The Effect of a New System of Haploscopic Coloured Filters on Rate of Reading and Visual Fatigue in Dyslexics

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Abstract

A new system for prescribing haploscopic (i.e. different for the two eyes) coloured filters, mounted as spectacle lenses, is described. It concentrates on the blue, short wavelength end of the spectrum in order to identify the optimal filters more accurately. Reading with the prescribed filters was compared with baseline performance, in a balanced design using the Wilkins Rate of Reading Test (WRRT), in a group of 73 dyslexic participants. The filters produced a 35% increase in reading rate, a substantial improvement on the only previous study prescribing haploscopic lenses which used lenses spread equally across the full spectrum (Harris and MacRow-hill (1999). In the present study, there was a strong inverse correlation between individuals' baseline reading rates and their proportional improvement when wearing the filters, indicating that at least part of the effect of the filters was specific to their dyslexia rather than being due to a general facilitation of reading rates in all participants. As part of the balanced testing design, the WRRT was given twice, in each case for two minutes. Comparing the performance, again using transformed data to give a proportional change, between the first and second minutes of each test showed no change over the first test. However, there was a deterioration in performance over the second test for the group without filters but not for the group wearing filters. It is suggested that this deterioration was due to visual fatigue which is reduced by wearing the filters.

Keywords: dyslexia, coloured filters, coloured lenses, reading, visual fatigue

Introduction

There has been a considerable amount of research and debate concerning the effectiveness of using coloured filters with dyslexics and, particularly, the mechanisms underlying the effects found with them. However, there is now a substantial body of experimental evidence demonstrating their beneficial effects when used in the form of overlays, lenses or ambient light filters (e.g. Chase *et al.* , 2003; Iovino *et al*, 1998; Lightstone *et al.,* 1999; Solan, 1990; Solan, 1998; Solan *et al.*, 1997; Solan and Richman, 1990; Solman and Cho, 1991; Wilkins *et al.,* 1994; Williams *et al.*, 1992). In the UK, a popular method of prescribing binocular (i.e the same for both eyes) coloured filters to assist dyslexics is to use the Intuitive Colorimeter (Cerium Visual Technologies Ltd, Tenterden, UK) developed by Wilkins (Wilkins *et al.*, 1992) to determine the optimal filter. The Intuitive Colorimeter is an instrument that varies hue, saturation and brightness for the individual and is marketed principally to opticians' practices where approximately 200 are in use (Noakes, T., Cerium Visual Technologies Ltd., personal communication, June 9, 2003).

The therapeutic application of colour is not new though. Henning, who used light, prisms and lenses in a method he called 'Chrome Orthoptics' used the technique during the 1920's and 1930's for a number of optometric and other conditions (Howell and Starley, 1988). He believed that a holistic treatment could be provided by affecting the autonomic nervous system as well as directly treating the symptoms of the disorder (Kaplan, 1983).

Since then, Irlen, who coined the phrase "scotopic sensitivity syndrome", a misnomer because scotopic, or dark adapted, vision, in which the retinal rod receptors are the main functioning receptors, is unlikely to be involved in reading, has raised the profile of coloured filters and overlays (Irlen, 1991). Meares first described the condition that Irlen treats and this is often referred to as the Meares-Irlen syndrome (Evans *et al.,* 1996; Meares, 1980). It is characterised by symptoms that include distortion to text in which, for example, the words appear to move or become blurred, or distracting patterns are formed by the gaps between words and lines and in which a benefit is found from the use of colour. Coloured overlays or coloured filters can be provided to reduce these distortions.

The work by Irlen remains controversial and some authors have been critical of the results achieved with the Irlen technique, querying even the existence of a distinct Meares-Irlen syndrome (Solan, 1990; Solan and Richman, 1990) and promoting the strength of the placebo effect when Irlen filters are prescribed (Solan and Richman, 1990).

More recently, work has been conducted in the U.K. with ChromaGen™ coloured filters (ChromaGen Ltd, Northamptonshire, UK) that are worn as either spectacle or contact lenses. These were originally developed by the first author as an aid for colour deficients, allowing subjective perception of a wider range of colour (Harris, 1997), and only later applied to dyslexia (Harris and MacRow-Hill, 1999; Hodd, 2000). ChromaGen™ filters are prescribed in such a way that the right and left eyes are assessed independently (haploscopic prescribing). So the final pair of filters may be either the same or of different colours, although it is common for two filters of the same colour to be prescribed (Hodd, 2000). An early pilot study with ChromaGen™ filters (Harris and MacRow-Hill, 1998) demonstrated significant improvements in reading for dyslexics when measured against a baseline with no intervention. Readings were also carried out with filters prescribed by the Intuitive Colorimeter (Cerium Visual Technologies, Tenterden, Kent). After measuring their baseline reading rate using the Wilkins Rate of Reading Test (WRRT) (Wilkins *et al.,* 1996), participants were randomly assigned to one of two groups that were assessed to determine either the ChromaGen™ or the Intuitive Colorimeter filters first. They were then tested on the WRRT with the first set of filters before being assessed and tested again with the alternate set of filters. Both groups showed an improvement although that when wearing the Colorimeter filters did not quite reach significance ($p = 0.06$) and was significantly smaller than when the ChromaGen™ filters were worn.

Later, more formal, experimentation following the pilot study with ChromaGen™ filters used a randomised, double-blind, placebo controlled protocol, testing with ChromaGen™ contact lenses, no intervention, or a placebo of inert lenses containing only a very light blue handling tint that did not affect visual performance (Harris and MacRow-Hill, 1999). The WRRT test was again used to measure reading performance. The results showed a 7.7% increase in performance over the baseline with the placebo contact lenses and 16.9% with ChromaGen™ lenses.

Harris and MacRow-Hill (1999) suggested that the effect of changing the speed of neurological transmission in the visual system by using visual filters (also suggested by Hannell *et al.,* 1989) is similar to the Pulfrich effect where the perceived path of a pendulum that swings laterally will alter to appear to swing in an elliptical path when a dark filter is worn before one eye to delay the transmission of information through that eye (Brauner and Lit, 1976). Their argument was that haploscopic prescribing may be more accurate in achieving the correct filter combination for an individual. Stein *et al.* (2000) and Stein and Talcott (1999) have argued that the neurological abnormalities found in some dyslexics, particularly in the magnocellular pathways, result in impaired neuronal timing which cause the visual instabilities which are alleviated by the use of coloured filters. Harris and McCrow-Hill suggested that if the visual filters had their beneficial effect on reading by changing the rate of neurological transmission (as with the Pulfrich effect), then the optimal filter might vary between the eyes. By selecting filters independently for each eye a greater enhancement in reading would be obtained than if the same filters were always prescribed for both eyes. In the ChromaGen™ system (Harris and MacRow-Hill, 1999), this is done using the standard spectral range of filters currently in use. With the original diagnostic system the practitioner uses an examination set containing 25 trial contact lenses and two sets of eight spectacle lenses, varying in hue across the full width of the spectrum, to determine the correct lenses for the patient. Although there are sixteen diagnostic spectacle lenses, these form two identical sets of eight lenses so that each eye has access to a complete set of eight lenses. The contact lenses also cover the eight principal hues but vary slightly from the spectacle lenses in hue, saturation and in the size of the central tinted section, the periphery of the lens being clear.

In order to improve the results with reading tests obtained with prescriptions of coloured filters, the spectral transmission distributions were examined both for the large number of ChromaGen™ filters that had been prescribed clinically and also in the results of empirical studies using coloured filters (e.g. Chase, *et al.,* 2003; Iovino, Fletcher, Breitmeyer and Foorman, 1998; Meares, 1980, Solan, 1990; Solan, 1998; Solan *et al.*, 1997; Solan and Richman, 1990; Solman and Cho, 1991; Williams *et al.*, 1992). These showed clearly that the maximum effect was obtained at the short wavelength, blue end of the spectrum. A new set of filters was therefore designed with spectral transmission concentrating on the short wavelength end of the spectrum[1]. It is

[1] Although not strictly relevant to the present study, the new procedure included prescribing lenses that permitted glazing the filters into a spectacle frame in the form of lenses for ease of use whilst wearing. This also permitted the incorporation of a refractive prescription where required to correct ametropia. In his way the spectral filters may be formed to contain a spectacle prescription in lens form and are hence named “Harris Lenses”. These filters also have the appearance of representing a range of hues but the hue range is accurately concentrated in the areas that have been demonstrated to produce maximum clinical benefit. The diagnostic filters that resulted from the research have increased in

the prediction that this will enable a more sensitive identification of the optimum filters for enhancing reading in dyslexics that is investigated in the present study. It examines the results obtained with the new filters for a total of 73 patients assessed using the WRRT. In the earlier randomised, double-blind, placebo controlled trial with ChromaGen™ filters (Harris and MacRow-Hill, 1999), the mean increase in reading words accurately was 16.9 per cent overall and the overall placebo effect for all groups was shown to be 7.7 per cent. By changing the design of the filters and refining the selection of the optimal filters, it was hoped to increase and thereby improve on this enhancement in the rate of reading of dyslexic individuals. In addition, by looking at the change in rate of reading over time, the consequences of wearing haploscopically prescribed coloured filters for visual fatigue effects in dyslexics will be investigated for the first time.

Methods

Participants

All participants were found from patients attending Harris Foundation clinics in the United Kingdom. Participants may have responded to media coverage or have been referred by professionals or former patients. All of the participants or their parents or guardians gave consent for anonymous information to be used in the trial. Exclusion criteria included being unable to read the 15 words that form the Wilkinson Rate of Reading Test (WRRT) (Wilkins *et al.,* 1996), failure to have had a recent eye examination by an optometrist, ophthalmologist or orthoptist or being unwilling to

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number and range from those lenses used in the ChromaGen™ system and there is also a different assessment protocol that allows a simpler assessment of dyslexics. The haploscopic nature of the ChromaGen™ lenses remains.

complete the testing procedure. All of the participants had an educationally recognised reading difficulty that was described as either dyslexia or specific learning difficulty. Eight participants, although they fulfilled all the other criteria, did not have a formal diagnosis from an educational psychologist. This may have been because of delay caused by unwillingness of the parents or guardians to have a psychological assessment performed privately or from a delay by the local education authority in carrying out formal assessment with an LEA psychologist.

There were no age restrictions on participants as the sample of patients used in the trial simply represented those who attended a clinic because of their difficulty with reading and it was felt that the trial should represent this diverse sample. The majority of the participants were young as it is these who most often have reading difficulty identified.

In total, 73 patients (39 in Group b-f and 34 in Group f-b) completed the testing process and consented to their data being used for the trial. Of these, 50 were male and 23 were female. The mean age of the participants was 14.79 years (males) and 15.23 years (females), giving an overall mean age of 15.01 years (S.D. 9.36 years, range 5-50 years for the groups as a whole).

Procedure

Testing was undertaken with the participants forming two groups that completed the WRRT in a different order to balance the results. Group b-f completed the test with a baseline reading (no intervention) first and reading using the prescribed filters second. Group f-b read using the prescribed filters first and reading with no intervention second.

Testing was conducted according to the following protocol:

Group b-f (Baseline first, filters second))

1. The participant reads aloud the list of 15 words that compile the WRRT in order to confirm suitability.
2. The participant completes the WRRT, with no intervention, in order to establish a baseline against which other readings may be compared.
3. A brief rest from testing is allowed for approximately 10-15 minutes.
4. Assessment to determine the optimum filters is undertaken and the participant completes another WRRT while holding the appropriate filters before their eyes. This was done with the participant's elbows resting on the table in order to minimise fatigue from holding the filters.

Group f-b (filters first, baseline second)

1. The participant reads aloud the list of 15 words that compile the WRRT in order to confirm suitability.
2. Assessment to determine the optimum filters is undertaken and the participant completes the WRRT while holding the appropriate filters before their eyes.
3. A brief rest from testing is allowed for approximately 10-15 minutes.
4. The participant completes the WRRT, with no intervention, in order to establish a baseline against which other readings may be compared.

The WRRT is composed of a block of text, totalling 150 words in a random order, formed entirely from fifteen words that are selected from the most commonly read words by seven year olds ('come', 'cat', 'see', 'the' etc). This test was used throughout as an objective measure of reading ability. It is a simple test that, providing the list of fifteen words from which it is compiled can be read by the participant beforehand, may be used without the fear of introducing new words that may be stressful to the participant. This would introduce a confounding element to the results and the results are therefore more accurate if this is avoided. Prior to commencing the timed part of the test the participant reads the 15 words making up the test aloud to establish that they would be able to complete it, once started. The words are arranged in a random order and thus nonsensically. The lack of contextual cues aids the accuracy of the test by failing to alert the participant to errors if they are made. Many of the participants were anxious about having to read and the fact that the text was nonsensical relieved them of this pressure.

The test is designed so that the participant must read the words aloud and as fast as possible for a minimum 60 second period while the examiner follows their progress on a marking sheet which contains the same text but with the words numbered to facilitate scoring. Errors are deducted from the total score and from this the number of words correctly read per minute (the rate of reading) is calculated. In the present study, the participants read for 120 seconds (two minutes) and progress for each 60 seconds was noted so that at the end of the two minutes it was possible to record the progress and the number of single word errors made during each of the two 60 second periods. Comparison of the reading performance between these two periods provided a measure of fatigue/practice effects.

Procedure for assessment of filters

A set of thirteen different handheld filters was used. Their spectral transmissions covered the full visible spectrum but with a greater concentration on the short wavelength end. Identification of the optimal filter was carried out according to the following protocol:

1. Whilst binocularly viewing a visually stressful sheet of randomised letters

(Times New Roman, 12 font, in varying word length groups and single spaced), the filters are presented randomly in no set order to the non-dominant sighting eye in order to determine those that are beneficial. As with optical prescribing, this depends on the participant's subjective judgement of the clarity of the text. After establishing the approximate position in the spectrum of the optimal filter, the selection is refined using a forced choice procedure, in which the filters are compared against each other in turn in order to determine the optimal filter from them all.

2. After identifying the optimal filter for the non-dominant eye, the procedure is repeated for the dominant eye whilst the optimal filter for the non-dominant eye is in-situ. The visual target is again viewed binocularly. Since there is only one sample of each filter it is not possible to have the same colours for both eyes.

Results

For each participant, the mean number of words read correctly per minute on the Wilkins Rate of Reading Test (WRRT) was entered as the dependent variable in a 2x2x2 mixed ANOVA. The relevant factors in this design were: counterbalanced group (Group b-f: baseline first, filters second; Group f-b: filters first, baseline second) as the between-subjects factor; test (first reading test, second reading test) as the first within-subjects factor; and minute (minute 1 and minute 2 of the WRRT) as the second within-subjects factor. These data are shown in Table 1.

Overall, there was no evidence that the groups differed in their reading speed on the WRRT: Group b-f, 82.99 (23.47); Group f-b, 78.40 (22.85); $F(1,71) < 1$. However, there was a highly significant group by test interaction, $F(1,71) = 277.64$, $p < 0.01$, the data for which are shown in Figure 1. As can be seen, the interaction arises because the conditions are ordered differently for the two groups, but for each group, the filters improve performance significantly compared to baseline: Group b-f, 93.82 (25.17) and 72.15 (22.99), $t(38) = 12.34$, $p < 0.01$; Group f-b, 89.43 (26.26) and 67.37 (20.50), $t(33) = 11.25$, $p < 0.01$. Combining the two groups gives an overall baseline score of 69.92 (21.85) compared with an overall score with the filters of 91.78 (25.6). The filters therefore improved reading by 34.53 (21.34)%

Of the remaining effects, there was no evidence to suggest that participants benefited from practice on the WRRT, because overall reading speed for the second reading test, 81.50 (26.52), was not reliably different from that for the first, 80.20 (25.89), $F(1,71) < 1$. However, within tests, there was evidence for a slight but significant fatigue effect: thus, reading speed in minute 2, 79.59 (23.80), was slower than that in minute 1, 82.11 (23.24), $F(1,71) = 6.58$, $p = 0.01$. The groups did not differ in this respect, $F(1,71) < 1$, but the significant test by minute interaction, $F(1,71) < 5.06$, $p = 0.03$, suggests that this fatigue effect was modulated according to the test's ordinal position. Indeed, post hoc t tests established that the drop in performance from minute 1 to minute 2 was significant for the second WRRT test: 83.71 (26.57) and 79.29 (27.56) respectively, $t(72) = 3.48$, $p < 0.01$; but not the first WRRT test, 80.51 (25.64) and 79.90 (27.46) respectively, $t(72) < 1$. Finally, the non-significant three way (group by test by minute) interaction, $F(1,71) = 2.43$, $p = 0.12$, showed that the differential fatigue effect was statistically equivalent across groups.

One problem with analysing absolute reading speeds is that statistically equivalent increases (or decreases) measured from different initial values, may nevertheless differ reliably when expressed as proportional changes. A proportional measure is therefore more appropriate when examining data for fatigue effects.The data were therefore transformed to give a measure of proportional change in reading speed (i.e. [reading speed minute 1 – reading speed minute 2] / [reading speed minute 1]), and then re-analysed, this time using a two-way (group by test) mixed ANOVA. These transformed data are shown in Table 2.

The important thing to note about this data is that the proportional reduction in reading speed from minute 1 to minute 2 for the second test is almost three times greater for Group b-f than for Group f-b. In other words, the fatigue effect in the second test is much greater when performed without than with filters. In support of this, the 2x2 mixed ANOVA revealed a significant group by test interaction, $F(1,71) = 4.19$, $p = 0.04$, and Bonferroni-corrected t tests revealed that the proportional change in reading speed was not reliably different for the first (baseline) and second (filters) tests in Group b-f, $t(38) < 1$, but was significant when the baseline test was performed second (i.e. Group f-b), $t(33) = 3.07$, $p < 0.01$.

The ANOVA revealed that the groups overall were not reliably different in terms of proportional change in reading speed from minute 1 to minute 2: Group b-f, -0.026 (0.11); Group f-b, -0.037 (0.14); $F(1,71) < 1$. There was, however, a significant difference between the first and second tests: first test, -0.008 (0.15); second test, -0.055 (0.16); $F(1,71) = 5.14$, $p = 0.03$. This is consistent with the significant two way (test by minute) interaction observed for the earlier analysis of the reading rate data.

A second proportional measure was also computed to capture the relative change in speed when reading without and with filters: [reading speed with Harris Filters – baseline reading speed] / [baseline reading speed]. It was then possible to determine if, across all participants, there was a relationship between baseline reading speed and change associated with wearing filters. The scatterplot is shown in Figure 2 and the Pearson correlation coefficient was -0.50 ($p < 0.01$). In other words, participants with lower baseline reading speeds improve proportionately to a greater degree.

Discussion

This paper explores the improvements in the rate of reading and visual fatigue effects when wearing the Harris Filters in comparison to baseline scores with no intervention, measured using the Wilkins Rate of Reading Test (WRRT). An overall improvement in performance of 34.5% was found when wearing the filters. When the raw change in reading speed was transformed to give a measure of the proportional improvement, there was a significant negative correlation of 0.5 between individual participant's baseline reading rate and this proportional improvement. Thus, those who were poorer at reading showed the most proportional improvement when using the filters. This finding is important because it indicates that the filters are not simply producing a general facilitation of reading rates in all participants; rather, at least part of their effect is specific to the dyslexia of the participants.

The WRRT was given for two minutes in this study. The transformed data (Table 2), which measured the proportional change in reading speed between the first and second minute, was used as the most reliable measure of fatigue during reading. This was minimal during the first reading test, though more in the group who were not wearing the filters. However, during the second test there was a significant deterioration in the second minute, but only in the group not wearing the Harris Filters for this test. The proportional reduction in reading speed was nearly three times greater for this group than it was for the group wearing the filters. In these dyslexic participants therefore there was good evidence that the Harris Filters reduced the development of visual fatigue during reading. This confirms an earlier finding by Tyrrell *et al.* (1995) using coloured overlays that in a fifteen minute reading test the overlays only improved performance in the last five minutes. One possible explanation for this is that the fatigue is caused by the difficulty of coping with visual distortions reported by many dyslexics (Evans, 2001) and the reduction in these distortions when wearing the filters makes reading less tiring.

Improvements in reading accuracy found in previous studies vary substantially, even when the measure used is the WRRT because of sampling and procedural differences. For example, in studies of children with reading difficulties using binocularly identical colours Bouldoukian *et al.* (2002), using overlays, found an increase of 4.0%; Lightstone *et al.* (1999) found an increase of 10.2% with overlays and 12.7% with lenses. In the only previous study using directly comparable haploscopic prescription of lenses selected from across the full spectrum (Harris and MacRow-Hill 1999), the overall improvement was 16.9%. When participants who either did not report visual distortions of text or had colour vision deficits were excluded the improvement rate was 20.4%, still substantially below the 34.5% improvement found in the present study. Although the testing procedure was slightly different in the two studies and contact lenses were used in the earlier study, there does seem to be at least strong circumstantial evidence that concentrating on the blue, short wavelength end of the spectrum increases the effectiveness of the prescription process. Assessment for filters involves a long and potentially tiring series of subjective judgments and shortening this process is likely to make the process more accurate.

The incidence of dyslexia or reading difficulty is widely accepted to be higher amongst males than females. The British Dyslexia Association (2005) quote an estimate of dyslexia being present in four times as many males than females. In the present study there also was a greater incidence of male participants than females (50 males, 23 females). However, this should be treated with caution. Recent work (Zabell and Everatt, 2002) indicates a more equal gender distribution and it may be that males are more likely to present than females for social reasons. One possible explanation for an apparent gender difference might be that the females may maintain a lower profile in the face of difficulties whereas the males may become more disruptive. Parents may also, for this and other reasons, be more likely to bring boys forward for treatment than girls.

Conclusion

This study demonstrates both a substantial increase in reading performance when using Harris Filters and also that reading performance reduction over time (that may be a result of visual fatigue) is reduced significantly when they are worn. The enhancement is proportional to the initial deficit, indicating that the filters are having an effect which is specific to the participant's dyslexia.

There is also evidence that the Harris Filters, which concentrate testing for prescription in the blue, short wavelength region are an advance on ChromaGen™ filters, also developed by the first author, which are spread more fully across the spectrum.

There is of course good evidence that other, non-visual factors are important in the aetiology of dyslexia. Phonemic awareness is considered central to the process of learning to read (Goswami and Bryant, 1990), though see Castles and Coltheart (2004) for a somewhat contrary view. So the primary cause of dyslexia is commonly argued to be a deficit in phonemic awareness (e.g. Snowling, 2000; Rayner *et al.*, 2001). Among other contributory, and probably overlapping, factors in dyslexia for which there is good evidence are cerebellar deficits (Brooks and Stirling, 2005; Nicolson *et al.*, 2001), oculomotor deficits, like the visual deficits perhaps linked to magnocellular abnormalities (Chase *et al*., 2003; Stein and Walsh, 1997), cortical excitability linked to sub-clinical epilepsy, also found to respond to coloured filters (Wilkins, 2003), and auditory processing deficits (Tallal and Benesich, 2002). A multi-disciplinary approach to reading difficulty, in which visual filters and appropriate tuition (e.g. Nicolson *et al.*, 1999) are combined, is therefore likely to be most effective in improving the reading ability of dyslexics.

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David Harris was instrumental in designing the Harris Lenses and in establishing the Harris Foundation, but has had no financial interest in either since 2003. Richard Latto and John Downes have never had any involvement, financial or otherwise, in either apart from the work reported here.

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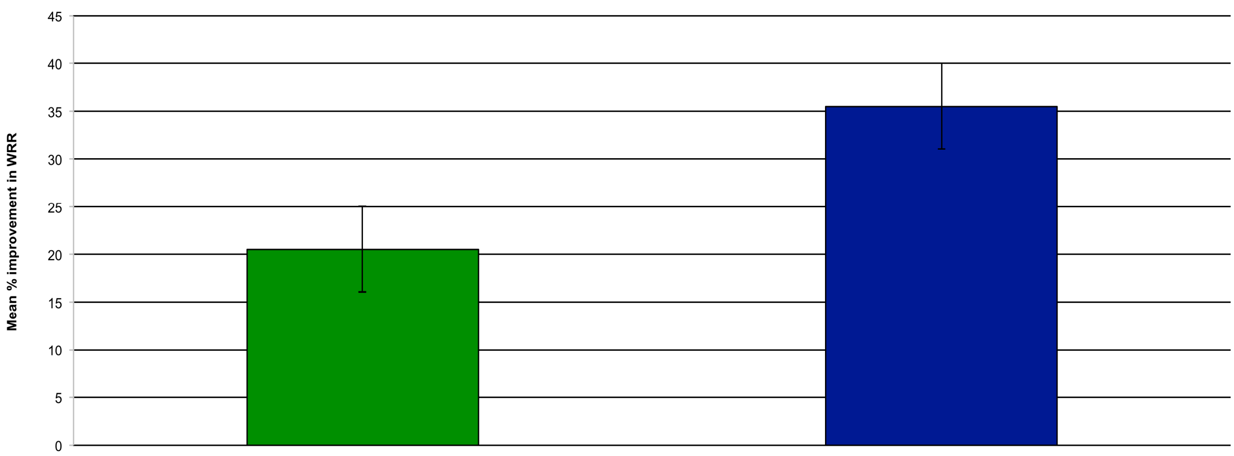
Table 1. Mean reading rate per minute (with standard deviations in parentheses) on the Wilkins Rate of Reading Test

Group *n*	First test Minute 1	First test Minute 2	Second test Minute 1	Second test Minute 2	Overall baseline	Overall with filters
b-f *39*	72.87 (22.37)	71.44 (24.72)	95.15 (25.54)	92.49 (26.21)	72.15 (22.99)	93.82 (25.17)
f-b *34*	89.26 (26.64)	89.60 (27.57)	70.59 (21.38)	64.15 (20.61)	67.37 (20.50)	89.43 (26.26)
Combined *73*	--	--	--	--	69.92 (21.85)	91.78 (25.60)

Table 2. Proportional change in reading speed from minute 1 to minute 2 on the Wilkins Rate of Reading Test (with standard deviations in parenthesis)
(Note: negative values indicate a reduction in reading speed; shaded cells indicate performance with filters)

Test	Group b-f	Group f-b
First	-0.024 (0.144)	0.010 (0.153)
Second	-0.029 (0.144)	-0.085 (0.181)

Comparison of the mean percentage improvement in the Willkins rate of reading test (WRR) using Chromagen and Harris lenses.



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