Br Ir Orthopt J 2010; **7:** 54–58

Influence of bar reader colour and contrast when reading

FIONA J. ROWE PhD DBO AND LAURA TREMARCO

Directorate of Orthoptics and Vision Science, University of Liverpool, Liverpool

Abstract

Aim: **To identify the effect of using different coloured bars on reading time for the bar reading task, along with an assessment of subject experience with different colour bars.**
Methods: **Inclusion criteria were: visual acuity better than 0.5 logMAR, presence of binocular single vision, and ability to understand and perform bar reading. Measurements were taken of visual acuity, near point of convergence, interpupillary distance, Bagolini glasses and prism fusion range. Bar reading was timed and undertaken with and without five coloured bars for N5 and N12 print.**
Results: **Forty subjects were recruited with a mean age of 38.5 years (SD 12.4). Two were excluded because of poor visual acuity in one eye. There was no significant difference in bar reading task duration with or without the bar in place and for different colour bars. Eleven subjects perceived difficulty with the task, mostly relating to maintaining physiological diplopia appreciation of the bar. White was the most popular bar colour.**
Conclusions: **Bar reading is a good indicator of binocular single vision and is useful as a home exercise. In our healthy controls no differences were seen when using different colour bars. A repeat of this study in a clinical population of symptomatic strabismic patients is required.**

Key words: Bar reading; Binocular single vision, Colour

Introduction

Bar reading is controlled reading which allows accommodation without over-convergence.[1] This task is based on physiological diplopia so that when the subject looks at the print, the bar held in front of the print is seen as a blurred double image. If the subject is binocular, the subject will be able to read the print as one eye will always see the text: the left eye sees to the left of the bar and the right eye sees to the right of the bar. If the subject is not binocular, the bar will hide part of the text.

Lyle and Jackson[2] state that reading bars are used to train patients to maintain binocular single vision for reading, while accommodation and convergence are in their correct relationship, for a given size of print at a given distance.

The process of using bar reading is to start the exercise using large print and then reduce down to smaller print.[1] Use of high-contrast bars has been suggested as a way of making the task easier, in that the bar is more easily seen in contrast to the text.[3]

Ability to bar-read with ease is an indicator of the strength of binocular single vision and thus is used as a home exercise to improve binocular single vision in patients with strabismus. Bar reading is advantageous in that it is a stabilising exercise for many patients, inexpensive, portable, fairly simple and not too tiresome as a home exercise. It is used as part of a series of orthoptic treatments.

Bars are available in different colours including black, yellow and red. It is unknown whether a difference in bar reading ability occurs when using these differing colours and whether subjects perceive different colour bars as easier or more difficult when undertaking the bar reading task. The purpose of this study was to identify the effect of using different coloured bars on reading time for the bar reading task, along with an assessment of subject experience with different colour bars.

Methods

Inclusion criteria included the following: presence of binocular single vision, best corrected visual acuity of 0.5 logMAR or better at distance and near fixation, ability to appreciate physiological diplopia, ability to understand the bar reading task, and age 18 years or over (no upper age limit).

A standardised testing protocol was designed and used throughout the testing, to ensure consistency between each subject. This protocol took the form of a subject record sheet used to indicate the order of testing.

To reduce fatigue effects, the colours of bars (black, white, red, yellow, lilac) used when testing were randomly selected. This randomisation was achieved by pre-drawn computer-generated randomised number lists.

Before undertaking any testing, each subject gave informed consent, by reading a participant information sheet and signing the consent form. All testing sessions were undertaken in the same room using standardised illumination, positioning and testing distances.

Subjects were first asked to read aloud the set text at N5 without any bars. The same text was used on repeated assessment. The subject was then asked to use

Correspondence and offprint requests to: Dr F. Rowe, Directorate of Orthoptics and Vision Science, Thompson Yates Building, University of Liverpool, Brownlow Hill, Liverpool L69 3GB. e-mail: rowef@liverpool.ac.uk

Table 1. Reading durations with and without a bar (seconds)

	Without bar	With bar							
		Lilac	Black	Yellow	White	Red	First tested	Last tested	Overall average
N5 text									
Mean value	66.76	63.71	64.26	64	64.58	64.18	66.32	62.63	64.15
Standard deviation	12.25	13.24	12.14	11.88	12.94	12.77	12.62	12.62	12.29
N12 text									
Mean value	37.84	36.13	35.50	35.79	35.74	35.25	36.66	35.00	35.68
Standard deviation	3.37	4.41	3.46	3.42	4.02	4.05	4.05	3.73	3.55

Mean values and standard deviations are provided for 40 subjects assessed with N5 and N12 text.

each of the five coloured bars in turn, the order having been previously generated by way of randomisation. Presbyopes wore their reading glasses for the task. Using their thumb to hold the bar in place, the bar was positioned by the subject between the two lines in the centre of the page. The subject had to focus on the text so that the bar became 'double' in their field of vision. The page then had to be moved to the point that the double bars were just within touching distance of each other. It was only at this point that the text could be read, maintaining this distance. The importance of keeping the head and bar still and not trying to look around the bar to see the text was emphasised to the subject. To help the subject focus on the 'two bars', they were told to try to 'Look through the bar'. The reading task was timed for each colour of bar. During the test the subject was asked to remain aware of any preferences they might have in favour of one particular bar colour and how they felt during the test. This information was then captured in a questionnaire at the end of the testing period. The testing was subsequently repeated with N12 text.

In addition to the bar reading task, the following data were collected: glasses prescription (if worn), best corrected visual acuity, ability to see a cross response on Bagolini glasses at 1/3 metre followed by maintenance of the cross during a prism fusion range measurement, interpupillary distance (IPD) measurement and near point of convergence measurement. If subjects had any prescription glasses, these were worn for the near and distance visual acuity tests, as required.

Data were entered onto an Excel spreadsheet and imported into the SPSS version 15 statistical package. Data for duration of reading task and test results (e.g. fusional vergence, IPD and near point of convergence) were assessed for distribution. Standardly distributed data were analysed with parametric *t*-tests with Bonferroni adjustment, and ANOVA tests. Data that were not standardly distributed were evaluated with non-parametric analysis (Wilcoxon or Mann-Whitney tests). For example, individual preferences for bar colour were evaluated using a Mann-Whitney test.

Results

Forty subjects who met the inclusion criteria were recruited to the study. Two patients were excluded because they were unable to undertake the bar reading task: due to monocular reduced visual acuity relating to anisometropic amblyopia in one subject and mixed myopic/hypermetropic refractive error in the second. Informed written consent was obtained from all subjects and the study conformed to the Helsinki Declaration.

Twelve subjects were male and 26 were female, with a mean age of 35.5 years (SD 12.4). Mean best corrected visual acuity was −0.10 logMAR (SD 0.15) at near fixation. Mean near point of convergence was 9.74 cm (SD 6.51) and mean fusional amplitude was 32.61^{Δ} (SD 14.36). The latter was based on a summed base-out and base-in prism fusion range measurement at near fixation. Mean base-out range was 20.39^{Δ} (SD 11.99) and mean base-in range was 12.82^{Δ} (SD 8.27). Mean IPD was 60.47 mm (SD 3.57).

The durations of each reading task are outlined in Table 1. The mean distance at which the text was held was 32.86 cm (SD 6.88) for N5 and 33.72 cm (SD 6.86) for N12. The mean reading duration for N5 text was 64.15 seconds (SD 12.29) and for N12 text was 35.68 seconds (SD 3.55). No significant difference in duration was found when reading without the bar or with bars of different colours.

In order to minimise the impact of fatigue on reading duration during the bar reading tasks, the colour of the bar was randomised for order of use during the reading tasks. Subjects were also allowed to read the text first without the bar in place. There was no significant difference in the duration of reading with or without the bar in place, or from first reading to last reading task with each bar in place, for either the N5 or N12 tasks.

Eleven subjects (28%) stated they experienced difficulty with the task. Six subjects stated they had difficulty getting the diplopic images of the bar to within touching distance while focusing on the text. The remaining 5 subjects reported individual difficulty with: reading around the bar; needed more concentration to read with the bar; maintaining diplopic images of the bar; holding the bar; and seeing N5 print with the bar in place. There was no significant association for those subjects reporting difficulty with the task when assessed against the variables of age, reduced convergence, reduced fusional amplitude, reading duration, text distance and colour of bar. The only variable approaching significance in association with reported difficulty was base-out fusion range, the subjects who reported difficulty having lower base-out fusion ($p = 0.066$; independent *t*-test).

Nine subjects had reduced convergence ranging from 12 to 32 cm. This was significantly associated with a reduced fusional amplitude and reduced base-out range ($p = 0.035$, 0.029 respectively; independent *t*-test) but not associated with any other variable.

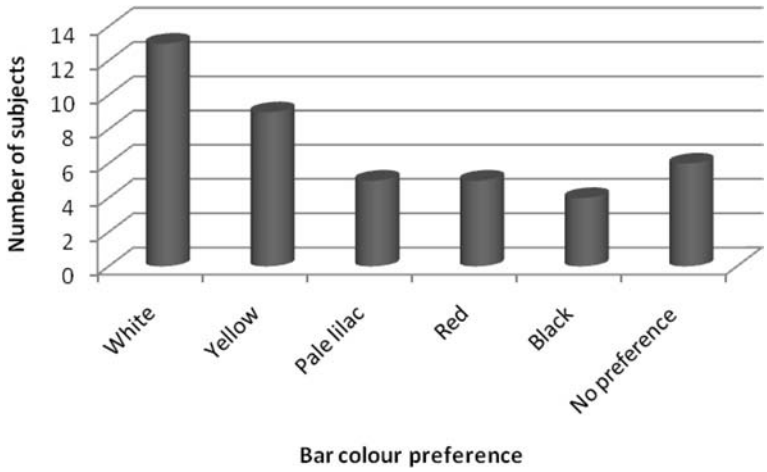

Fig. 1. Bar colour preference.

When asked about their preference for bar colour, 6 subjects stated they had no preference. White was the most popular colour followed by the yellow bar. Lilac, red and black were the least preferred colours (Fig. 1). However, there was no significant increase in duration of reading task with a preferred colour relative to a least preferred colour.

When using a bar reading test, it is possible to calculate a predicted distance (x) at which the text will be held based on the IPD and known distance of the bar from the text. The following calculation was used:

$$\text{Tan} = \text{half of bar width} \div \text{distance of bar from book (mm)}$$

$$= 6.5 \div 80 = 0.08125.$$

$$\text{Tan} = \text{half of IPD} \div x.$$

Therefore

$$x = (\text{IPD} \div 2) \div 0.08125.$$

This was calculated for the subjects in this study and is shown in Fig. 2a. The actual distances at which the text was held were measured for both the N5 and N12 reading tasks and are shown in Fig. 2b and 2c. Although a linear relationship is seen for the theoretical distance and IPD, the same is not seen for actual distances.

Discussion

Physiological diplopia is a natural component of binocular single vision. Its use in bar reading ensures continued viewing of the text despite the temporary block of viewing of each eye in turn by the bar. It is, however, important to ensure that head movements are avoided that would allow the subject to look round the bar.[2]

Colour and contrast are reported to affect reading and attention.[4] Readability of documents depends on the contrast between text and background. High-luminance backgrounds have been shown to have an inhibitory effect on texts of medium or low luminance. Furthermore, the readability of documents depends on the effect of colour on luminance and the select attention in visual search that enhances processsing.[5] Colour and form complexity are shown to increase viewing time[6] and, thus, manipulation of colour, form and luminance can alter the capture of attention.[7] When colour contrast is high, subjects have been reported to read as rapidly as with high-luminance contrast.[8] Individuals with attention deficits have been shown to perform better with high stimuli than low.[9] An early report on bar reading stated that a high-contrast bar allows easier perception of physiological diplopia.[3] This may relate to a high colour contrast attracting and maintaining attention to the task.

Although bars of different colours are available there has been no formal study of whether bar colour makes a difference to achievement of the bar reading task. During this study we randomised the use of five different coloured bars: white, black, lilac, red and yellow. Duration of the reading task was not significantly different for reading without the bar followed by reading with bars of different colours. N5 and N12 text sizes were used in the study and although N5 was more difficult to read because of the smaller print size, there was no significant increase in reading time when the bar was in place compared with unhindered reading of the text with the bar removed. It is acknowledged that the lack of significance found in repeated measures may reflect the small ($n = 40$) numbers of subjects in this study.

Eleven subjects reported difficulty with the task, predominantly related to the ability to focus on the text and not the bar in order to achieve and then maintain physiological diplopia. They needed to make a conscious effort to 'see through' the bar. This has been alluded to in the literature.[1,2] Despite the perceived difficulty, none of these subjects showed any differences in ability to complete the tasks or in the time it took them to complete the task in comparison with those who stated they had no difficulty. There was a trend towards a reduced base-out fusion range in the subjects who experienced difficulty but this did not reach significance level ($p = 0.06$). However, the subjects tested in this study had normal visual acuity, no strabismus and were visually asymptomatic, which constitutes a limitation

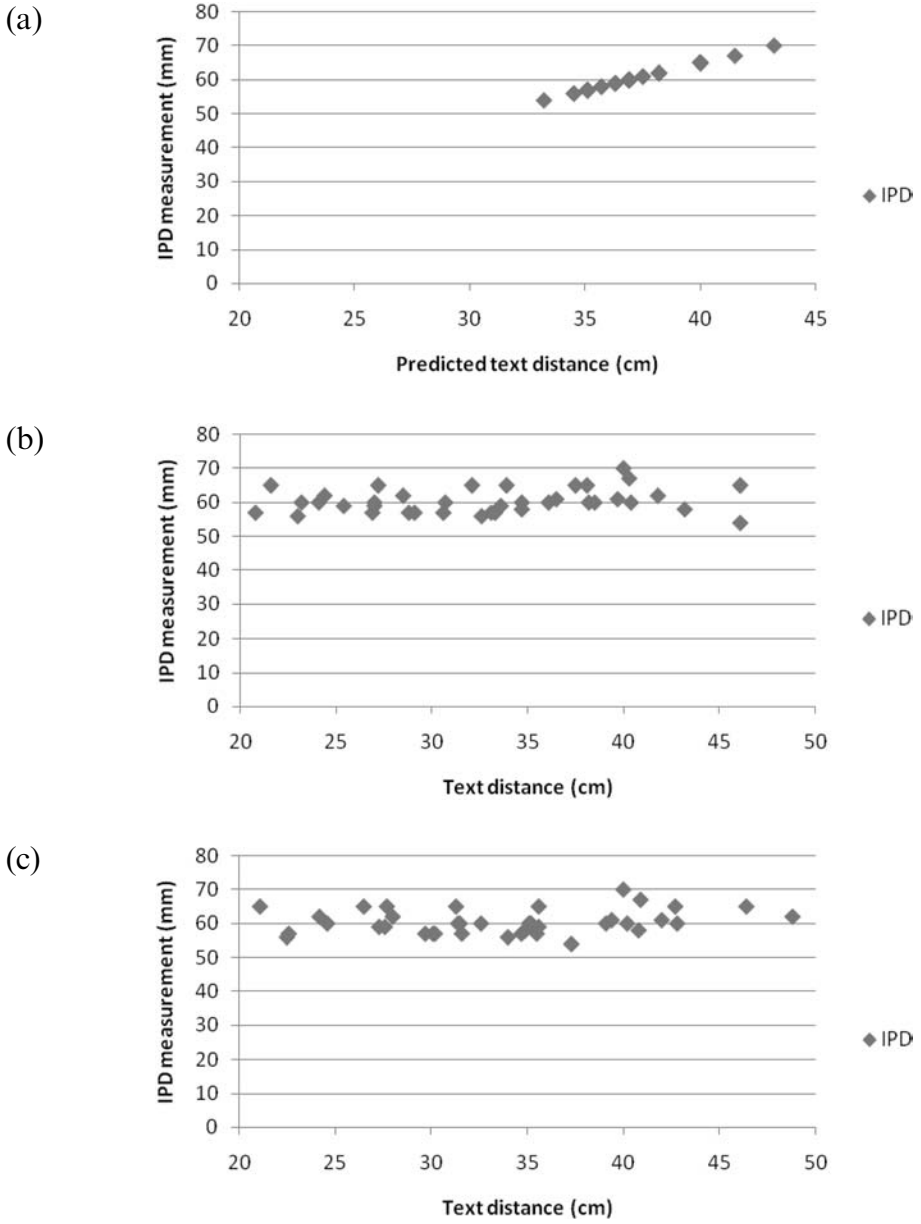

Fig. 2. Interpupillary distance and reading distance relationships. (*a*) Predicted distance. (*b*) Actual distance when reading N5 text. (*c*) Actual distance when reading N12 text.

of the study. Assessment of a clinical population of symptomatic strabismic patients is warranted. Further study with these bar reading tests and perceived difficulty could be hypothesised to show significant associations with reduced binocular single vision measurements in clinical scenarios involving symptomatic strabismic patients. Such a study is a recommendation of this paper.

The use of different colours of bars was evaluated in this study. High colour contrast was achieved with the black, red and yellow bars, with lower contrast being achieved with the lilac and white bars. It has been stated in the literature that bar reading is easier with a high-contrast bar.[3] White was the subjects' most preferred bar colour, followed by yellow. Thus high- or low-contrast colours did not rate very differently. Equally when bar colour was compared with the reading duration for the task, no significant differences between colours were found. A further recommendation of this study would be to evaluate colour preference in a clinical population of symptomatic strabismic patients to determine whether a high-contrast bar is easier to use when initially undertaking bar reading before progressing to a low-contrast bar to make the task harder.

One final aspect of this study was to look at the distance at which the text was held. It is possible to calculate a predicted distance at which the text will be held based on the subject's IPD and the distance of bar from the text. Clinically we have noted that the distances from the subject at which the text is held varies between subjects. However, the actual distances at which the text was held differed from the predicted measurement. The predicted measurement is based on geometric calculation of IPD, bar width and tan angle. What this does not account for is relative accommodation and vergence in

response to accommodative load, which varies considerably among individuals, and this may explain the difference between actual and predicted text distances. Thus, the distance at which the text is held is an individual characteristic that cannot be predicted.

Conclusions

Bar reading has been reported to be a good indicator of binocular single vision at near fixation. The ability to undertake the task on small text such as N5 indicates good control of ocular alignment. Where binocular single vision is weak, bar reading can be used as a home exercise for patients who understand the test procedure and are compliant with it. In this study of subjects with good binocular vision and no strabismus, the choice of bar colour did not show a significant association with improved ability to undertake the task. Thus it may be that the important aspect of the task is the presence of physiological diplopia, regardless of the colour of these diplopic images.

We thank Mrs Gail Stephenson and Mr Craig Murray for their clinical support during the recruitment for this study and Dr Anna O'Connor for her organisation of Nuffield student projects. We should also like to thank the staff at the University of Liverpool for giving their time to participate in the study.

References

1. Hugonnier R, Clayette-Hugonnier S. Strabismus, heterophoria, ocular motor paralysis. In: *Clinical Ocular Muscle Imbalance*. St Louis: Mosby, 1969.
2. Lyle TK, Jackson S. *Practical Orthoptics in the Treatment of Squint*, 3rd edition. London: Lewis & Co., 1949.
3. Mayou S. Mayou bar-reader. Model II. *Br Orthopt J* 1957; **14:** 88–90.
4. Knoblauch K, Arditi A, Szlyk J. Effects of chromatic and luminance contrast on reading. *J Opt Soc Am Assoc* 1991; **8:** 428–439.
5. Fogo de Mattiello ML, Pescio S, Alvarez R. Influence of colour and attention in visual search and readability (abstract). In: *Perception: European Conference on Visual Perception*. 2006; 35: Suppl.
6. Leme-Stern S. Children's visual attention: effects of colour, complexity, movement and incongruity. Education Resources Information Centre.
7. Turatto M, Galfano G. Colour, form and luminance capture attention in visual search. *Vision Res* 2000; **40:** 1639–1643.
8. Legge GE, Parish DH, Luebker A, Wurm LH. Psychophysics of reading. XI. Comparing color contrast and luminance contrast. *J Opt Soc Am Assoc* 1990; **7:** 2002–2010.
9. Zentall SS, Falkenberg SD, Smith LB. Effects of color stimulation and information on the copying performance of attention-problem adolescents. *J Abnorm Child Psychol* 1985; **13:** 501–511.