S Afr Optom 2011 **70**(2) 69-74

Chromagen lenses and abnormal colour perception

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Received 26 October 2010; revised version accepted 16 May 2011

Abstract

Background: The Chromagen lens system comprises of tinted spectacle or contact lenses, each with a specific colour wavelength filter which controls the spectra of the light entering the eye. This study investigated whether spectacle-mounted Chromagen lenses would enhance colour perception in individuals with abnormal colour vision.
Methods: The Ishihara colour test was used to test for colour vision deficiency (CVD) and also to evaluate the effect of the Chromagen spectacle lens on colour perception in 13 subjects. An Oculus Anomaloscope was used to confirm and sub-classify the types of CVD. Subjects comprised of school age children from the Riyadh area in Saudi Arabia.
Results: The distribution amongst the male participants comprised two subjects with protanomaly, two with protanopia, five with deuteranomaly, and two with deuteranopia. Amongst the two female participants, one subject showed deuteranomaly, and one showed protanomaly. Different types of Chromagen spectacle lenses displayed some levels of colour vision enhancement depending on type of CVD.
Conclusion: The findings support the notion that chromagen lenses could enhance colour vision perception in some cases of red-green colour vision defects. Clients with CVD should be managed on an individual case basis. (*S Afr Optom* 2011 **70**(2) 69-74)

Key words: Chromagen lenses, colour vision deficiency, Ishihara colour test, anomaloscope

Introduction

Individuals with abnormal colour vision may simply have a reduced sensitivity to certain colours, which appear rather muted and lack natural colour vibrance. However, this reduced sensitivity can be very significant, with the affected person having considerable difficulty discriminating amongst even quite marked differences in shades (hues) of a given colour[1]. Conversely a patient may have such a minor colour vision deficiency that he or she may be completely unaware of the problem until it is detected during a routine or screening eye examination. This can sometimes be a considerable shock, especially if the subject is engaged in a career making decision where the desired career involves making colour based judgements[1]. For example, traffic lights would generally look different to people with red-green CVD. However, most drivers with CVD would judge traffic lights based on the position of the lights and rarely present with problems in identifying the traffic light indicators. The several daily challenges faced by individuals with CVD un-

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derscore the significance of colour vision enhancement ophthalmic aids to individuals requiring such aids. One type of colour vision enhancing aid is the Chromagen lens system.

The most common forms of inherited CVDs are the red/green types with the blue defects occurring very rarely in inherited form. Complete achromatopsia - a complete lack of colour vision in which an individual can only see shades of grey, is also very rare. The prevalence of both congenital blue defects and achromatopsia is estimated[1-3] at a frequency of 1:30300, affecting males and females equally[4]. In humans, colour vision sensations are produced by different combinations of the primary colours: red, green and blue. In terms of terminology, deficiencies in colour vision may result from a partial (-anomaly) or complete (-anopia) inability to perceive any of the primary colours. According to the deficient or abnormal cone pigments, colour blindness may be classified into protan (red), deutan (green) and tritan (blue) types.

Normal colour perception has a significant impact on optimal educational, professional, and social activities/performance. Any assistive device that can help those with abnormal colour perception would be beneficial. A currently available assistive device that has been promoted commercially for colour perception enhancement in clients with abnormal colour vision is the series of Chromagen spectacle or contact lenses. A survey of the ophthalmic literature shows that experimental investigation regarding the use of the Chromagen lens in improving the colour perception has not been fully explored[5-11]. The Chromagen lens system was developed by David Harris in England, and has been widely promoted particularly in the United Kingdom[5]. The Chromagen lens system comprises of lenses, each with a wavelength filter which controls the spectra of the light entering the eye. The Chromagen lens tints are available in seven hues (magenta, pink, violet, yellow, aqua, orange and green), and most tints are available at light, medium and dark densities. The question is 'how does the Chromagen lens system work?'. The CVD patient uses an appropriate tinted lens in one of the eyes, usually the non dominant eye. In this case both eyes actually see different colours and because of that the brain can extract some other information out of certain colours. Patients can also use two different tints in each of their eyes. This depends very much on patient's personal impression and choice. It should be noted that the system will not work if the same coloured lenses are used in both eyes[11].

However, despite the widespread promotion and prescribing of the Chromagen lens system, there still exists a dearth of information in peer-reviewed scientific literature regarding the lens[5]. The Chromagen lens system in both contact lens and spectacle lens forms, uses filters to make comparative changes in the brightness of coloured objects, thus enhancing colour perception. It should be noted that the concept of assisting colour perception in individuals with CVD, utilizing tinted lenses was first proposed in 1837 by a German scientist, namely August Seebeck who wrote about the possibility to correct colour vision deficiency with some sort of coloured lenses[6]. Historical reviews regarding the development of coloured ophthalmic lens aids for CVD are available in the literature[7-11].

Every colour defective individual has a different colour perception level. The results of Swarbrick *et al*[5] suggest that deutan subjects are likely to show greater improvement with Chromagen lenses, than protan subjects using a colour test such as the Ishihara colour plates. Also, Richer and Adam[9] were of the opinion that deutan subjects are likely to derive more useful luminance information from the use of a red filter, while protans may be more reliant on chromaticity cues[9]. The objective of the present study was to investigate the effect of the Chromagen lens on the colour vision of Saudi Arabian school children with abnormal colour vision perception.

Methods

Participants ranged between 8 and 19 years of age and were randomly selected from schools in Riyadh city. Children were screened for colour vision defects and the results are reported elsewhere by the same authors[12]. Colour vision deficient subjects and their parents were questioned about any history of previous medical or ocular disease or long-term use of medication to rule out acquired colour defects. Near visual acuity for all subjects was normal. Subjects with any evidence or history of ocular pathology were excluded. Informed consent was obtained from all subjects. The study received the appropriate approval from the King Saud University College of Applied Medical Science Research Committee, and the protocol for the research project followed the tenets of the Helsinki declaration. Colour vision was tested using the

Ishihara 24 plate colour test (at a reading distance of approximately 60 - 70 cm from subject's face), under stable non-flickering fluorescent light with a minimum illumination of 280 lux. The minimum illumination of 280 lux has been described to be adequate for valid colour vision testing[13, 14]. The Ishihara is a generally accepted method for clinical colour screening and gross detection of congenital red/green colour defects by investigators[15-19]. The Ishihara colour plates were held 60 - 70 cm from the subject and tilted so that the plane of the page was at right angles to the subject's line of vision.

All the tests were conducted under binocular viewing conditions. Each subject was asked to read the numbers on the first 13 plates, and describe what he or she could see on pages 14 and 15 with five seconds per plate allowed. The test was performed twice for all subjects. A subject who made five or more errors between plates 1 and 15 during the first and/or second test sessions was judged to have a red/green CVD. Every subject considered to have failed the test was retested for a third time. According to the manual, some of the subjects with red/green deficiency could erroneously describe plate 14 as 5, and plate 15 as 45 (making it a total of 15 pages that subject had to identify, hence the calculation for percentage improvement was based on 15 pages as the denominator). Subjects who had at least five errors at two out of three test sessions were then shown the Ishihara diagnostic plates (16 and 17) to determine if the CVD was a protan or deutan type. Plate numbers 18 to 24 were not used in this study as subjects could read numerals. The responses provided by subjects for each plate were recorded on a special study form which contained information such as age, code number, gender, type of red/green deficiency (as observed), type of chromagen lens used (based on wavelength transmission), and number of correct responses without and with the application of Chromagen lens.

The data were then analysed, and the CVD cases were classified and confirmed using the Oculus Heideberg Multicolour (HMC) Anomaloscope into: red colour deficiency which included mild deficiency (protanomaly) or severe (protanopia); or green colour deficiency, which was either mild (deuteranomaly) or severe (deuteranopia). The anomaloscope was used in its screening mode to quickly uncover any abnormal colour vision. The subject was shown five different colour matching presentations in succession by the instrument program; and was required to evaluate them as being identical or different by pressing the *equal* button (on the right of instrument) or *unequal* button (on the left of instrument). For the screening mode, it is not necessary that the subject undertakes a colour adjustment in the upper mixed colour field, therefore the subject was instructed to use only the lower knob. The results obtained with the anomaloscope enable the researchers to classify the subjects as being normal or having a protan or deutan defect. Subjects were then further sub-classified into protanopes (dichromats), protanomalous trichromats, deutanopes and deutanomalous trichromats with the anomaloscope.

The numbers of correct responses with the Ishihara colour plates without and with Chromagen lens type employed were determined, and the percentage level of improvement in colour perception was calculated for each subject. The colour vision screening revealed 19 subjects with red-green defects. However, only 16 subjects (age range: 8 to 19 years) were confirmed by the anomaloscope test which sub-classified the CVDs as explained above, and 13 subjects agreed to participate.

Firstly, all the subjects that agreed to participate went through oculo-visual examination to re-assess their refractive error status and corrections. Appropriate compensation for any refractive error was employed. Secondly, the non-dominant eye was determined. Thirdly, the subject's attention was directed to the Ishihara plates, and different Chromagen trial lenses placed in front of the non-dominant eye to determine the appropriate lens for that eye. The subject was asked to identify, and indicate whether the colour plate was clearer and easier to read with or without the chromagen lens. Fourthly, the subject's positive chromagen filter lens selections were narrowed down to a single lens by forced choice clinical approach, with the selected lens held in front of the non-dominant eye in a trial frame. Then, there was a repeat of the procedure from the third step with the dominant eye.

Results

Thirteen subjects participated in the study and amongst the male subjects there were two with protanomaly, two with protanopia, five with deuteranomaly, and two with deuteranopia. While among the

female participants, one subject showed deuteranomaly, and one showed protanomaly. Different types of Chromagen spectacle lenses showed different levels of colour perception improvement based on the type of colour vision defects present. The Chromagen lens was tested on the 13 subjects, out of which 11 experienced some level of enhancement in their colour vision perception, and two did not report any difference with the chromagen lens selections. Figure 1 shows the relative comparison between the CVD types with respect to gender. Table 1 shows the summary of the types and pattern of CVDs without and with the type of chromagen lenses selected.

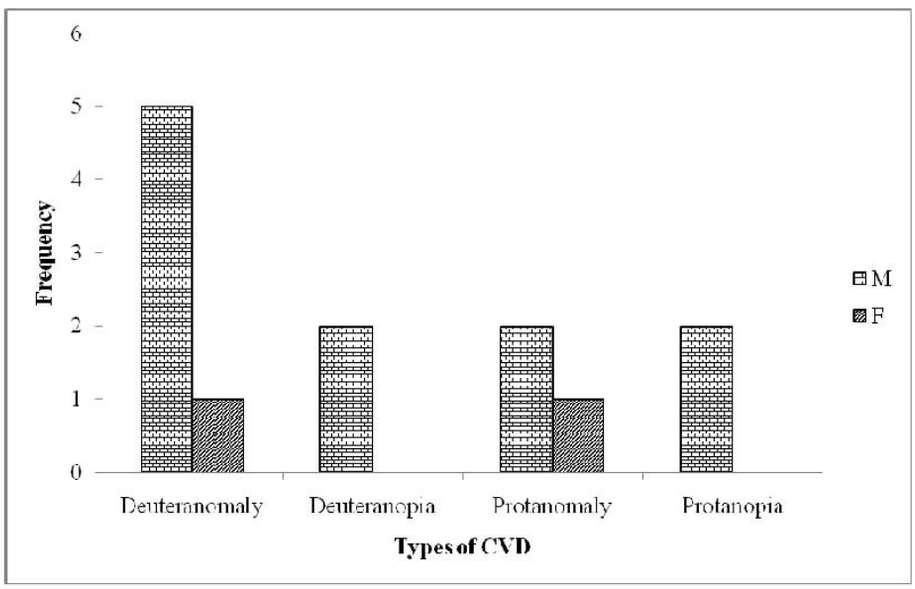

Figure 1 Relative comparison between the CVD type in terms of gender distribution (M and F represent male and females, respectively on the graph)

Table 1 Types of CVD, Dominant eye, Chromagen lens tint chosen by the subject, and Colour perception level before and after Chromagen lens evaluated with Ishihara 24 colour plates (2007) edition. Subject numbers 8 and 12 were the 2 females with CVD in the results.

Subject Number	Age (Years)	Type of CVD	Dominant eye	Number of pages identified correctly without lens	Chromagen filter lens tint selected	Number of pages identified correctly with Chromagen lens	Percentage improvement
1	13	Deuteranomaly	OD	10	Orange	14	27%
2	18	Deuteranomaly	OD	7	Magenta	14	47%
3	12	Deuteranomaly	OD	9	Magenta	14	33%
4	17	Deuteranopia	OD	1	Magenta	11	67%
5	8	Deuteranomaly	OS	6	Pink	10	27%
6	13	Deuteranopia	OD	1	Pink	12	73%
7	8	Protanomaly	OD	9	Pink	12	20%
8	16	Protanomaly	OD	7	Magenta	11	27%
9	20	Protanomaly	OD	10	Pink	14	27%
10	9	Protanopia	OS	1	Magenta	10	60%
11	14	Deuteranomaly	OS	8	No choice	No difference	NA
12	16	Deuteranomaly	OD	4	Magenta	12	53%
13	15	Protanopia	OD	1	No choice	No difference	NA

Note: *Percentage improvement is calculated by subtracting the Number of pages identified correctly without Chromagen lens from the Number of pages identified correctly with Chromagen lens, divide by 15 pages and multiply by 100. NA means not applicable.*

Discussion

Overall, the present study indicates that the subjects with deutan defects (i.e. deutans) improved more in their colour perception compared to subjects with protan defects (that is, protans) with the application of the chromagen lenses. This finding is in agreement with Swarbrick *et al*[5] who also found that deutans improved more than protans on the Ishihara plate test in their study with ChromaGen contact lenses. In the analysis of the CVD sub-classifications, the subjects with deuteranopia saw an average of 7% of the 15 Ishihara test pages at screening, but achieved an average of 70% improvement with the chromagen lenses. However, the subjects with deuteranomaly achieved approximately 33% improvement in their colour perception level. The lower improvement achieved among the subjects with deuteranomaly (deuteranomalous trichromats) might be due to the fact the number of pages seen correctly without the chromagen lens was about 45% compared to 7% in the deuteranopes (subjects with deuteranopia or dichromatic deutans). For the protans, without the chromagen lens, the number of pages seen correctly among subjects with protanomaly ranged from 27 to 55% (average 40%), which improved by an average of 24% with the chromagen filter lenses. The two subjects with protanopia (dichromatic protans) without the chromagen lens, initially identified only 7% out of the 15 pages correctly, this value improved by 60% in only one protanope with the chromagen spectacle lens, while the other subject with protanopia did not experience any improvement.

Though using two different tests, it can be argued that the results with the Ishihara test, showing deutans to achieve more improvement with the chromagen lenses as obtained in this study is comparable to previous finding with the D-15 test by Richer and Adams[9]. The trend of the data in this study appears to be in line with the comment made by Richer and Adams[9] that deutans are likely to derive more useful luminance information from the use of a red filter with the D-15 test, while protans may be more reliant on chromaticity cues, resulting in poorer performance due to confusion. They[9] also hypothesised that individualised filters could be designed to optimise colour vision for specific occupational tasks, a concept that possibly underlies the ChromaGen lens system's multiple tint design.

Our finding also support that of Hodd[20], that the Chromagen lens can enhance colour perception, that is to some individuals, make colours appear brighter and more obvious[21]. This seems true particularly in those with dyslexia[22]. The Chromagen lenses have been successful for vocational use by electricians, electronic engineers, graphic artists, police officers, sign writers, textile workers, photographers and others[20]. Despite the positive reports in the literature about the efficacy of chromagen lens colour vision therapy[20], there still exists certain cautions on the clinical dispensing such as informing the patients of the pronounced three dimensional view at the initial stage which gradually becomes natural with time[5, 20], however, this is beyond the scope of the present study. Further study is required for long term follow-up assessment on subjects who actually wear the Chromagen spectacle lenses.

In conclusion, this study provides additional information on the effects of chromagen tinted lenses on red/green colour perception. The results show that subjectively, 15% of participants did not observe any difference with the chromagen lens, while 85% reported some enhancement in colour perception with the chromagen filter lenses. Generally, it is expected that operators of public or commercial transportation must have normal colour vision, and also police officers, firefighters, and pilots. Some occupations do not have formal requirements but the nature of the work may put people with colour vision defects at a disadvantage.

Currently, no medical treatment exists that can cure colour vision defects, except in some rare cases in which the colour vision defect was acquired, and the underlying pathology was successfully treated. In addition to chromagen lenses (UK), there are other colour correction lenses such as ColorMax (USA), ColorView (USA), and Colorlite (Hungary). However, it should be noted that there are some drawbacks with coloured or tinted filter lenses, such as visual experience difficulties in dim light or at night when wearing tinted lenses to improve colour perception, therefore the optometrist or ophthalmologist should be consulted for professional care. One limitation in this study is that it is a one session assessment of the improvement with the chromagen lenses. Although the Ishihara test is the most commonly used in clinics, future study is however needed to investigate whether other tests such as the FM 100-Hue test, Farnsworth

D-15, Desaturated D-15, Medmont C100 and anomaloscope would yield similar results.

Acknowledgement

The authors would like to thank all the participants in the study, and Khawater Alqabbani and Dr Hossam Shaban of the Riyadh Eye Care Center for their assistance.

Disclaimer: The authors have no commercial or proprietary interest in any product mentioned.

References

1. McIntyre D. Colour blindness - Causes and effects. Chester, UK: Dalton Publishing, 2002 pp4-141.
   Pokorny J, Smith VC, Verriest G. Congenital Color Defects.
2. In: Pokorny J, Smith VC, Verriest G, Pinkers AJLG, eds. *Congenital and Acquired Color Vision Defects.* New York: Grune and Stratton, 1979 pp183-241.
3. Voke J, Voke PR. Congenital dyschromatopsia among Saudi Arabians. *Saudi Med J* 1980 **1** 209-214.
4. Muller RF, Young ID. *Emery's Elements of Medical Genetics.* Ed 11. Edinburg: Churchill Livingstone, 2001 pp101-104.
5. Swarbrick HA, Nguyen P, Nguyen T and Pham P. The ChromaGen contact lens system: colour vision test results and subjective responses. *Ophthal Physiol Opt* 2001 **21** 182-196.
6. Schmidt I. Visual aids for correction of red-green colour deficiencies. *Can J Optom* 1976 **38** 38-47.
7. Fletcher R. The prescription of filters for Daltonism. *Ophthal Opt* 1980 **20** 234-340.
8. Egan DJ. The application of selected broadband red filters for red-green deficiencies. *Can J Optom* 1982 **44** 50-57.
9. Richer S, Adams AJ. An experimental test of filter-aided dichromatic color discrimination. *Am J Optom Physiol Opt* 1984 **61** 256-264.
10. Harris D. *ChromaGen Clinical Procedures*. Chromagen, Wirral, UK, 1997.
11. Harris D. Colouring sight: a study of CL fittings with colour-enhancing lenses. *Optician* 1997 **213** (5604) 38-41.
12. Oriowo OM, Alotaibi AZ. Colour vision screening among Saudi Arabian children. *S Afr Optom* 2008 **67** (2) 56-61.
13. Dain SJ, Honson VJ. Selection of an optimal light source for the FM-100 hue test. *Doc Ophthalmol Proc Ser* 1989 **52** 425-432.
14. Littlewood R, Hyde F. Screening for congenital colour vision defects: A comparison between the Ohkuma and Ishihara plates. *Aust NZ J Ophthalmol* 1993 **21** 31-35.
15. Grosvenor T. The incidence of red-green color deficiency in New Zealand's Maoris and Islanders. *Am J Optom Arch Am Acad Optom* 1970 **6** 445-450.
16. Norn M. Prevalence of congenital colour blindness among Inuit in East Greenland. *Acta Ophthalmol Scan* 1997 **75** 206-209.
17. Rebato E, Calderon R. Incidence of red/green colour blindness in the Basque population. *Anthropol Anz* 1990 **48** 145-148.
18. Mueller WH, Weiss KM. Colour blindness in Colombia. *Ann Hum Biol* 1979 **6** 137-145.
19. Birch JA. Practical guide for colour vision examination: a report of the standardization committee of the international research group on colour vision deficiencies. *Ophthal Physiol Opt* 1985 **5** 265-85.
20. Hodd NB. Putting Chromagen to the test. *Optometry Today* 1998 **38** (14) 39-42.
21. Wilkins AJ, Evans BJ, Brown JA, Busby AE, Wingfield AE, Jeanes RJ, Bald J. An experimental test of filter-aided dichromatic color discrimination. *Ophthal Physiol Opt* 1994 **14** (4) 365-370.
22. Harris D, MacRow SJ. Application of Chromagen haploscopic lenses to patients with dyslexia: a double-masked, placebo-controlled trial. *J Am Optom Assoc* 1999 **70** 629-640.