin et al., 1997; Kriss and Evans,

2005; Singleton and Henderson, 2007a, b; Singleton and Trotter, 2005; Wilkins and Lewis, 1999; Wilkins et al., 2001; Wilkins, Jeanes and Pumfrey et al., 1996). The assessment pack contains 10 different chromaticities based on findings that the colour of the filters needs to be prescribed individually and with precision (Robinson and Foreman, 1999; Smith and Wilkins, 2007; Wilkins, Evans and Brown et al., 1994). Symptoms of visual stress during reading have been found to be alleviated by the use of both coloured overlays that are placed over text (Wilkins, 2003) and by coloured lenses (Irlen, 1983; 1991; Meares, 1980), with the latter being more effective and suggested for long-term use (Evans, Patel and Wilkins et al., 1999; Wilkins et al., 1994).

Wilkins et al. (1996) devised the Wilkins Rate of Reading Test (WRRT), which tests the impact of Intuitive Overlays on reading. It consists of four texts of randomly ordered high-frequency words (e.g., cat, dog), which are read with and without overlays. Jeanes et al. (1997) reported that approximately 50% of their sample of primary and secondary-aged children showed improvements in reading rate on WRRT with the overlays, either in single or paired combinations (see also Kriss and Evans, 2005). Evans and Joseph (2002) found that 34% of their sample of undergraduate students read faster using the overlays. Thus, overlays appear to improve reading rate of jumbled text in a significant proportion of children and adults.

There are no generally accepted criteria for how much faster someone should read with an overlay, or for what period of time the person has to use the overlay over a sustained period in order to receive a diagnosis of visual stress (Singleton and Henderson, 2007a). Some studies have used the voluntary sustained use criterion. For instance, in Jeanes et al. (1997), 36% of the children of primary school who chose an overlay were still using it after 3 months; 24% were using the overlay after 10 months. However, the most widely adopted criteria is the immediate >5% increase in reading rate with an overlay (Nichols et al., 2009; Wilkins et al., 1996). Wilkins et al. (1996) found that 20% of their sample of 77 children chose an overlay and showed an improvement in reading rate on WRRT of more than 5% when reading with it. However, it has been argued that the >5% criterion is too lenient, and therefore more people receive the diagnosis than should do (Type 1 errors; Jeanes et al., 1997; Kriss and Evans, 2005). Rather, Jeanes et al. (1997) suggested that an increase of >8% in reading rate with an overlay may provide a better indication of a benefit of the use of overlays.

It is reasonable to assume that the experience of visual discomfort and perceptual distortions would interfere not only with reading accuracy and fluency but also with comprehension. In a preliminary test of this hypothesis, Lewis and Wilkins (unpublished data, cited in Wilkins, 2002) found that reading speed and speed of comprehension of connected text were improved by overlays. However, while it is acknowledged that improving reading rate per se could be helpful, it remains unclear whether this improvement extends to measures of reading *accuracy* and *comprehen-*

sion, both skills are critical for students at university who are often recommended overlays.

Given that an improvement in reading rate with an overlay is frequently used as a means of identifying visual stress, it is important to demonstrate that the reliability of overlay testing with WRRT is high. Wilkins et al. (1996) tested children on the WRRT, using the Intuitive Overlays, at the beginning and at the end of the summer term (after 8 weeks). Approximately 40% of the children who chose an overlay at the beginning of the summer term were still using it at the end of the term. The correlation between reading rate without a coloured overlay at each testing point was high ($r = 0.83$), but the correlation between the improvement obtained at each testing point was not reported. According to Wilkins et al. (1996) the overlay benefit increased according to the frequency with which the children used it. Wilkins et al. (2001) reported that 87% of children chose a coloured overlay on two different sessions, but only 47% of these children chose the same colour. Nevertheless, the improvement in reading with an overlay was strongly correlated between the two sessions ($r = 0.72$), implying good test–retest reliability in children.

Singleton and Trotter (2005) carried out a preliminary investigation into the prevalence of visual stress in undergraduate students with ($n = 10$) and without ($n = 10$) dyslexia using overlays and a symptom questionnaire. Within each group, five students had low visual stress symptom scores ('low visual stress') and five students had high scores ('high visual stress'). Overall, participants read faster using their optimal colour. The 'dyslexic high visual stress' group showed significant gains in reading speed with an overlay (mean 16%), but the remaining groups showed gains of 3–4% that were not significant. Studies with children have been more mixed. Singleton and Henderson (2007b) reported that children aged 6 to 14 years with dyslexia (mean age 10) showed greater improvements in reading rate with coloured overlays and reported more symptoms of visual stress than compared to reading-age controls. In contrast, Ritchie, Della Sala and McIntosh (2011) reported less favourable results for the benefit that coloured overlays can have on the reading skills of children with reading difficulty. Sixty-one children (aged 7–12 years) with reading difficulties were tested for visual stress; 77% were diagnosed by an Irlen diagnostician as having the condition. However, there was no evidence that individually prescribed Irlen coloured overlays had any immediate benefit for reading rate on WRRT. Furthermore, there was no evidence that overlays had immediate benefits for reading fluency or reading comprehension on the Gray Oral Reading Test (Wiederholt and Bryant, 2001).

Aims of the present study

This study investigated visual stress in undergraduate students with and without dyslexia. We explored whether students with and without dyslexia benefit from coloured overlays during reading. Given the requirement of university undergraduates to comprehend large volumes of text, we also investigated whether overlays show the same benefit in reading rate for connected text and whether this

benefit translates to reading comprehension. Finally, we investigated the test–retest reliability of overlay screening using WRRT. Recent reviews have noted that the studies performed to evaluate visual stress are often of poor quality (Albon, Adi and Hyde, 2008; American Academy of Pediatrics, 2009; Hyatt, Stephenson and Carter, 2009). A key methodological issue includes the pre-selection of participants who have already reported a benefit from coloured overlays. Therefore, in the present study, participants were not selected for having reported using overlays in the past.

Method

Participants

Forty-two undergraduate students (26 controls, 16 dyslexics) took part in this study. They were recruited from a variety of departments including Psychology, Chemistry, Environment, Health Sciences, Management, and History. The dyslexic group (4 males, 12 females; aged 19.5–30.25 years) all had received formal diagnoses of dyslexia from educational psychologists. The comparison group (6 males, 20 females; aged 19.25 to 34.75 years) were free from self-reported literacy or language problems and were recruited from the same departments as the dyslexic group. All participants were native English speakers and reported having normal or corrected-to-normal vision and hearing.

The two groups were matched for age and nonverbal ability (as assessed by Matrix Reasoning, from the Wechsler Abbreviated Scale of Intelligence; Wechsler, 1999) (see Table 1). As expected, the dyslexic group scored significantly lower than controls on measures of word and non-word reading (the Test of Word Reading Efficiency; Torgesen, Wagner and Rashotte, 1999). To confirm that the dyslexic students had impairments in phonological skills, we administered a nonsense passage reading task and a spoonerism task (Hatcher, Snowling and Griffiths, 2002). For the nonsense passage reading task, each participant read two short passages taken from Gross-Glenn, Duara and Barker et al. (1990). The first passage contained 17

non-words embedded in a context of 52 words. The second passage contained 13 non-words embedded in a context of 44 words. Both reading time and errors were recorded. The spoonerism task assessed the students' ability to segment and to manipulate phonemes by asking them to exchange the beginning sounds of two words. Speed and accuracy of each response was recorded. The dyslexic group performed significantly worse on these tasks than the control group.

Design and materials

Identification of visual stress. The Intuitive Overlays (Wilkins, 2001), 11 different coloured acetates, were used in this study as specified in the manual. Participants first selected their optimal colour and then were tested on the WRRT (Wilkins et al., 1996). This test requires speeded oral reading of a passage of text comprising 15 high-frequency words (familiar to children from 7 years) that are repeated in random order, ensuring that no word can be guessed from the context. The test was administered with and without the chosen overlay placed over the text to test for an immediate benefit in reading rate. The test materials provide a choice of two fonts of different size; the smaller one was used for the study. Reading rate was calculated as the number of words read correctly per minute (wpm) not including errors, omitted words and omitted lines.

A brief questionnaire was also administered to investigate symptoms of visual stress associated with reading (see Appendix A). The items were positively biased (the higher the scores, the higher the susceptibility). The questions were selected from questionnaires previously used with adults: the Visual Processing Problems Inventory (Singleton and Trotter, 2005) and a questionnaire used by Evans and Joseph (2002). Questions were included that related to general symptoms (i.e., 'How often does reading make you feel tired?'), visual discomfort during reading (e.g., 'Does reading become harder the longer you read?'), and asthenopia (e.g., 'Do you see words double when reading?'). As with the majority of visual stress questionnaires, it is important

Table 1: Mean (SD) on background measures for the dyslexic and control groups

	Dyslexic group (n = 16)		Control group (n = 26)		<i>F</i> (1, 40)
	Mean	S.D.	Mean	S.D.	
Age (months)	283.94	40.33	271.42	54.22	0.63
WASI Matrix Reasoning†	55.06	8.17	54.65	7.59	0.03
TOWRE SWE‡	86.25	8.43	97.30	11.48	11.09**
TOWRE PD‡	93.25	13.47	107.53	9.82	15.75***
TOWRE‡	88.25	11.96	102.88	12.04	14.71***
Nonsense passage errors (/30)	4.63	3.70	1.23	0.99	19.81***
Nonsense passage RT (s)	61.48	29.85	42.30	8.26	9.73**
Spoonerisms (out of 24)	22.13	1.93	23.26	0.87	6.93*
Spoonerisms RT (s)	2.31	1.07	1.27	0.38	20.19***

Notes: WASI, Wechsler Abbreviated Scale of Intelligence; SWE, Sight Word reading Efficiency subtest of the TOWRE; PD, Phonemic Decoding subtest of the TOWRE; TOWRE, total reading efficiency score.

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$.

†T-scores.

‡Standard scores.

to emphasise that some of the questions may be associated with difficulties other than visual stress (e.g., decoding, pronunciation, oculomotor impairments affecting binocular convergence). Furthermore, we did not administer a screening battery for normal refraction, eye disease or binocular disorders to rule out that reported difficulties on the questionnaire were due to these factors rather than visual stress. Consequently, the data from this questionnaire (though similar to ones frequently used in educational settings) can only provide ‘screening’ for symptoms of visual stress.

Using overlays with connected text. Two passages were adapted from passages in the secondary school edition of the York Assessment of Reading for Comprehension (YARC) test which was under development when this study was carried out (Stothard, Hulme and Clarke et al., 2011). Both passages were selected as suitable for undergraduate students: both non-fiction texts (biographical pieces about Florence Broadhurst and Louise Nevelson). Passage 1 comprised 311 words, and Passage 2 comprised 302 words. Five questions were administered for each passage. The passages were presented on card using as similar font type, font size, line spacing, character spacing, space surrounding the text, text/card colour and contrast as the WRRT materials as possible.

Procedure

Participants were tested individually in a quiet room that was illuminated by 50 Hz fluorescent lighting (care was taken to avoid glare from overhead lights and windows). The order of the tests (symptom questionnaire, WRRT, connected text task) was counterbalanced across the participants. For the symptom questionnaire, the participants were asked to read and answer the questions. For the WRRT, the procedure was administered as specified in the manual. For the connected texts, the participants were asked to read one passage covered with their chosen overlay and the other without. They read them silently and then answered five comprehension questions for each passage, which were read out by the examiner. They were permitted to look back to the text while answering the comprehension questions. Half of the participants read Passage 1 with an overlay, and the other half read Passage 2 with an overlay. The order of presenting the text with/without the overlay was counterbalanced across the participants. Statistical analyses were performed with ‘order’ as a factor; however, there were no significant main effects or interactions of ‘order’.

Results

Overlay testing

All participants chose an overlay. Nine out of 16 of the dyslexic group reported using coloured overlays in the past,

whereas none of the controls had ever used an overlay before. A large number of controls chose the aqua overlay (12/26; 46.15%); the most frequently chosen colours in the dyslexic group were aqua, lime-green, mint-green and orange, which all had equal preferences (3/16; 18.75%).

A higher percentage of students with dyslexia met criteria for visual stress than controls according to the immediate benefit criteria: Fifty eight per cent of controls (15/26) showed an increase in reading rate with an overlay of >5%, 46% (12/26) an improvement of >8% and 35% (9/26) an improvement of >10%. For students with dyslexia, the increase was seen in 75% (12/16), 63% (10/16) and 44% (7/16) of the group, respectively.

The data in Table 2 shows that both groups read more words per minute with their optimal colour than without, and the dyslexic group showed marginally larger gains in reading rate with an overlay than controls, though this difference must be interpreted cautiously because they were slower at baseline (without an overlay). Reading rate with an overlay was significantly faster than reading rate without [$F(1,40) = 41.32, P < 0.05, \eta_p^2 = 0.51$]. The group with dyslexia showed significantly slower reading rate than controls [$F(1,40) = 9.03, P < 0.05, \eta_p^2 = 0.18$]. The critical Group \times Overlay interaction was not significant [$F(1,40) = 2.60, P > 0.05, \eta_p^2 = 0.06$], suggesting that there was no group difference in improvement in reading rate with an overlay.

Pearson’s r correlations were performed between reading rate without an overlay and percent improvement in reading rate with the overlay for controls, $r = -0.58, P < 0.01$, and for the dyslexic group, $r = -0.52, P < 0.05$. These data suggest that regardless of group, individuals with slower reading rates are more likely to show greater improvements in reading rate with an overlay than individuals with faster rates of reading.

Symptoms of visual stress

The maximum score on the visual stress symptom questionnaire was 55. Table 3 shows the dyslexic group reported significantly higher scores than the control group for seven of the questions (1,2,3,4,6,7,8). When Bonferroni correction was applied to these group comparisons, significant group differences remained for questions 2, 6 and 7. Although question 2 (‘Do you lose your place when reading?’) can be attributed to issues other than visual discomfort, questions 6 (‘Does the print seem to move when you read?’) and 7 (‘Do the letters become fuzzy and blurry the longer you read?’) are more characteristic of visual

Table 2: Mean (SD) for reading rate with and without an overlay on Wilkins Rate of Reading Test and per cent improvement with an overlay for controls and students with dyslexia

	With overlay (wpm)	Without overlay (wpm)	% improvement
Control	182.42 (29.51)	173.60 (33.49)	5.91% (7.70%)
Dyslexic	157.57 (25.46)	142.85 (26.96)	11.16% (9.43%)

wpm, words per minute.

Table 3: Mean (SD) and range scores on each symptom for the dyslexic and control groups

	Dyslexic		Control		<i>F</i> values (1, 40)
	Mean (SD)	Range	Mean (SD)	Range	
1. How often does reading make you feel tired?	3.81 (0.65)	2–5	3.19 (1.06)	1–5	4.42*
2. Do you lose your place when reading?	3.75 (0.77)	2–5	2.54 (1.03)	1–5	16.40***
3. How often do the letters jumble, when you read?	2.69 (1.14)	1–5	1.69 (0.93)	1–4	9.58**
4. Do you miss words when reading?	3.56 (1.26)	2–5	2.31 (1.19)	1–5	10.49**
5. Do you see words double when reading	1.81 (0.75)	1–3	1.54 (0.99)	1–4	0.90
6. Does the print seem to move when you read?	2.87 (1.26)	1–5	1.46 (0.71)	1–3	21.86***
7. Does reading become harder the longer you read?	4.06 (1.06)	2–5	2.77 (1.28)	1–5	11.51**
8. Do the letters become fuzzy or blurry when you read?	3.50 (1.26)	1–5	1.81 (1.13)	1–4	20.25***
9. Do you get tired eyes when reading for a long time?	4.19 (1.11)	1–5	3.77 (1.07)	1–5	1.47
10. Does the white page between the words form patterns like 'rivers' when you read?	2.62 (1.46)	1–5	1.85 (1.22)	1–5	3.48
11. Do you get headaches when reading for a long time?	3.12 (1.15)	1–5	2.77 (1.24)	1–5	0.86
Total Scores	36.00 (8.66)	15–48	25.69 (8.14)	12–38	15.13***

Note: * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$.

stress. The students with dyslexia showed higher scores on the questionnaire (mean total score 36, SD = 8.66) than the controls (mean total score 25.69, SD = 8.14), $F(1, 40) = 15.13$, $P < 0.05$.

To test whether participants who report more symptoms also showed greater gains in reading rate with an overlay, Pearson's r correlations were performed between total symptom questionnaire scores and improvement in reading rate with an overlay for each group separately. For the control group, there was a weak positive correlation, $r = 0.39$, $P < 0.05$, but there was no correlation for the dyslexic group, $r = -0.04$, $P > 0.05$.

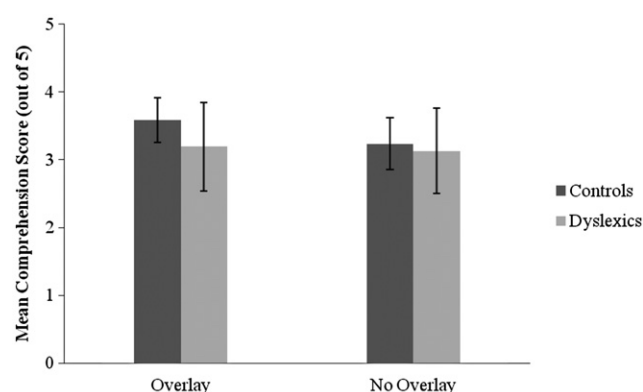
Connected text

Reading comprehension scores were calculated by awarding one point for a correct answer and 0 points for incorrect answers (maximum score for each passage = 5). Reading rate was calculated as wpm for each participant.

Mean comprehension scores were similar whether the passage was read with or without an overlay (Figure 1) for both groups. A mixed-design analysis of variance (ANOVA) confirmed that neither the main effect of Overlay [$F(1,40) = 0.88$, $P > 0.05$, $\eta_p^2 = 0.02$], nor the Overlay \times Group interaction [$F(1,40) = 0.43$, $P > 0.05$, $\eta_p^2 = 0.01$] was significant. Further, there was no main effect of Group, $F(1, 40) = 1.22$, $P > 0.05$, $\eta_p^2 = 0.03$. Therefore, overlays did not improve comprehension of the passage for either group.

The dyslexic readers were slower to read the passages overall, but neither group read the passage faster with an overlay than without (see Figure 2). A mixed-design ANOVA confirmed the effect of Group, $F(1,40) = 4.58$, $P < 0.05$, $\eta_p^2 = 0.10$ but found neither an effect of Overlay, $F(1,40) = 1.32$, $P > 0.05$, $\eta_p^2 = 0.03$, nor a significant Group \times Overlay interaction, $F(1, 40) = 1.09$, $P > 0.05$, $\eta_p^2 = 0.02$.

Figure 1: Mean scores of both groups on the comprehension questions of York Assessment of Reading for Comprehension passages read with or without an overlay (error bars show 95% confidence intervals)



Reliability of overlay screening

Two weeks after the first session (Phase 1), 23/26 of the controls and 13/16 students with dyslexia returned for a second testing session (Phase 2). Analyses indicated that those lost to sample did not differ from those returning in any systematic way. The WRRT was administered as in Phase 1; participants were reminded that they did not have to choose a colour, or pick the same one as in their first testing. We selected this procedure rather than re-testing on WRRT with the same overlay to provide a fairer estimate of test–retest reliability for the whole screening procedure. Providing participants with the same overlay as in Phase 1 may have artificially heightened test–retest reliability rates.

Overall, 7/23 controls (30%) chose the same coloured overlay as in the first testing phase compared to 8/13

students with dyslexia (62%). Table 4 shows the mean reading rate with and without an overlay and per cent improvement with an overlay in Phases 1 and 2. Both groups read faster with an overlay than without.

To investigate whether reading rate without an overlay was stable over time, Pearson's r correlations were performed between reading rates without an overlay on the two occasions. For the control group, the correlation was $r = 0.94$, $P < 0.01$ and for the dyslexic group, $r = 0.89$, $P < 0.01$. These strong correlations show that reading rate *without* an overlay has high test–retest reliability. However, the per cent improvement in reading rate with overlays in Phase 1 was not significantly correlated with the improvement in Phase 2 for either group (controls, $r = 0.40$, $P = 0.06$; dyslexic $r = 0.38$, $P > 0.05$). Although these results suggest that the benefit provided by coloured overlays was not stable over time, it should be noted that the correlations were moderate, and the sample size was small suggesting limited power to detect a relationship. Furthermore, difference scores on which these are based are inherently reliable.

To further investigate group differences in reading rate with and without overlays in Phases 1 and 2, a mixed-design ANOVA was performed. In line with previous analyses, the students with dyslexia group read significantly more slowly than controls [$F(1,34) = 8.36$, $P < 0.05$, $\eta_p^2 = 0.19$], and participants read faster with an overlay than without [$F(1,34) = 14.53$, $P < 0.05$, $\eta_p^2 = 0.30$]. There was

also evidence of improvement over time with participants reading faster in Phase 2 than in Phase 1 [$F(1,34) = 52.65$, $P < 0.05$, $\eta_p^2 = 0.61$]. However, of critical importance was the overlay by phase interaction: this assesses whether the improvement with an overlay was similar in Phase 1 and Phase 2 [$F(1,34) = 1.70$, $P > 0.05$, $\eta_p^2 = 0.05$]. However, the Overlay \times Phase \times Group interaction was marginally significant, $F(1,34) = 3.63$, $P = 0.065$, $\eta_p^2 = 0.10$: while controls showed similar increases in reading rate with an overlay in Phases 1 and 2, $t(22) = 0.35$, $P > 0.05$, the dyslexic group showed a significant reduction in the benefit from an overlay in Phase 2, $t(12) = 2.5$, $P < 0.05$ (Figure 3).

Discussion

This study addressed three important questions relating to visual stress: (1) Are undergraduate students with dyslexia more likely to experience visual stress during reading than undergraduate students without dyslexia? (2) Does the benefit shown by overlays in reading unconnected text extend to reading rate and comprehension of meaningful connected text? (3) Does the improvement shown by coloured overlays on WRRT have good reliability?

All participants in the present study chose an overlay in comparison to 84% of participants in Kriss and Evans (2005). Overall, students read the unconnected text faster with overlays than without, consistent with previous studies (Evans and Joseph, 2002; Kriss and Evans, 2005; Singleton

Figure 2: Reading rate for connected text for each group when the passage was read with and without an overlay (error bars show 95% confidence intervals)

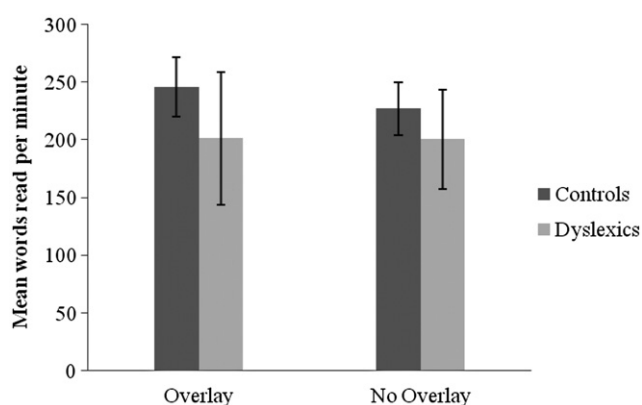


Figure 3: Improvement in reading rate with an overlay for each group in Phase 1 and Phase 2 (error bars show 95% confidence intervals)

Note. The mean per cent improvement shown at Phase 1 is for the participants who took part in both Phase 1 and Phase 2.

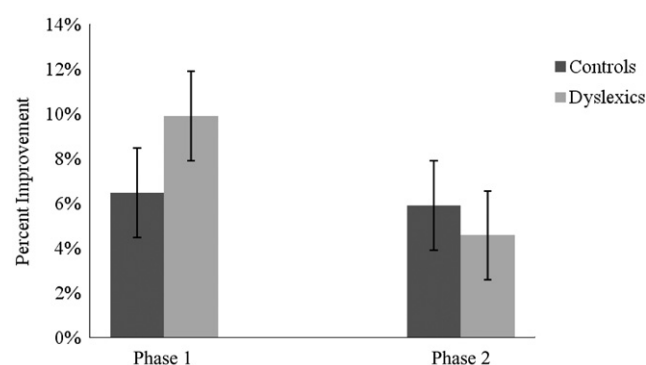


Table 4: Mean (SD) for reading rate with and without an overlay on Wilkins Rate of Reading Test for the control and dyslexic groups who participated in Phase 1 and Phase 2

	Phase 1			Phase 2		
	With overlay (wpm)	Without overlay (wpm)	% improvement	With overlay (wpm)	Without overlay (wpm)	% improvement
Control	182.01 (27.53)	172.24 (31.01)	6.47% (7.94%)	189.53 (30.71)	178.45 (30.95)	5.93% (5.03%)
Dyslexic	156.83 (26.87)	143.22 (26.26)	9.92 (7.74%)	157.98 (25.06)	151.33 (28.33)	4.57% (5.39%)

wpm, words per minute.

and Trotter, 2005; Wilkins et al., 1996; 2001). Over half (58%) of the normal readers and 75% of the dyslexic readers showed more than a 5% increase in their reading rate when using the overlays. Therefore, using this criterion, more dyslexics could be classified as having visual stress than controls.

Although they reported experiencing symptoms of visual stress on a questionnaire, the students with dyslexia in this sample did not show greater gains in reading rate with an overlay than controls. This finding is inconsistent with Singleton and Henderson (2007b) who reported that children with dyslexia showed greater gains in reading rate with overlays than controls.

Singleton and Trotter (2005) reported that only dyslexic adults with visual stress significantly benefited from overlays in contrast to dyslexic adults without visual stress, non-dyslexic adults with visual stress, and adults without either dyslexia or visual stress. However, in the present study, the correlation between total symptoms reported and improvement in reading rate with an overlay was weak for controls and not significant for the dyslexic group. Counter to expectations, this implies that individuals who experience more symptoms of visual stress do not benefit more from overlays than individuals who experience few symptoms of visual stress. This finding sparks concern, suggesting that the two main methods of identifying visual stress may not lead to the same diagnostic conclusions. Indeed, Wilkins (2003) stated that ‘... sometimes individuals who show dramatic improvements in reading fluency with a coloured overlay report no symptoms and show no signs of visual stress’ (p. 18). Visual stress questionnaires are problematic because many symptoms can be attributed to binocular vision and accommodative anomalies as well as decoding problems. Given that increased rates of visual and oculomotor difficulties have been reported in individuals with dyslexia (Evans, 1998; 2001; Evans et al., 1999), the higher scores for the dyslexic group on the questionnaire may not reflect susceptibility to visual stress, but rather, the presence of other visual anomalies. This is problematic since overlays are frequently distributed solely on the basis of symptom questionnaires or subjective beneficial reports of coloured overlays or lenses without a formal assessment of optometric function.

Consistent with Ritchie et al., 2011, we found that neither reading comprehension nor rate of reading connected text was improved by overlays in either group. This finding questions the value of overlays for reading naturalistic texts. While it is important for the present results to be replicated using a wider variety of passages of varying difficulty, the results question the value that overlays can have for undergraduate students with or without dyslexia.

The dyslexic group showed slower reading rate overall. Moreover, there was a significant negative correlation between reading rate without an overlay and the improvement shown in reading rate with an overlay for both

groups. A linear relationship has been reported between baseline latency and difference scores (Chapman, Chapman and Curran et al., 1994), suggesting that the size of improvement in reading rate with an overlay on WRRT is confounded by baseline reading rate. Thus, individuals with dyslexia who have a slower reading rate without an overlay have more ‘room for improvement’ than individuals who start out with faster baseline reading rate. This may inflate the improvement scores and account for previous findings that dyslexics show larger improvements in reading rate with an overlay than controls. Hence, caution should be taken when using such difference scores as a diagnostic indicator, particularly with dyslexic readers.

We also carried out a preliminary investigation of the reliability of overlay testing using the WRRT in undergraduates with and without dyslexia. This issue is particularly important given that overlay testing with WRRT is often used as a means to identify visual stress as well as being the primary treatment method. Both groups read more words per minute in Phase 2 than in Phase 1, suggesting that reading rate on WRRT increases with practice. Although the test–retest reliability of reading *without* an overlay was strong for both groups, consistent with Wilkins et al., 1996; Wilkins et al., 2001, the reliability coefficients for the *improvement* in reading with overlays were weak. Mean overlay improvement did not significantly differ in Phase 1 and 2 for the controls, but was significantly reduced for the dyslexic group in Phase 2. These results suggest that this means of testing for the benefit of overlays is not reliable when used with young adults. Although the present sample may have contained only a handful of individuals with visual stress, the test–retest reliability of assessment procedures should be high regardless of the sample to be tested.

None of the previous studies that have used the immediate benefit criterion have examined the same participants twice in a month as in this study. Wilkins et al. (2001) examined children after 8 months of sustained use, and Jeanes et al. (1997) tested children after 3 and 10 months of sustained voluntary use. Therefore, these participants had been using overlays for prolonged periods which could have increased the test–retest reliability. Nevertheless, any measure which is used as a diagnostic tool should strive for strong reliability. Although it is important to emphasise the preliminary nature of the present findings and that the reliability coefficients reported here must be replicated in studies with larger samples, one would have anticipated greater agreement between the improvement scores in Phase 1 and 2.

The benefit shown from overlays on WRRT significantly decreased in Phase 2 for the dyslexic group but not for the control group. The improvement scores may have been inflated at Phase 1 because of the lower baseline reading rate in this group (Chapman et al., 1994). An alternative explanation could be that individuals with dyslexia are

more prone to novelty effects than controls and that these decrease with repeated exposure. This is particularly likely if the students with dyslexia were aware that overlays are known to aid reading fluency. Indeed, a large proportion (56%) of the dyslexic students had previously been provided with coloured overlays. In the light of the present results, this practice raises concern.

In conclusion, visual stress remains a controversial subject. The dyslexic undergraduates in this study reported experiencing significantly more symptoms of visual stress than undergraduates without dyslexia. However, it remains unclear whether these symptoms were solely attributable to visual stress, or rather to other visual anomalies. All participants read faster with an overlay than without, however, in contrast with previous findings, undergraduates with dyslexia did not benefit from coloured overlays to a greater extent than undergraduates without dyslexia. Furthermore, benefit in reading rate with an overlay did not extend to reading connected text or to reading comprehension, questioning the practical value of coloured overlays as a remediation for reading difficulties. Finally, the improvement in reading rate with an overlay was not consistent over time and can therefore not be regarded as a reliable indicator of visual stress for dyslexic students. The findings from this study question the use of coloured overlays as a means of identifying or treating visual stress as a remediation for reading difficulties. A limitation of our study was the small sample size and the possibility that the students tested were not representative of all those studying in higher education. Although our findings are in need of replication with a larger sample, our results, together with the lack of causal evidence highlighted by previous reviews, suggest that great care should be taken before recommending coloured overlays in the remediation of dyslexia.

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Appendix A

Questionnaire

Please answer the following questions under your experience in relation to reading (any kind of reading). Please circle the number that best describes your experience from 1–5, with 1 representing the lowest frequency (never). There is no right or wrong answer for this. Please remember to answer to **all** the questions, giving only **one answer** for each question.

How often does reading make you feel tired?	1	2	3	4	5
Do you lose your place when reading?	1	2	3	4	5
How often do the letters jumble, when you read?	1	2	3	4	5
Do you miss words when reading?	1	2	3	4	5
Do you see words double when reading?	1	2	3	4	5
Does the print seem to move when you read?	1	2	3	4	5
Does reading become harder the longer you read?	1	2	3	4	5
Do the letters become fuzzy or blurry when you read?	1	2	3	4	5
Do you get tired eyes when reading for a long time?	1	2	3	4	5
Does the white page between the words form patterns like 'rivers' when you read?	1	2	3	4	5
Do you get headaches when reading for a long time?	1	2	3	4	5
Have you been documented as having dyslexia?					
Do you wear glasses or contact lenses?					
Have you used coloured overlays before?					

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