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The Effect of Wearing ChromaGen Lens II on Visual Stress, Binocular Visual Functions and Reading Performance in Children with Dyslexia

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Abstract

Dyslexia is a neurodevelopmental disorder that primarily affects reading ability. There are many anecdotal claims that coloured lenses and overlays improve reading performance. However, the effectiveness is still controversial. This study aimed to compare visual stress levels, binocular visual functions and reading performance on children with dyslexia without and with the second generation of ChromaGen lens (ChromaGen lens II). A total of 28 children with dyslexia were invited to participate in this study. All subjects were free from ocular and systemic diseases and never had any visual intervention for their dyslexia problem. The study involved pre -and post-assessments of visual stress, binocular visual functions and reading performance without and with ChromaGen lens II wear. Each individual subject chose their own preferred colour of the Chromagen lens II. For both pre-and post-assessments, the subjects completed a computerised visual stress test (Lucid ViSS) and a series of binocular visual function tests (stereopsis, amplitude of accommodation, fixation disparity, lag of accommodation and near point of convergence). The reading performance was assessed based on reading rate and time. The results for visual stress showed no significant difference with and without wearing the ChromaGen lens II (Z = -1.107, p = 0.268). There were no significant differences in other binocular vision functions except for stereopsis (Z = -4.413, p = 0.00) with and without wearing ChromaGen lens II. There were also no significant improvements in reading time (Z = -0.159, p = 0.873) and reading rate (Z = -1.0.47, p = 0.295) with and without wearing the ChromaGen lens II. The findings suggest that ChromaGen lens II does not improve reading performance in children with dyslexia. It also does not change most binocular vision functions except stereopsis.

Keywords: Dyslexia, visual stress, reading, coloured lenses, binocular visual performance

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INTRODUCTION

Dyslexia is a Specific Learning Disorder (SLD) with impairment in reading. It is a type of neurodevelopmental disorder. Individuals with dyslexia have difficulties with word identification because they have poor ability in decoding and spelling (Nourbakhsh et al., 2013). About 80% of people with learning difficulties have dyslexia (Waijuihian & Naidoo, 2011).

Globally, 10%-15% of the population is affected by dyslexia (International Dyslexia Association, 2010). In Malaysia, it has been reported that 10%-15% of the primary school children have symptoms of dyslexia (Nordin, 2015). According to the statistics of the Department of Special Education, Ministry of Education Malaysia, there are about 314,000 children in Malaysia who are suffering from dyslexia (Nor Afzan, 2006). According to the Ministry of Education Malaysia, on average, there is one dyslexia case identified in every 20 students (Komala, 2004).

Children with dyslexia have cognitive function deficits in the higher-order processing or executive control processes, such as, spoonerism, verbal categorical and phonological fluency, visual-spatial and auditory attention, verbal and visual short-term memory and verbal working memory (Brainard 2005; Varvara et al., 2014), poor visual attention span that greatly affects their reading skill (Talcott et al., 2000), difficulties with memorizing (Thomson, 1984) and letter identification (Czaplewska et al., 2011). There are also significant deficits in phonological processing, verbal working memory and processing speed (Hayenga et al., 2009).

Apart from that, these children always report to have difficulty concentrating during reading. They report that the words or letters seen are blurred, double and shake when reading. Headache and eye-strain during reading have also been reported by children with dyslexia. Some of them have difficulty reading under bright light because of glare. The same symptoms have been reported by individuals with visual stress. According to a study, the prevalence of visual stress is high amongst individuals with dyslexia (Singleton & Henderson, 2007). The study also shows that 41% of children with dyslexia had visual stress.

Visual stress is the inability to see well without any interference (Wilkins 1995). When a person experiences visual stress, the ability to read for a long time is interrupted. The theory that link dyslexia and visual stress is hyper-excitation of the visual cortex. This hyper-excitation is caused by extreme sensitivity to contrasts or patterns that dazzle while reading (Wilkins et al., 2004) whereby the visual neurons fire inappropriately (Wilkins, 1995).

Children with dyslexia encounter various difficulties. Therefore, it is vital to have structured effective interventions. Most of the interventions have focussed on teaching methodologies. A systematic review of research done in improving reading using coloured lenses and overlays have been published in 2016 (Griffiths et al., 2016). The study reported that majority of studies were subject to 'high' or 'uncertain' risk of bias in one or more key aspects of study design or outcome, with studies at lower risk from bias providing less support for the benefit of coloured lenses/overlays on reading ability. The study also noted that while many studies reported improvements with coloured lenses, the effect size was generally small and/or similar to the improvement found with a placebo condition.

The general objective of this study was to compare visual stress levels, binocular visual functions and reading performance on children with dyslexia without and with the second generation of ChromaGen lens (ChromaGen lens II).

METHODS

Participants

The subjects consisted of children with dyslexia aged 7 to 12 years and were selected from two Dyslexia Centres in the Klang Valley. Subjects had met the following selection criteria; have normal visual acuity of 6/9 or better with best correction of refractive power or emmetropia, free from ocular and systemic disease and never had any visual intervention for dyslexia.

This study was approved by the Ethics Committee of Universiti Kebangsaan Malaysia and followed the tenets of the Declaration of Helsinki in using human subjects. The purpose and procedure of the study was explained to the parents and the participants. Written informed consent was obtained prior to commencement of the study. The sample size was calculated using the Cochran (1963) formula. The sample size required was 27 subjects after taking into account the dropout of subjects. A total of 41 children with dyslexia were screened for this study. However, it was found that only 28 children with dyslexia met the selection criteria and were given permission by the parent/guardian to participate in this study.

Procedure

Before the study began, a comprehensive eye examination was performed on all subjects. This included assessment of visual acuity for distance and near, retinoscopy, and subjective refraction, the amplitude of accommodation, near point of convergence and ophthalmoscopy. Subjects who fulfilled the inclusion criteria were then recruited into the study. First, a pre-assessment was conducted, followed by a selection of ChromaGen lens II and finally post-assessment was done.

Pre-assessment

The pre-assessment was conducted after the completion of the comprehensive eye examination. If any subject required spectacles or contact lenses, a prescription was given but the pre-assessment was carried out after 2 weeks. This was done to allow for adaptation to the prescription. If the subject did not require any new prescription, the pre-assessment was conducted after a 15 minutes rest period.

The pre-assessment tests consisted of computerised visual stress level assessment, binocular vision function assessment and reading time and reading rate determination. The binocular vision functions that were assessed were stereopsis using TNO, the amplitude of accommodation and near point of convergence using the RAF rule, lag of accommodation using monocular estimation method (MEM) and fixation disparity (FD) using the Mallet Near Unit. This was followed by determining the reading time and reading rate with a standard text. MEM is a form of dynamic retinoscopy used to objectively measure accommodative response at a near working distance. A special near-point card having a central hole was attached to the head of the retinoscope. The card had a paragraph with approximately 6/9 text on the card. The examiner evaluated the retinoscopy reflex with the streak oriented vertically, while the subject read the text on the card adjacent to the central hole. The examiner used lenses to neutralise the reflex motion. The lowest power lens that neutralised the reflex was recorded as the lag of accommodation. The Mallet Near Unit used to measure FD has a central fixation target 'OXO' which is seen with both eyes and two monocular markers in line with the 'X' which is seen with each eye using cross polarising filters. There was also text in the background. The test can measure horizontal fixation disparity and vertical fixation disparity. The subject was asked to wear polarising filters and instructed to first read the text in the background to stabilise the accommodation response on the plane of the Mallet Near Unit. The subject was then directed to see the 'OXO' target and indicate if the two marker lines were aligned or not. If they were not aligned, the examiner placed a prism until the two marker lines were aligned. The minimum prism needed to align the two lines was noted as the fixation disparity.

Visual Stress Measurement

Lucid ViSS (Visual Stress Screener) is an objective computerised test that has been developed to screen visual stress for children from age 7 to adult. The test by ViSS delivered by computer and required minimal supervision. The screening test in the form of word search game, it takes 20-30 minutes to finish. The format and content of a word search game are according to the age of person being screened. This test is done under two conditions; visually stressful and visually non-stressful. The result comes in a graphical scale of susceptibility to visual stress; from 'low' to 'extremely high', and a full statistical analysis is also provided.

The visual stress level is displayed on a 7-point graphical scale which include low, borderline, slight, moderate, high, very high and extremely high. The degree of susceptibility to visual stress measure is according to the following data; the probability level associated with the t statistic, percentage increase in search time from the non-stressful condition to the stressful condition and the effect size. For example, if the t statistic is not significant (i.e., $p>0.05$) or if the percentage increase in search time from the non-stressful condition to the stressful condition is less than 10%, ViSS will classify the child as having a 'low risk' of visual stress. If, however, the t statistic is significant (i.e., $p<0.05$ or smaller) or if the percentage increase in search time from the non-stressful condition to the stressful condition is 10%-19% or greater, ViSS will classify the person as exhibiting 'borderline risk' and so on.

Procedure for reading performance

Reading text with the standard distance between words was constructed for this study. Twenty words were randomly selected from a group of syllables to form a more systematic set of words. Syllable consists of a consonant and vowel. Each reading text consisted of 20 unrelated words. Words were printed in Arial font with 16-point size letters. Unrelated reading text consisting of 20 words were printed in the form of five lines with four words in each row. Each set of words was printed on white A4 paper (80 gsm) with 100% contrast.

Reading time was measured according to the length of time needed for the subject to finish reading the text (in seconds). Reading rates are speed needed by subject to read the words correctly (in words per minute). The formula for reading rates is as follows:

$$B = \frac{(20 - \chi) \times 60}{\check{T}}$$

B = rate of reading (the number of words per minute, ppm)
χ = error of reading the word (number of words)
$\check{T}$ = time it takes to read all the words (in seconds).

Unit for the reading time is second (s) while the unit for reading rates is words per minute (wpm). Subjects were required to read the standard text and the results were recorded.

ChromaGen lens II selection

The ChromaGen II lens system comprises of sixteen different shades of grey coloured lenses. The system helps in treating visual distortions by resynchronising the wavelength of light reaching the eyes, which claims to enable the individual with dyslexia to improve their ability in reading. Besides helping dyslexia problems, the ChromaGen II can also help colour vision deficiency patients. The ChromaGen II lens system gives a better cosmetic outward appearance with neutral tinted colour lenses compared to other colour corrective lenses for dyslexia and colour vision deficiency problems.

The optimum ChromaGen lens II was determined according to the recommended manufacturer's instructions given in the manual. Subjects select their own preferred lens shades monocularly to ensure that each eye receives the best and optimum lens shade. Subjects wore their full prescription. In bright lighting conditions, the dominant eye was determined. The subject was asked to look at the standard reading text placed at 40cm. The ChromaGen lens II was first placed on the dominant eye one at a time. ChromaGen lens II selection began with lens label 1 and ended with lens label 16. The subject was asked to compare the level of text clarity between each lens and asked to state which lens provide the best clarity and comfort while reading. This is chosen as the optimum lens for the patient. The procedures were repeated for the non-dominant eye. Once optimum lenses had been selected for each eye, both eyes now wore the chosen lenses for the following examination.

Post-assessment

Fifteen minutes rest was given to the subject. The subjects then wore their chosen ChromaGen lens II. All pre-assessment measurements of computerised visual stress level assessment, binocular vision function assessment and reading time as well as reading rate were measured again.

RESULTS

A total of 28 children with dyslexia with a mean age of 8.93 ± 0.281 years participated in this study. The mean distance and near visual acuity were both 0.00 ± 0.00 logMAR (see glossary list below). The mean spherical equivalent was 0.01 ± 0.38 D for the right eyes and 0.09 ± 0.43 D for the left eyes, mean amplitude of accommodation was 19.71 ± 1.08 D, mean near point of convergence was 5.07 ± 0.38 mm.

Visual Stress

The visual stress level of children with dyslexia was determined through a computerized visual stress test, Lucid ViSS. Table 1 shows the visual stress levels without and with wearing ChromaGen lens II.

Fifty percent of the subjects (14 subjects) had low levels of visual stress and only 3.6% (1 subject) had high visual stress level. Wearing the ChromaGen lens II seemed to increase the visual stress of subjects to moderate and high levels.

As can be seen from Table 2, the level of visual stress with wearing the ChromaGen lens II was higher (2.39 ± 1.59) compared to without wearing ChromaGen lens II (2.07 ± 1.21). However, Wilcoxon Sign Rank test results indicate that there are no significant differences for visual stress level without and with wearing the ChromaGen lens II ($Z = -1.107$, $p = 0.268$). Similarly, there was no significant difference in search time for both visually stressful and visually non-stressful screen without and with wearing ChromaGen lens II.

Reading performance

Reading time and reading rate of subjects without and with wearing ChromaGen lens II are shown in Table 3. There was no significant difference in reading time and rate without and with ChromaGen lens II. There was a significant difference in reading time and rate without ChromaGen lens II between high and low visual stress levels.

Binocular vision functions

Wilcoxon Sign Rank test was used to test differences in mean stereopsis, amplitude of accommodation, fixation disparity (FD), lag of accommodation and near point of convergence before and after wearing ChromaGen lens II. Test results indicated that there were significant differences in stereopsis ($Z = -4.413$, $p = 0.00$) without and with wearing ChromaGen lens II. However, there were no significant differences in the amplitude of accommodation ($Z = 0.00$, $p = 1.00$), fixation disparity ($Z = 0.00$, $p = 1.00$), lag of accommodation ($Z = 0.00$, $p = 1.00$) and near point of convergence ($Z = 0.00$, $p = 1.00$) without and with wearing ChromaGen lens II. The mean values for stereopsis without and with wearing ChromaGen lens II were 87.10 ± 77.21 sec of arc and 131.61 ± 74.97 sec of arc.

Table 1. Visual stress levels without and with wearing ChromaGen lens II.

Visual Stress Level	Number of subjects (without ChromaGen lens II)	Number of subjects (with ChromaGen lens II)
Low	14	14
Borderline	2	2
Slight	9	3
Moderate	2	5
High	1	4

Table 2. Mean level of stress and mean search time without and with wearing ChromaGen lens II.

	Level of visual stress	**Mean search time for visually stressful screen (sec)**	**Mean search time for visually non-stressful screen (sec)**
Without ChromaGen lens II	2.07 ± 1.21	44.30±30.83	35.93±21.94
With ChromaGen lens II	2.39 ± 1.59	33.66±23.02	31.15±23.89
	p = 0.268	p = 0.329	p = 0.055

Table 3. Reading time and reading rate without and with wearing ChromaGen lens II.

Level of stress	**Reading time Without ChromaGen lens II**	**Reading time With ChromaGen lens II**	**p-value**	**Reading rate Without ChromaGen lens II**	**Reading rate With ChromaGen lens II**	**p-value**
Low	56.33±46.14	74.42±55.50	0.685	33.68±23.57	29.03±27.65	0.976
High	110.16±51.41	80.31±57.75	0.584	12.53±9.72	23.43±19.62	0.613
	p = 0.003	p = 0.087		p = 0.001	p = 0.074	

DISCUSSION

In this study, we compared the visual stress, binocular vision functions, reading time and reading rate of children with dyslexia., and also without and with ChromaGen lens II. We found that 50% of the subjects (14 subjects) had low levels of visual stress and only 3.6% (1 subject) had high visual stress level. Irlen (1980) also stated that 46% of individuals with dyslexia suffer from visual stress. It was also seen that wearing ChromaGen lens II seemed to increase the visual stress of subjects to moderate and high levels. Although the level of visual stress with wearing the ChromaGen lens II was higher (2.39 ± 1.59) compared to without wearing ChromaGen lens II (2.07 ± 1.21) it was not statistically significant. Similarly, there was no significant difference in search time for both visually stressful and visually non-stressful screen without and with wearing ChromaGen lens II. Our study showed that there was a significant difference in reading time and reading rate without ChromaGen lens II between high and low visual stress levels. However, there was no significant difference in reading time and reading rate with ChromaGen lens II between high and low visual stress levels. There was also no significant difference in reading time and rate between without and with ChromaGen lens II for both the high and low visual stress levels. This is different to the study by Lopez (2011) in which reading speed improved in the subjects without visual stress but did not improve in the subjects with visual stress. However, many studies had shown that use of coloured lenses did improve reading performance of subjects with visual stress (Saint-John & White, 1988; Robinson & Conway, 1990, 1994; Robinson & Foreman, 1999a, 1999b). According to Lopez (2011), this improvement could be due to attributable bias in which subjects changed their visual stress response criterion.

To date, only 4 studies have been conducted to determine the effectiveness of ChromaGen lens to improve reading performance. The first study was by Harris and MacRow-Hill (1999) in which a comparison was made between ChromaGen contact lens and a placebo lens carrying a light blue handling tint to improve reading fluency in adults with dyslexia. The study was described as 'double-blind' but the subjects would have been aware of the type of lenses they were wearing. Nevertheless, the research team who conducted the assessments were masked to the group status. The study showed that there was a statistically significant increase of 12 wpm (a 15% increase) relative to the baseline reading rate. Similarly, there was also a significant increase of 7 wpm with the placebo lens (an 8% increase) compared to baseline. However, the improvement in reading rate with the ChromaGen lenses was statistically significant relative to both the baseline reading rate and the improvement seen with the placebo lenses. It was noted that the subjects who received the ChromaGen lenses first before the placebo lenses showed a significantly larger improvement in reading rate compared to those who received the placebo first. There was also bias in that the subjects were recruited through publicity advertising the benefits of coloured lenses.

The study by Cardona et al., (2010) compared reading speed between subjects wearing ChromaGen lenses and a clear placebo lens. The subjects were told that placebo lens had a new invisible tint. The study showed that both placebo lenses and ChromaGen lenses improved reading speed relative to the control group where no lenses were worn. Another 2 studies (Hall et al., 2013; Harries et al., 2015) compared Harries lenses with blue or yellow lenses from the Dyslexia Research Trust (DRT) system. Both studies recruited students from mainstream state primary school, thus, removing external bias. However, both studies had no placebo group or no lens control group. The study method was also not clear as to whether the subjects who chose the filters used it for a continuous 3-month period. At the end of 3 months, both groups showed improvement in reading ability in children with reading delay. Our study also has the same limitation as we had no placebo group.

In our study, most binocular vision functions except stereopsis did not change without and with wearing ChromaGen lenses. The stereopsis of children with dyslexia was reduced after wearing ChromaGen lens II. This could be due to the colour of the lenses.

CONCLUSION

Our study showed that ChromaGen lens II does not improve reading performance in children with dyslexia. However, the results are from immediate effect after wearing ChromaGen lens II. The improvement in reading performance for children with dyslexia maybe significant if these lenses were worn for a longer period.

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GLOSSARY

Dioptre (D)
A unit of refractive power, which is equal to the reciprocal of the focal length (in metres) of a given lens.

Log MAR
An acronym for *Logarithm of the Minimum Angle of Resolution*. This describes the letter size scoring from a vision test that uses LogMAR vision chart. LogMAR 0.00 is equivalent to 20/20 vision.

RAF rule
An acronym for *Royal Air Force Rule*. This ophthalmic tool is used to measure objective and subjective convergence and accommodation. Convergence ability is measured in centimetres and amplitude of accommodation is measured in dioptres.

TNO
An acronym for *Toegepast Natuurwetenschappelijk Onderzoek* (Dutch), also known as Netherlands Organisation for Applied Scientific Research. The TNO test is developed as a screening test for stereopsis and depth perception and measured in seconds of arc.

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