Enterprise and Learning Committee
EL(3) 09-07 (p4) : 7 November 2007

Blue or yellow filters can improve reading in dyslexic children

Abstract

Introduction

Up to 10% of school children fail to acquire reading skills as well as their classmates, despite adequate intelligence and education [Rutter, 1975 #303]; this is often termed 'developmental dyslexia' by analogy with acquired dyslexia due to brain damage. The most widely accepted explanation is that these children's problems are due to poor phonological awareness, ie failure to learn how words can be split into the separate sounds that are represented by the letters ([Snowling, 2001 #227]).

However this does not explain why these children fail to acquire phonological skills. One reason may be that they may have difficulties seeing the letters properly in order to match them with word sounds. Many dyslexics complain of visual confusions when reading [Stein and Fowler, 1981; Evans, 1996 #273]; the letters appear to blur, move around and change places, or the page glares and gives them a headache. This visual confusion impairs their ability to see the letters properly, hence it may impair their ability to match them with their sounds in order to acquire accurate phonological representations.

(Meares 1980) reported that coloured filters could markedly reduce these visual confusions in some children. This was speedily taken up commercially; there are now several different types of coloured filter for the treatment of reading difficulty on the market (Wilkins and Nimmo Smith 1984; Irlen 1991; Harris and MacRow-Hill 1999). Irlen developed the Irlen coloured overlays and tints to help children who complained of perceptual distortions, visual stress, headaches, glare, and sore, tired eyes. She termed this the 'scotopic sensitivity syndrome' and claimed that her filters reduced crucial light wavelengths that cause distortions in the brain. However independent research has suggested that the benefits claimed were probably mainly due to placebo effects [[Blaskey, 1990 #278] Robinson, 1999 #277].

A more recent brand of coloured filter ([Wilkins, 1994 #295]) was developed using his "intuitive colorimeter" to help identify more precisely the specific tint that would alleviate 'cortical hyperexcitability' that he believes cause visual symptoms in some people ([Wilkins, 1994 #306]). Once selected, the filters may redistribute activity in the brain in a more even manner that prevents this hyperexcitability, although how the tints may achieve this is not explained. However, [Wilkins, 1994 #295] conducted the first double-blind placebo-controlled study testing the effect of coloured filters on visual symptoms and reading speed. Both his 'precision' tints and the placebo control produced a reduction in visual symptoms, but the benefits were slightly greater after the precision tints.

Most of the commercially available filters make the assumption that the colours must be prescribed on an individual basis (Wilkins, (Wilkins and Nimmo Smith 1984; Irlen 1991; Harris and MacRow-Hill 1999)]. This necessitates a lengthy consultation with a trained practitioner to find the appropriate hue for each child, which increases the cost of the whole process. Evidence that each child may need an individualised tint was provided by Wilkins [Wilkins, 2001 #302]. He tested children three days apart and found that they tended to choose a similar colour on both occasions. Further, slightly greater reading speed improvements were made by children who chose exactly the same colour.

But it is still not clear whether coloured filters really do improve reading significantly or whether they just have a placebo effect. Because the manufacturers can charge substantial amounts of money for different filters, there has been little incentive to design properly controlled trials to assess whether they really are effective. Many of the studies that have been published are poorly controlled, none have used standardised reading measures and most do not provide any clear physiological basis to explain why the coloured filters may aid reading. However there are too many anecdotal reports of very great improvements in children's reading to ignore this phenomenon altogether. Since parents continue to buy expensive coloured filters to help their children, as for any procedure claimed to help reading, it is important that their efficacy should be properly investigated by means of randomised controlled trials, and that research is carried out to explain why they exert their claimed effects.

We have found studying children in our dyslexia research clinics in Reading and Oxford that when they are offered a choice of colours, almost invariably they choose only either yellow or blue. We have therefore carried out a randomised placebo controlled trial employing standardised reading measures, using only these two colours. We have been routinely measuring the near-point of vergence and accommodation at the clinic. Therefore we also assessed whether improvements in reading were associated in any way with improvements in accommodation and vergence.

Methods

Subjects

The Dyslexia Research Trust runs clinics in Reading and Oxford to study visual problems in children with reading difficulties. They are referred by their GPs, school nurses or teachers, or directly by their parents. Any child visiting the clinics between Sep 2002 and Dec 2004 was considered for this study. Over this period the clinics saw 486 new children.

All the children were given a full visual examination including history, visual acuity, cover test, eye movements, stereopsis and colour vision (Ishihara). Their near points of convergence and accommodation were measured using the RAF rule. This is a 50 cm long rule with a plastic slider holding a rotating four sided drum, presenting a choice of four possible different visual targets. The near end of the rule is placed on the patient's cheeks using a comfortable plastic cheek rest. The targets are moved towards the patient until blurred vision or diplopia is reported. For accommodation we used the Times Roman type face size N5, and for convergence a vertical line and central fixation dot. For this study the orthoptist was not aware of children's reading ability when she measured their convergence and accommodation. The vision of all the children reported here, including their colour vision, was within normal limits according to the usual clinical criteria.

Next the children were asked to look at N5 sized text through various coloured filters to if see if any of them made the text look clearer. Grey, red, pink, green, deep yellow (negative blue) and deep blue (negative yellow) Wratten filters matched to pass approximately the same amount of light overall were presented in random order. 29% of the children chose the yellow; 21% chose the blue filters; less than 5% chose either pink, green or grey; and 45% did not think any of the filters made any difference.

We also administered the matrices, similarities subtests of the British Abilities Scales (BAS II) to measure general intelligence, recall of digits to assess short term memory and the BAS standardised reading and spelling subtests to measure literacy(Elliott 1985).

With their parents' consent and ethics permission provided by the Central Oxford Research Ethics Committee, 58 of these children were selected for further study because they were aged between 7 and 16 years (mean 9.5 yrs), their BAS reading or spelling scores were at least 1.5 sds below their matrices or similarities scores for general intelligence (ie their literacy was below the 7th percentile expected for their intelligence); they complained of visual problems when reading (letters blurring, glaring, appearing to move around); and they found that reading through either yellow or blue filters improved text clarity for them.

Summary statistics for this group are shown in table 1.1. The baseline scores for those who received their chosen filter (yellow or blue) were not significantly different from those who received the window placebo. Those given blue were on average a year older than those who received the yellow filters, but this difference was not statistically significant. As expected, the reading, spelling and recall of digits of all the groups were much lower than would be expected of normal readers of the same age

Table 1.1 Baseline scores: t scores (mean = 50, sd = 10) given for BAS subtests, similarities, matrices and recall of digits. s scores (mean = 100, sd = 15) for reading and spelling subtests. Convergence and accommodation were measured with the RAF rule.

	Yellow filter		Blue filter		Window	
	Mean	SD	Mean	SD	Mean	SD
N	18		11		29	
Age (months)	110.2	19.6	122.7	26.5	115.7	25.6
Similarities (t)	56.7	6.9	57.4	10.3	57.4	7.4
Matrices (t)	56.7	5.6	56.4	5.9	56.4	6.9
Recall of Digits (t)	48.3	9.9	44.7	11.6	45.6	8.9
Convergence (cm)	7.5	2.8	6.8	2.0	8.4	5.0
Accomm. (cm)	10.2	4.8	10.4	4.9	13.4	5.7
Randot (arcsecs)	25.6	13.8	24.7	7.6	25.5	9.0
TNO (arcsecs)	73.4	65.0	53.8	29.6	58.4	25.4
Reading 1st visit (s)	88.7	7.9	87.0	13.4	88.6	9.4
Spelling 1st visit (s)	87.3	8.8	84.8	14.5	87.7	10.7

Materials and Procedure

The blue or yellow filters were standard, Wratten type, ‘negative yellow’ or ‘negative blue’ respectively, made up into children’s plano spectacles (cost c. £1). Their spectral transmissions are shown in figure 1. The alternative placebo treatment was a card with a window cut in it, so that only one line of text could be seen at a time, thereby limiting ‘crowding’ distractions from surrounding text. This technique has been found to help some subjects with reading difficulties (Geiger and Lettvin 1987). It was chosen as a contrasting ‘visual’ treatment, and it was stressed to both children and parents that both treatments were likely to be effective. Neither the children or their parents were aware what other children had been given.

Those choosing yellow or blue and satisfying the criteria outlined above were given either their chosen filter or the windowed card to use for three months. The children were allocated to the filter or placebo group by author RP from a set of random numbers, but she did not administer any of the tests. Those who did administer the tests were not aware which children had received placebo or filters. After 3 months the BAS II reading and spelling tests and the eye examination were repeated. All subjects returned for their 3-month follow-up assessment.

14 of the yellow choosers and 9 of the blue choosers who had been using the window were then given their choice of filter to wear for a further 3-months (single crossover), when their reading and spelling was retested. They were not informed that the window had been a placebo, so they were blind to whether they had received the active or placebo treatment. Unfortunately after the crossover, 4 yellow choosers and 2 blue choosers were unable to attend for their third appointment. Crossing those who had received the filters to the window placebo was not appropriate because they eye control of many of these children appeared to have improved permanently without having to wear the filters any more.

Subjects were asked not to bring their filters or window with them to their follow-up appointments. The children did not wear any filters during the administration of any of the tests and were asked not to say what treatment they'd been given. So all testers were blind to what treatment a child had been receiving.

RP asked both the children and their parents how often they had worn the filters or used the windowed card for reading. They all claimed to have done so on most occasions that they were trying to read and there were no significant differences between the groups with regard to their compliance. No adverse effects of using either the coloured filters or placebo window were reported by either children or parents.

After the 1st three months, analysis was by intention to treat and there were no dropouts. Even though the Kolmogorov-Smirnov Test showed that the data were normally distributed, conservatively, we have used non-parametric tests for our analysis since the groups were small. The initial 3-months comparison data were analysed using the Mann Whitney U test. The cross-over results were analysed using the Wilcoxon signed ranks test. In fact using parametric tests confirmed the non-parametric results but with higher statistical significance.

Results

Yellow

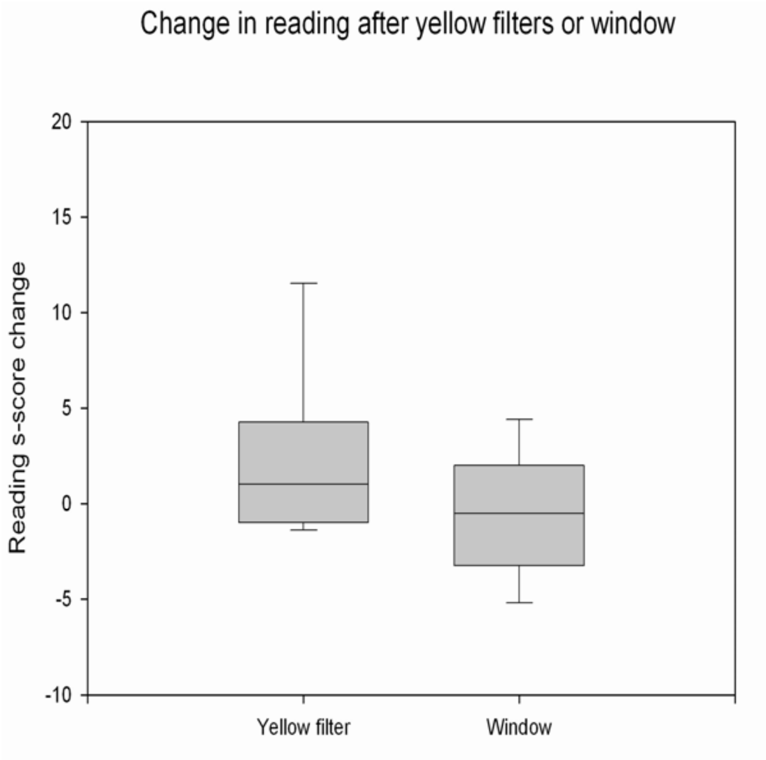


Table 1.2 Reading and spelling s scores for yellow choosers (mean = 100, sd = 15)

	Window n=18		Yellow n=18	
	Mean	SD	Mean	SD
Reading 1st visit (s)	89.3	9.4	88.7	7.9
Reading 2nd visit (s)	88.7	9.8	91.4	10.4
Reading 3rd Visit (s) (N=14)	87.9 (from 86.8)	11.5	.	.
Spelling 1st visit (s)	89.0	10.7	87.3	8.8
Spelling 2nd visit (s)	89.9	11.6	90.2	10.9
Spelling 3rd visit (s) (N=14)	86.8 (from 87.3)	10.3	.	.

Table 1.2 and Fig 1.2 show the results for the yellow choosers. There were no significant differences between those who were allocated the yellow filters or placebo windows at their first visit. But after the first 3 month period the yellow choosers had improved their reading s-scores by almost 3 points; this is equivalent to an increase in reading age of 7 months (ie 2.3 months per month). In contrast the reading of those who received the placebo window dropped by almost 1 point in the 3 months (equivalent to increasing their reading age by only 1 month in the 3 months, or 0.3 months per month). The advantage to those given the yellow filter was statistically significant using the non parametric Mann Whitney test ($Z=-1.7$, $p<0.05$). The effect size was: eta = 0.11.

Although those who were crossed over from placebo to wearing yellow filters at 3 months improved their reading after a further 3 months by 1.1 score points, this was not significantly better than during the previous 3 months using the window.

The spelling of those who received the yellow filters improved by 3 score points whereas the window users only increased by 0.9 points; but this difference was not statistically significant ($Z=-0.7$, $p=0.243$), and the spelling of the crossover group actually deteriorated slightly - by 0.5 points.

Blue

Table 1.3 Reading and spelling s scores for blue choosers (mean = 100, sd = 15)

	Window n=11		Blue n=11	
	Mean	SD	Mean	SD
Reading 1st visit (s)	86.7	9.3	87.9	13.4
Reading 2nd visit (s)	86.3	12.5	91.6	16.3
Reading 3rd visit (s) (N=9)	91.8 from 87.2	16.9		
Spelling 1st visit (s)	84.9	8.6	84.8	14.5
Spelling 2nd visit (s)	84.6	8.8	87.5	13.6
Spelling 3rd visit (s) (N=9)	86.1 from 84.7	7.6		

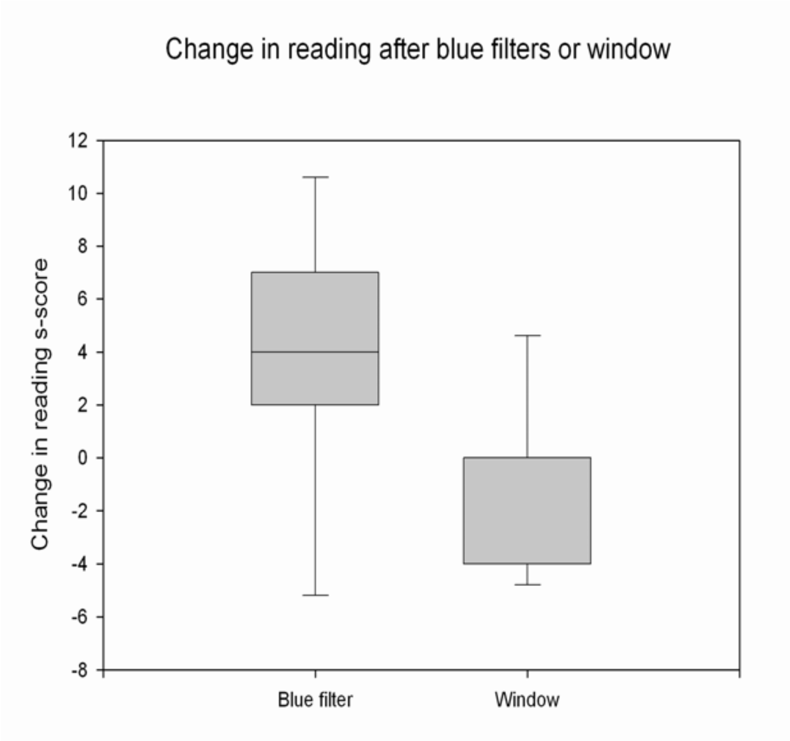


Fig 1.2. Changes in BAS II Reading s scores before and after 3-months' using the yellow filter or placebo window (Thick black lines – median; box limits - 25th and 75th percentiles; whiskers - 95% confidence intervals).

Fig 1.3. Reading s-score changes before and after 3-months using blue filter or window. (Thick black lines – median; box limits - 25th and 75th percentiles; whiskers - 95% confidence intervals).

Table 1.3 and Figure 1.3 show that those given the blue filters improved their reading even more than the yellow choosers did. They gained 3.7 score points in the 3 months (equivalent to 13 months increase in reading age), whereas those given the window lost about 1 point (equivalent to only 1 month's increase in reading age over the 3 months). This difference was statistically highly significant (Z = -2.14, p <0.01). The effect size for the blue filters was greater than for the yellow: eta= 0.27.

When those who had received the window were crossed over to wearing their chosen blue glasses their reading also began to improve faster. They increased their reading s score by 4.5 points. This was also significantly greater than the reading improvements they had achieved with the window (Wilcoxon signed rank test - Z=-2.67, p<0.01).

Although the spelling of the blue choosers also improved by 2.2 score points in the first 3 months this was not statistically significantly more than in the placebo group (Z=-0.17, p=0.44), nor was it in the crossover group.

Vergence and Accommodation

Thus we found that children whose visual symptoms were alleviated by blue or yellow filters improved their reading significantly more after three months wearing them than did children using the placebo window. This confirmed that coloured filters can indeed help children with visual reading problems to overcome them, and that they are significantly more effective than placebo. But also, if only two colours, yellow or blue, are required our results suggest that it may not be necessary to identify a specific optimal tint for each individual. Therefore we need to explain how filters that come in only two colours could improve reading.

Those who advocate individualised tints argue that filters improve reading by limiting input to the eye from specific wavelengths that cause cortical hyperexcitability in that individual. But they offer no explanation why different wavelengths could affect different children differently. Also this hypothesis implies that each child should wear his specific filters permanently. However we observed that after wearing our filters for 3 months children often found that their visual confusions had gone, even when they were not wearing the filters. This suggests that the filters work not by removing distorting wavelengths, but by enabling some permanent modification in visual pathways that promotes more effective visual processing.

The system that controls convergence and accommodation is one obvious candidate. It is well known to be particularly vulnerable to drugs and disease, and children suffering visual problems when reading often report blurring, distortions and motion of text, glare from the page and headaches/sore eyes, just like patients suffering from vergence and accommodative anomalies. Hence reading problems have often been associated with poor accommodation and vergence (Stein 1981); Evans, 1996; Eden, 1994, Scott, 2002[Scott, 2002 #308]).

Since we measure vergence and accommodation at our dyslexia clinics, we were able to test whether the improvements in reading that we saw after giving children coloured filters for three months were associated with any changes in accommodation and vergence.

Subjects

To our original 58 subjects, we added 31 extra children selected from the 486 Dyslexia Research Trust clients. They were chosen if they were aged between 7:11 and 16, they showed a preference for either yellow or blue filters for reading, their reading was below average (<100) for their age; yet their IQ was greater than 100. This gave us 89 subjects in all. Of these 66 chose yellow and 23 chose blue. The children who could see the N5 size target clearly at 8cm distance or less on the RAF rule were described as having good accommodation. Those with near-point accommodation at 10cm or further away were described as having reduced accommodation.

Table 2.1 Similarities, matrices and recall of digits BAS subtests: t scores (mean = 50, sd = 10). Reading and spelling: s scores (mean = 100, sd = 15)

	Group			
	Normal accommodation		Reduced accommodation	
	Mean	Std Deviation	Mean	Std Deviation
Age in months	109.90	17.36	115.47	23.07
Similarities t score	52.60	8.80	54.22	9.79
Matrices t score	53.25	7.76	51.33	9.81
Recall of Digits t score	44.97	7.31	45.10	8.63
Reading s score 1st visit	87.10	8.68	84.80	9.24
Spelling s score 1st visit	87.10	8.57	85.37	11.62
Convergence (cm) 1	6.40	1.13	11.06	8.11
Accommodation (cm) 1	7.05	1.01	15.92	7.11

Results

Neither the age, IQ nor the literacy scores of the group with poor convergence and accommodation were significantly different from those with good convergence and accommodation.

We measured the children's reading ability before and after 3 months wearing the yellow or blue filter. The important finding was that those who had reduced accommodation and convergence (AC) at the beginning of the trial made much greater improvements in reading than those with good AC to begin with. This was true for the yellow choosers ($t(64) = -2.6$, $p < 0.05$), the blue choosers (Wilcoxon signed ranks test because of small numbers; $z = -2.5$, $p < 0.05$) and for the groups as a whole (fig #, t=(87) -2.2, $p<0.01$).

There was also a significant correlation between the improvement in reading and the improvement in AC for the whole group ($r = 0.23$, $p < 0.05$). However their significance did not survive analysis of the two filter colour groups separately, probably because of the small numbers (yellow: $r = 0.26$, $p > 0.3$; Blue: $r = 0.37$, $p = 0.09$, figure #).

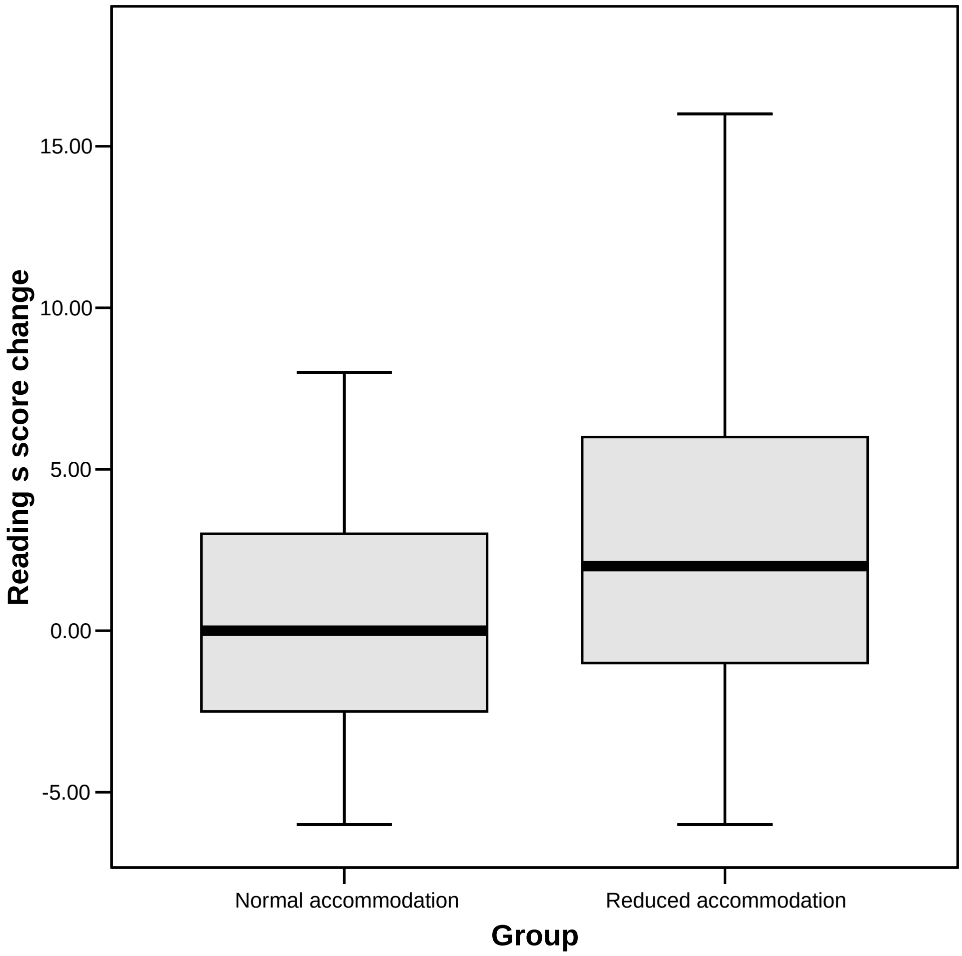


Fig #. Change in reading s-score after wearing filters in children with reduced (>9cm) or normal (<9cm) near-point accommodation. Thick black lines are medians, box limits are 25% and 75% percentiles, whiskers are 95% confidence intervals.

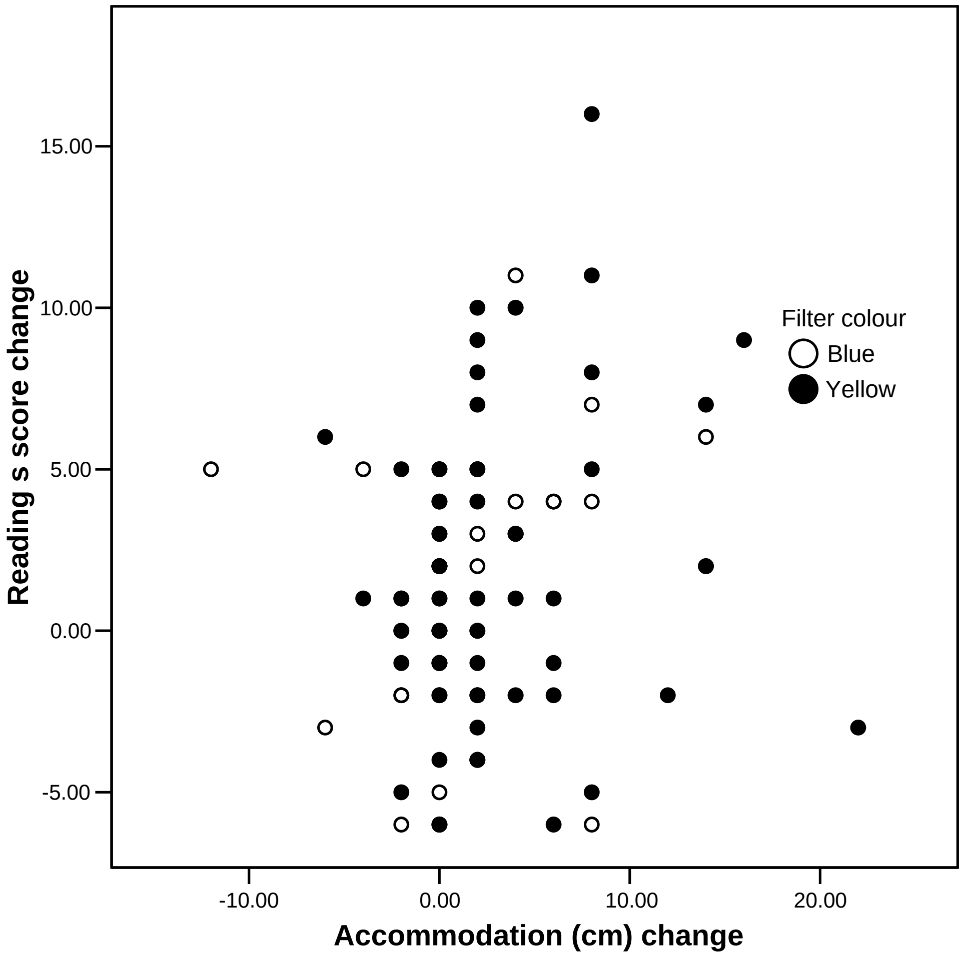
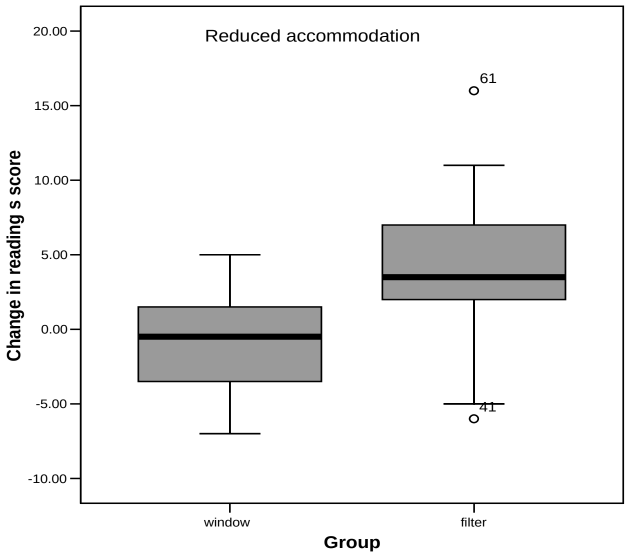
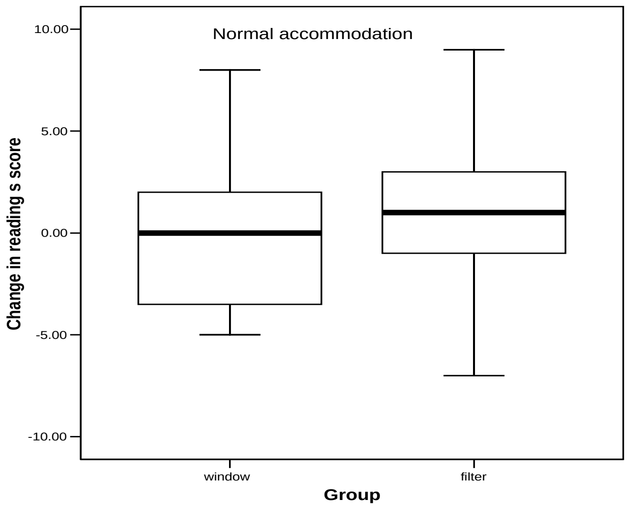


Fig #. Scatter plot showing improvement in accommodation against the improvement in reading ability after wearing filters. Yellow wearers are filled and blue wearers are unfilled circles.

We tested whether the reading improvements were driven mainly by those with reduced accommodation. This turned out to be the case. When only children with normal accommodation were included in the analysis, the improvements made after three months wearing the filter (n =15) were not significantly greater than for placebo (n = 12, z=-0.96, p > 0.3, Man Whitney U test). In contrast, if only those with reduced accommodation were analysed the improvement after filter (n =14) was significantly greater than with placebo (n =16, z = -2.6, p <0.01). See figs # and #.



Fig#. Improvement in reading after filter or placebo in children with reduced accommodation. Thick black lines are median scores, box limits are 25th and 75th percentiles, whiskers are 95% confidence intervals.



Fig#. Improvement in reading after filter or placebo in children with normal accommodation. Thick black lines are median scores, box limits are 25th and 75th percentiles, whiskers are 95% confidence intervals.

Discussion

This double blind randomised control trial confirmed that yellow or blue filters helped children with severe reading difficulties to learn to read significantly better than did a windowed card placebo. The children said that the filters stopped the letters moving around and blurring. They improved their reading by an average of 3.1 standard score points, which is equivalent to 9.2 months increase in reading age over 3 months (ie 3.7 months per month). This was a very worthwhile gain for a very simple, short and cheap treatment, hence we feel that all those who deal with children with reading difficulties should be made aware of the potential of using these blue or yellow coloured filters to help them.

In contrast the standard reading score of those receiving the placebo decreased by 0.6 points; ie their reading age increased by only 0.7 month per month. By definition a normal child's reading age improves by 1 month per month, whereas those with severe reading problems tend to fall further and further behind improving by only around 0.5 months per month. So the window probably did provide a small placebo effect of c. 0.7- 0.5 = 0.2 months/month improvement in reading.

The spelling of the children who wore the filters did not improve so much however. Very often spelling proves more resistant to treatment and progresses more slowly. We are in the process of following up the children over a longer period to see whether their initial reading improvements may lead to later spelling progress, and also to check whether their reading continues to progress a year later.

We have deliberately avoided the use of the term 'dyslexia' in this paper. Although most of these children could be classified as dyslexic, because their reading and spelling were very far behind that expected from their general intelligence, many of those who believe dyslexia to be a purely phonological/linguistic problem would deny that these children with visual problems were 'truly' dyslexic.

Our trial was different from many previous studies assessing the efficacy of coloured filters in three main ways. First, we used a double blind randomised control design which enables the proper assessment of any placebo effect. Second we used standardised measures to assess reading progress. This is important because the standardisation provides a large database of children to control for normal reading progress over time. Therefore the improvements that we recorded indicate that the children were actually catching up with their peers.

Third, we used only deep yellow (negative blue) or deep blue (negative yellow) filters; the same shades were given to all participants. It is often claimed that filters need to be individually tailored for each subject (Wilkins, Nimmo Smith et al. 1992; Harris and MacRow-Hill 1999). Our results do not settle whether the specific yellow and blue we used are better than individually prescribed colours. Individual differences in cone inputs to magnocells are seen (Kremers 2003), so that individual prescription might be superior. However just yellow or blue seemed to produce the desired improvement. More studies are required to compare our standard blue or yellow with individually prescribed filters.

It is important to emphasise that coloured filters will not benefit all backward readers. They only seem to help those who complain of visual reading problems such as letters blurring, glaring, moving around or mislocating, and who have reduced convergence and accommodation. But we find this to be true of a high proportion of the children we see in our clinics.

Convergence and Accommodation

We found that only the children with reduced near-point convergence and accommodation (CA) improved their reading. Those who showed the greatest improvements in reading were those who also showed the largest gains in CA, and those who showed no CA improvement did not significantly improve their reading. Hence the filters did not help children without initially reduced CA. This suggests the possibility that improved convergence and accommodation contributed to the improved reading. Unstable convergence might be the cause of apparent movement of letters, whilst inaccurate accommodation would cause blurring of the text. These are precisely the symptoms of which these poor readers so often complain.

The normal reading distance is around 20cm, hence most of the children in the reduced accommodation group would still have been able to see text clearly; thus the reduced accommodation we observed is unlikely to be a direct cause of their reading difficulties. However the RAF rule requires children to concentrate on making the effort to accommodate accurately just for a short time. It is possible that those who cannot maintain convergence or focus below 10cm for a moment may also find it difficult to maintain them at the reading distance of 20 cm throughout a much longer time such as that required for reading. Indeed, ( ) found that visual discomfort was often only measurable after 10 mins of reading.

Both the colours we used could improve vergence and accommodation, because the vergence and accommodation system probably responds differentially to different cone isolating stimuli (Rucker and Kruger etc). The yellow and blue filters we used were very saturated and designed to stimulate different cone types selectively although they were not completely cone isolating. The blue filters were ‘negative yellow’ allowing only short wavelengths to pass, while the yellow filters were ‘negative blue’, removing the short wavelengths.

Blur caused by inaccurate accommodation does not indicate whether the lens is over or under focussed. However only if it is overaccommodating do blue fringes appear round the edges of an image. Despite the paucity of blue cones, the accommodative system seems to be able to use this chromatic aberration cue, in addition to vergence cues, to decide whether blur is myopic or hyperopic. Thus even though we do not consciously see blue fringes, s-cones probably make an important contribution to fine adjustments of accommodation and vergence. Hence Bedford and Wyzecki (1957) found that the accommodative system is actually more sensitive to wavelength change in the blue than yellow range of colours. Kruger and Rucker (2001, 2004) and Seideman and Schaeffel (2002) found that the eye over accommodates when the response is mediated by s-cones alone, as is the case with the highly saturated blue filters used in the present study. Thus giving children with deficiencies in this system blue filters may encourage them to overaccommodate and thus ‘tune up’ their accommodation and vergence control, leading to a more accurate response even with white light without filters.

Because the yellow filters we used transmit more long than medium wavelength light, they encourage focus of the longer wavelengths. Normally the accommodative system focuses at the average of the L- and M-absorbtion maxima (greeny yellow) so that red light focuses behind the retina. But focussing the extra red light transmitted by our filters probably requires extra accommodative effort than required for the balanced green and red found in white light. Again therefore by emphasising the long wavelengths our yellow filters may have helped these children to tune up the system to work more efficiently even in white light.

If the benefits from filters can be attributed to the improvements in accommodative skill by the mechanisms suggested here, only yellow or blue should be effective, contrary to those who claim that even a slight departure from an individuals’ optimal tint can reduce the benefit gained. It is therefore important that trials are carried out to compare the effectiveness of these simple blue and yellow filters with proprietary more selective filters.

Scott (2002) suggests that benefit from coloured filters cannot be attributed to their effect on accommodation, because measures of such in children who choose to wear the filters are clinically insignificant. However the data reported here suggest that even mild impairments in near-point accommodation can be associated with benefits from filters. What may be considered clinically insignificant when assessing accommodation with a near-point rule, may actually cause significant distortions to text after a prolonged period of reading.

In conclusion this study suggests that children with visual reading problems can be assisted to see print more clearly and reliably using very cheap and safe yellow or blue filters, and that this is often followed by significant reading improvements. Therefore we feel that all those who deal with children suffering reading problems should be made aware of this highly cost effective treatment and that it should be made much more widely available. Hopefully this could help to significantly reduce the number of children who leave school without being able to read properly, and thus avoid some of the personal, family and social costs that this failure brings in its train.

Acknowledgements

This research was supported by the Dyers and Colourists Trust and the Dyslexia Research Trust.

References

Elliott, C., Smith P, McCulloch K. (1985). British Ability Scales: Second Edition. Chiswick, England, NFER-Nelson Publishing Co.

Geiger, G. and J. Y. Lettvin (1987). "Peripheral vision in persons with dyslexia." New England Journal of Medicine **316**(20): 1238-1240.

Harris, D. and S. J. MacRow-Hill (1999). "Application of ChromaGen haploscopic lenses to patients with dyslexia: a double-masked, placebo-controlled trial." J Am Optom Assoc **70**(10): 629-40.

Irlen, H. (1991). Reading by colours. New York, Avery.

Kremers, J., Stepien MW, Scholl HP, Saito C. (2003). "Cone selective adaptation influences L- and M-cone driven signals in electroretinography and psychophysics." Journal of Vision **3**.

Meares, O. (1980). "Figure/ground brightness contrast and reading disabilities." Visible Language **14**: 13-29.

Stein, J. F. S. (1981). "Visual dyslexia." TINS, **4,**.

Wilkins, A. J. and I. Nimmo Smith (1984). "On the reduction of eye-strain when reading." Ophthalmic Physiol Opt **4**(1): 53-9.

Wilkins, A. J., I. Nimmo Smith, et al. (1992). "Colorimeter for the intuitive manipulation of hue and saturation and its role in the study of perceptual distortion." Ophthalmic-Physiol-Opt **12**(3): 381-5.