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Case Report: Effect of Haploscopic Filter on Contrast Sensitivity Function and Colour Vision Tests.

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Abstract:	Significance The options that can help subjects with congenital color vision defect, to a better professional and leisure adaptation, are very limited. Different haploscopic lenses can be considered, and their effects need to be investigated in patients with different defect. Purpose The purpose of this study was to present and discuss the effect of a pair of asymmetric long-pass filters fitted for deuteranopia, with the result of a 60% improvement on distinguishing red-green plates when compared with baseline. Case Report We report a case of a 51-year-old male with congenital deuteranopia fitted with haploscopic Chromagen filters. During the 2-month follow-up, we observed a decrease in left eye logMAR visual acuity and contrast sensitivity with an increased ability to discriminate the plates of different color vision tests (Ishihara, Farnsworth and Hardy-Rand-Rittler). The visual outcomes are discussed considering the spectral sensitivity curves of each filter, measured with a spectrophotometric device. Conclusions This report describes an improvement in the ability to resolve color vision plates after using asymmetric CG filters showing a left eye decrease in logMAR visual acuity and contrast sensitivity function. Subjects with a history of color vision deficiency might benefit from using haploscopic filters that selectively minimize the transmittance within a specific bandwidth in order to improve the color discrimination in deutan colour vision deficiency. The simultaneous analysis of the color vision outcomes and transmittance spectrum of the haploscopic filters might contribute to a better understanding of the mechanisms behind the claimed efficacy of these devices.

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February 12th 2020

Michael Twa
Editor-in-Chief
Optometry and Vision Science

Dear Editor,

Please find enclosed the paper entitled "**Case Report: Effect of Haploscopic Filter on Contrast Sensitivity Function and Colour Vision Tests**", for consideration to be published in Optom Vis Sci Journal.

We reported a case of 51-year-old male with congenital deuteranopia fitted with asymmetric haploscopic Chromagen lenses. The simultaneous analysis of the color vision outcomes and transmittance spectrum of the haploscopic filters might contribute to a better understanding of the mechanisms behind the claimed efficacy of these devices.

Hope that, this case series will be strong enough to be attractive for the reader and for the Editorial Board and the reviewer's panel of Optom Vis Sci Journal.

Sincerely yours,

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Case Report: Effect of Haploscopic Filter on Contrast Sensitivity Function and Colour Vision Tests.

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Short Title: Visual outcomes after haploscopic lens wear

Acknowledgement and Disclosure:
The authors declare that they do not have any proprietary or financial interest in any of the materials mentioned in this article.

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Abstract

Significance

The options that can help subjects with congenital color vision defect, to a better professional and leisure adaptation, are very limited. Different haploscopic lenses can be considered, and their effects need to be investigated in patients with different defect.

Purpose

The purpose of this study was to present and discuss the effect of a pair of asymmetric long-pass filters fitted for deuteranopia, with the result of a 60% improvement on distinguishing red-green plates when compared with baseline.

Case Report

We report a case of a 51-year-old male with congenital deuteranopia fitted with haploscopic Chromagen filters. During the 2-month follow-up, we observed a decrease in left eye logMAR visual acuity and contrast sensitivity with an increased ability to discriminate the plates of different color vision tests (Ishihara, Farnsworth and Hardy-Rand-Rittler). The visual outcomes are discussed considering the spectral sensitivity curves of each filter, measured with a spectrophotometric device.

Conclusions

This report describes an improvement in the ability to resolve color vision plates after using asymmetric haploscopic filters showing a left eye decrease in logMAR visual acuity and contrast sensitivity function. Subjects with a history of color vision deficiency might benefit from using haploscopic filters that selectively minimize the transmittance within a specific bandwidth in order to improve the color discrimination in deutan colour vision deficiency. The simultaneous analysis of the color vision outcomes and transmittance spectrum of the haploscopic filters might contribute to a better understanding of the mechanisms behind the claimed efficacy of these devices.

Background

Color vision deficiency: Normal color vision is possible due to specific proportional photoreceptors dotation in the central retina. These cones have different light-sensitive pigments that enable us to recognize for red-green, and blue-yellow components of color vision and luminance.[1] The loss of function in any type of cone photoreceptor causes congenital color vision deficiency. Researchers have determined that these defects involve the photoreceptor pigment genes. Congenital color vision deficiency is seen in 8% of males and 0.5% of females.[2] The most common deficiency is associated with the reduced ability to discriminate red-green (protan-deutan defect) and is inherited as X-linked recessive. The genes for the red and green pigments are quite close to one another, and because men have only one X-chromosome, they are more likely to be missing or to have a recombined abnormal gene.[3]

Diagnostic tests: Color vision deficiency can be detected by standardized tests, tables, and devices. However, there is a lack of uniformity on the use of color vision tests across the world.[4] Many tests for diagnosing this deficiency are in clinical use, including Ishihara and Hardy-Rand-Rittler pseudoisochromatic test plates, the Farnsworth D-15 test, the Farnsworth-Munsell 100 Hue Test, and the Nagel anomaloscope. It is accepted that pseudoisochromatic tests are at the forefront of these methods due to ease of use and sensitivity.[5] Ishihara test plates are the most popular and widely used pseudoisochromatic test plates, but Hardy-Rand-Rittler provides more information, as it includes plates that detect tritanopia in addition to protan and deutan defect and has a carefully designed set of plates to differentiate protan, deutan, and tritan deficiencies and grade their severity.[6] These tests must be performed separately for each eye because deficiency types and their extents can occur in each eye.

Limitations and aids: Patients with color vision deficiency have important professional limitations, such as military corps, security, aviation, marine, architecture and interior design. Moreover, some subjects experience difficulties in daily tasks in terms of color vision, such as clothes selection, drive or different video computer activities.[7] Currently, no treatment exists for congenital color vision deficiency and the options that can help subjects are very limited. Haploscopic spectacles or contact lenses can be considered to get a wider variation in light levels, and their effects have been studied by several investigators.[8-9] These haploscopic filters are more transparent for a specific wavelength range, while less transparent for other wavelengths. Hence, luminous contrast occurs between the colored object and the ground, and the patient's color perception increases with no change in cone sensitivity. An interesting form of these haploscopic lenses are ChromaGen filters. A wide range of spherical or cylindrical power can be added to this filter.

In this report, we present a male carrying a congenital severe deuteranopia. Herein, we describe the clinical response of the subject to color vision tests and contrast sensitivity baseline and 2-month after use of haploscopic ChromaGen lenses. Finally, we discuss the putative underlying mechanisms leading to the improvement in color interpretation after ChromaGen filter spectroscopic analysis.

Case Presentation

History: A 51-year-old male presented with congenital deuteranopia. There is a family history for color vision deficiency since his brother was diagnosed for the same defect. Difficulties distinguishing colours were noticed at the age of 15 years. Furthermore, a congenital cataract was diagnosed in the left eye at the age of 21 years-old with no ocular anomalies in the right eye. Cataract surgery with the FineVision® trifocal IOL (PhysIOL, Liège, Belgium) implantation was performed at the age of 48 years old. Colour vision had not been analysed prior to the subject entering in his current professional activity as educator and researcher at the University.

Ocular examination: The patient underwent a complete routine ophthalmic examination, including best-corrected visual acuity, slit lamp biomicroscopy, contrast sensitivity function and colour vision examination. Myopia and astigmatism with a refractive error of -0.25 sph -0.50 cyl 90º (right eye) and -0.75 cyl 140º (left eye) were found. The best-corrected visual acuity was measured using a high-contrast (93%) and low-contrast (10%) visual acuity charts (Precision Vision, USA) at 4.0 m distance under 80 cd/m^2. A best-corrected visual acuity of 20/20 (63 letters) was found for the right eye and 20/25 (59 letters) for the left eye at baseline (**Figure 1**).

Contrast sensitivity: The contrast sensitivity function was performed using an orientated sine wave grating device (Topcon CC-100 XP, Japan). Test was performed monocular and binocular, using the refractive calculated correction at 2.0 m distance under 80 cd/m^2 standard photopic conditions.

Colour vision tests: The subject was examined using three different tests to characterize subject color vision deficiency. Using the 24-Ishihara plates edition (Kanehara Trading Inc, Tokyo, Japan), we found 18/20 errors in both eyes, and was diagnosed as acute deutan. The subject was also examined with the Farnsworth D-15 test, and the results were indicative of a deutan. Finally, on-screen Hardy-Rand-Rittler pseudoisochromatic test chart (Topcon CC-100 XP, Japan), clearly demonstrated the subject´s severe deuteranopia (**Figure 1**).

Haploscopic lenses: ChromaGen lenses (Chromagen Ltd, Chester, UK) were used to assist the subject to improve his ability to distinguish color plates. A specific filter was determined following the diagnostic routine filter selection recommended by the manufacturers. A rose-pink colored filter (**Figure 2**) was chosen for each eye and worn by the subject binocularly, with the refractive correction calculated previously. Additionally, a spectrophotometric analysis was made using a Lambda 25 UV/Vis spectrometer (Perkin Elmer, MA, USA).

Spectrophotometric measurements for the right and left ChromaGen filters are presented in **Figure 3**.

Visual outcomes: No changes in best-corrected visual acuity were found when comparing baseline, 1-week or 2-month examination for the right eye, but logMAR scores were diminished by 7 and 8 letters for the high and low-contrast charts respectively after 2-month examination for the left eye. When contrast sensitivity function was examined after using ChromaGen haploscopic glasses, results were similar for the right eye when compared baseline and 2-moth wearing ChromaGen glasses, but decreased contrast sensitivity was found for 12 c/d and 18 c/d spatial frequencies in the 2-moth follow up visit (**Figure 4**) for the left eye.

When the color vision test was made, Ishihara plates revealed 5/20 errors and diagnostic plates suggested a low deutan defect, Farnsworth D-15 test showed a non-clear pattern (**Figure 5**) with a trend to tritan failure, while Hardy-Rand-Rittler plates revealed a moderate deutan pattern with a binocularly 40% (40% right eye and 20% left eye) of improvement on distinguishing red-green plates when compared with baseline. Additionally, the patient reports an esthetic handicap as a “rose-pink fantasia image” suggesting only a comfortable sporadic use mainly in personal indoor activities.

To check a time-dependent effect, the patient was instructed to a gradually increase the wearing ChromaGen filter glasses during the daily activities. After a two-month period, Ishihara plates revealed the same 5/20 errors found in the previous session, Farnsworth D-15 test shows an unclear pattern (**Figure 5**), while Hardy-Rand-Rittler test revealed a slight deutan pattern with a binocularly 60% (80% right eye and 40% left eye) of improvement on distinguishing red-green plates when compared with baseline ability (**Figure 1**).

All experimental protocols were carried out according to the guidelines approved by the Ethics Committee of the Universidade de Santiago de Compostela, Spain, and in accordance with the Declaration of Helsinki. Informed consent was obtained from the patient for publication of this case report and accompanying images.

Discussion and conclusions

Previous studies: There are a few studies on the use of long-pass filters to improve color vision discrimination in subjects with color vision deficiency. Authors using haploscopic filters such as X-Chrom on protan defect patients have found a mixed effect, allowing the patient to improve the interpreting colors capacity but decreasing best-corrected visual acuity and contrast sensitivity.[9-10] When this filter is used in deutan subjects, Sato et al found that while the simulated red filter improves the performance of deutans to arrange the caps in the D-15 test, this is not the case for protans.[10] More recently different authors have applied the ChromaGen filter as a contact lens aid with similar findings.[9] It appears that haploscopic filters used to induce changes in color vision deficiency patient's luminance contrast between the protan and deutan types, resulting in deuteranopes performance improvement while protanopes deteriorates.

This study: During the 2-month follow-up, the ChromaGen glasses used in this study did not cause a reduction of visual acuity and contrast sensitivity for the right eye but for the left eye with no apparent binocular effect. However, we found an increased ability to discriminate the plates of different color vision tests which is in good agreement with findings described recently by other authors using different lenses.[10-11] However, findings are not completely in agreement with data reported by Ilhan et al who found less benefits of ChromaGen in deutan patients and decreased visual acuity and contrast sensitivity.[9] Moreover, in the present study we found a remarkable asymmetric effect with major visual outcomes concerning to the filter with less transmittance values (**Figure 1**). The severity of the deficiency analyzed, the implemented

ChromaGen filter configuration, the individual filter selection procedure and the refractive error at baseline may be possible explanations.

Haploscopic filters: The spectrophotometric analysis practiced in this study revealed that the right eye ChromaGen filter is more permeable to short (with a peak of 50% transmittance in 404nm) and large wavelengths (with a maximum value of 60% transmittance for 762nm), while medium wavelengths are less permeable showing two relative minimum values of transmittance <5% in 517 and 553 nm, both relative corresponding to the green light spectrum. Evaluation of ChromaGen lens for the left eye showed a decreased permeability for short wavelengths (with a relative maximum value of 23% transmittance for 409 nm), being the medium wavelengths the less permeable again (showing a minimum value of 5% transmittance at 514 nm), with the higher permeability to large wavelengths with a peak of 60% transmittance for 705 nm. These patterns may well explain the tritan trait observed in the graphs corresponding to the Farnsworth test using ChromaGen glasses. A different spectrophotometric pattern of blocked wavelengths inducing decreased light transmittance can be observed for each eye in order to obtain an individual response. Therefore, luminous contrast occurs between the colored stimuli and the ground. Thus, color discrimination increases, yet the enlightenment of the retina decreases. That circumstance explains some visual limitation in best-corrected visual acuity or contrast sensitivity found in this study for the left eye, and by other authors using similar haploscopic filters such as X-Chrom,[12] or ChromaGen contact lens wear.[9]

The medium wavelengths cut-of configuration observed in filters used in this study, coinciding with the peak of spectral sensitivity of the human eye, might enhance the chromatic discrimination around the axis of confusion. That is, ChromaGen filters induces differences in the luminance between combination colors, changing the spectral stimuli perceived for the patient when judging a chromatic content. Since the technique introduces transmittance differences between both eyes, it would be interesting to evaluate the effect of applying two filters with a similar cut-of pattern in the performance of different color vision tests in color vision deficiency subjects using this haploscopic aids.

In conclusion, this report describes an improvement in ability interpreting colors after using asymmetric ChromaGen filter glasses showing a left eye decrease in visual acuity and contrast sensitivity but with no binocular alteration. ChromaGen lens tested in this case report selectively minimize the transmittance within a specific bandwidth in order to improve the color discrimination in deutan defect. The simultaneous analysis of the color vision outcomes and transmittance spectrum of the haploscopic filters might contribute to a better understanding of the mechanisms behind the claimed efficacy of these devices.

Acknowledgements

We thank the Photonics4Life group from Universidade de Santiago de Compostela for technical assistance in spectrophotometric analysis of CGs lenses.

Consent for publication

Written informed consent was obtained from the patient to publish the medical information supplied in this case report.

Ethics approval and consent to participate

All procedures performed involving human participants were in accordance with the tenets of the WMA Declaration of Helsinki and have been approved by the Ethics Committee of the University of Santiago de Compostela, Spain.

Figure Legends

Figure 1. Clinical Timeline: 51-year-old white male diagnosed and managed for deutan deficiency. HC: High-contrast; LC: Low-contrast; RE: Right Eye; LE: Left Eye; CSF: Contrast Sensitivity Function; HRR: Hardy-Rand-Rittler test; AD: Acute Deutan; MD: Moderate Deutan; LD: Low Deutan.

Figure 2. ChromaGen haploscopic filters (top) marked to be analyzed with the Perkin Elmer Lambda 25 UV/Vis spectrophotometer (bottom).

Figure 3. ChromaGen lens transmittance analysis for the right and left filters used in this study. Note the asymetric configuration around the confusion axis.

Figure 4. Contrast Sensitivity Function: Baseline right eye (A) and left eye (B); After 2-month using ChromaGen haploscopic glasses for right eye (C) and left eye (D). Note the major decrease in the 18 c/d spatial frequency for the left eye with the ChromaGen lens.

Figure 5. Farnsworth D-15 graphs for both eyes: A) Monocular data baseline; B) Monocular data after 2-month; C) Binocular data after 2-month using ChromaGen lenses.

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Figure 1

Figure 1

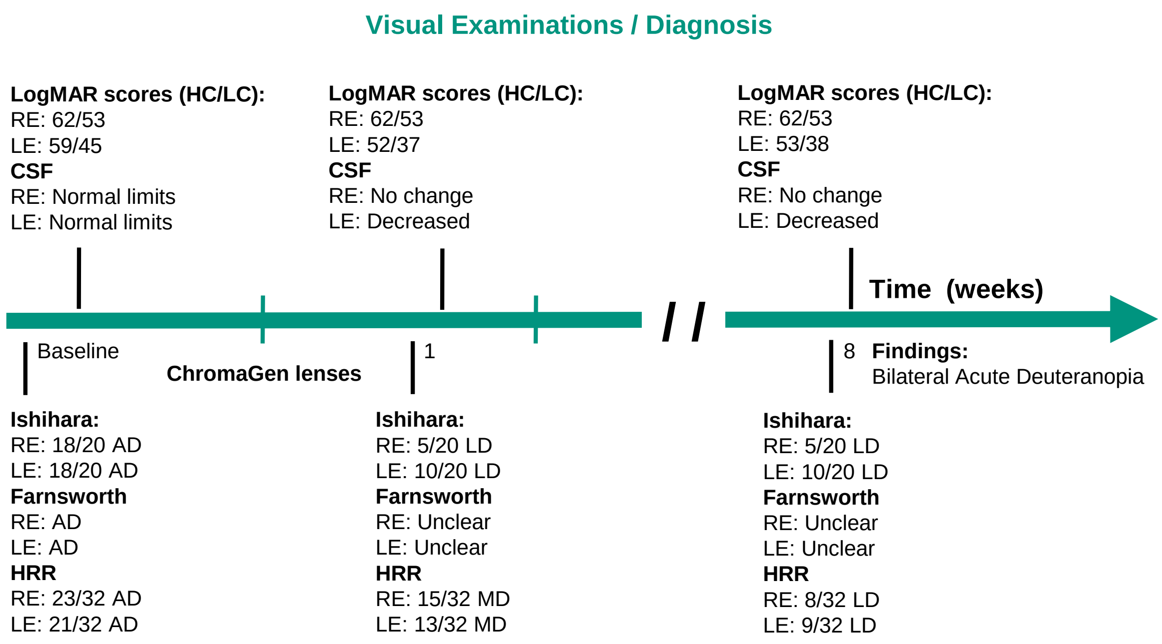

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Figure 2

Figure 2

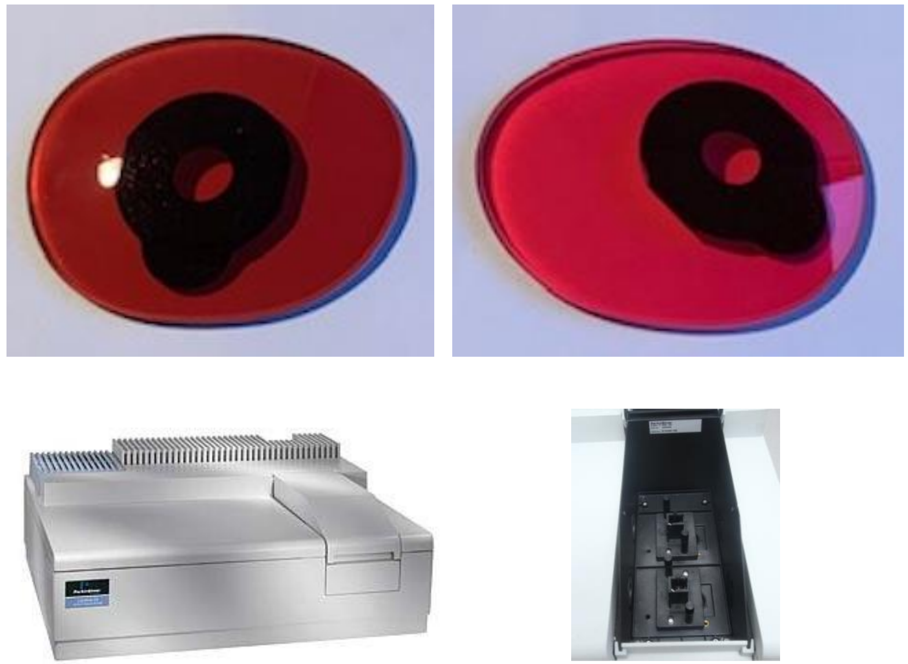

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Figure 3

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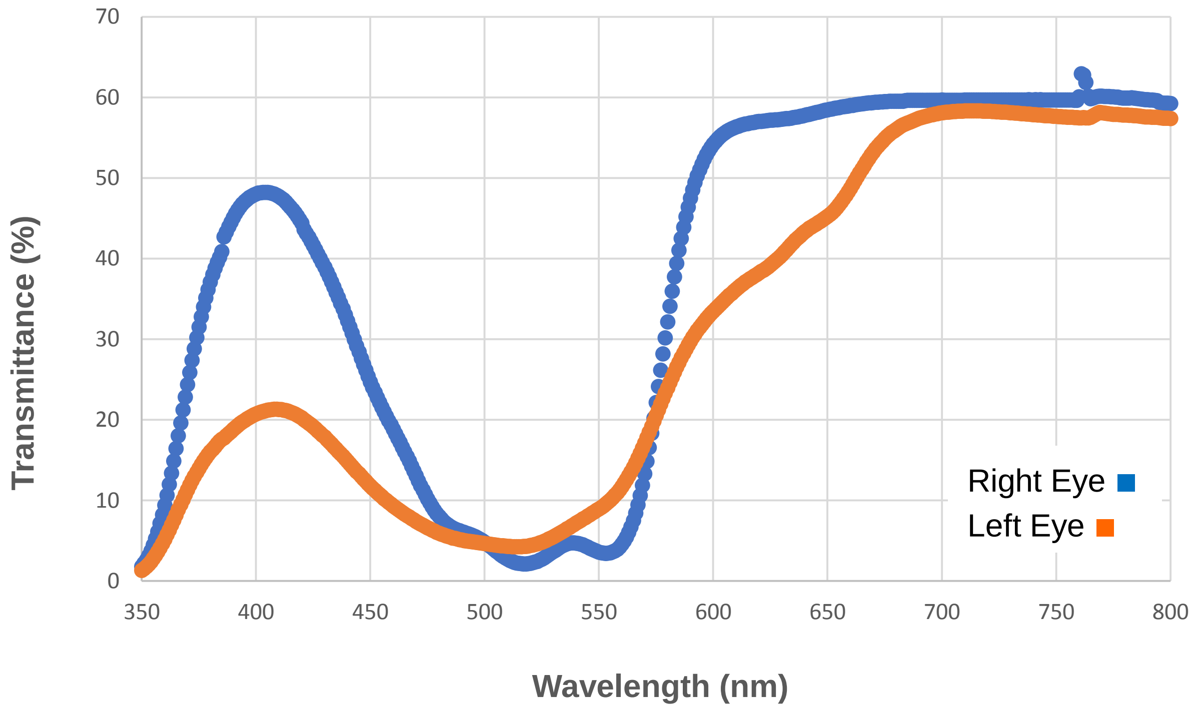

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Figure 4

Figure 4

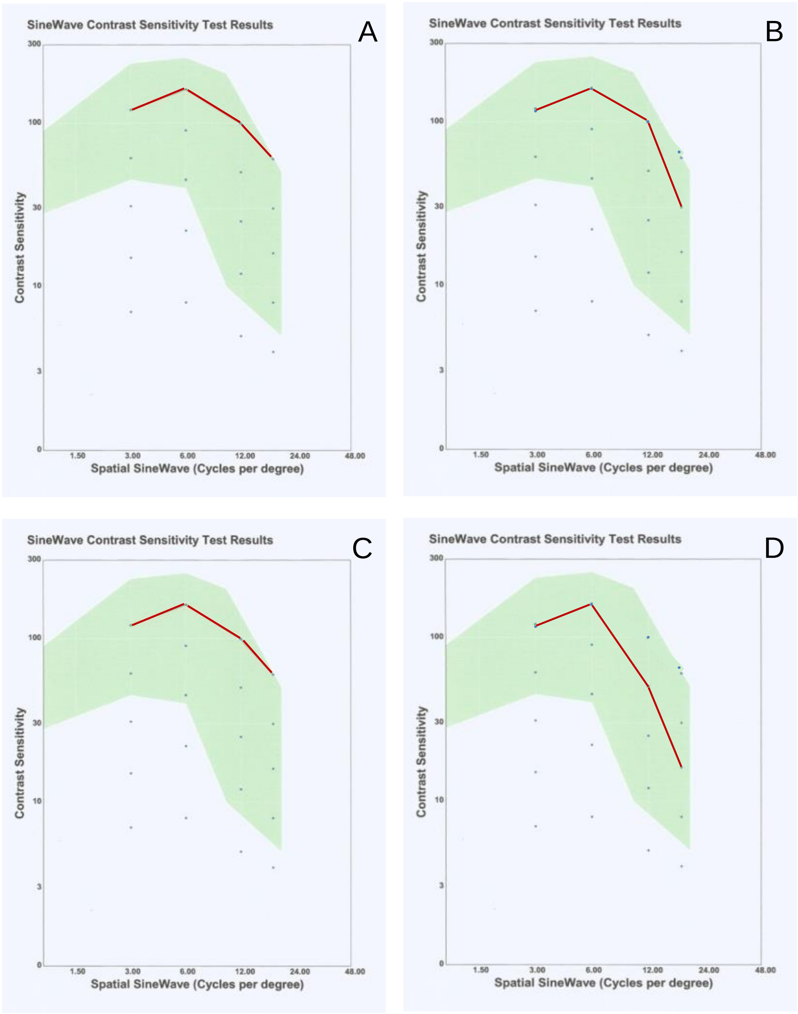

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Figure

Figure 5A

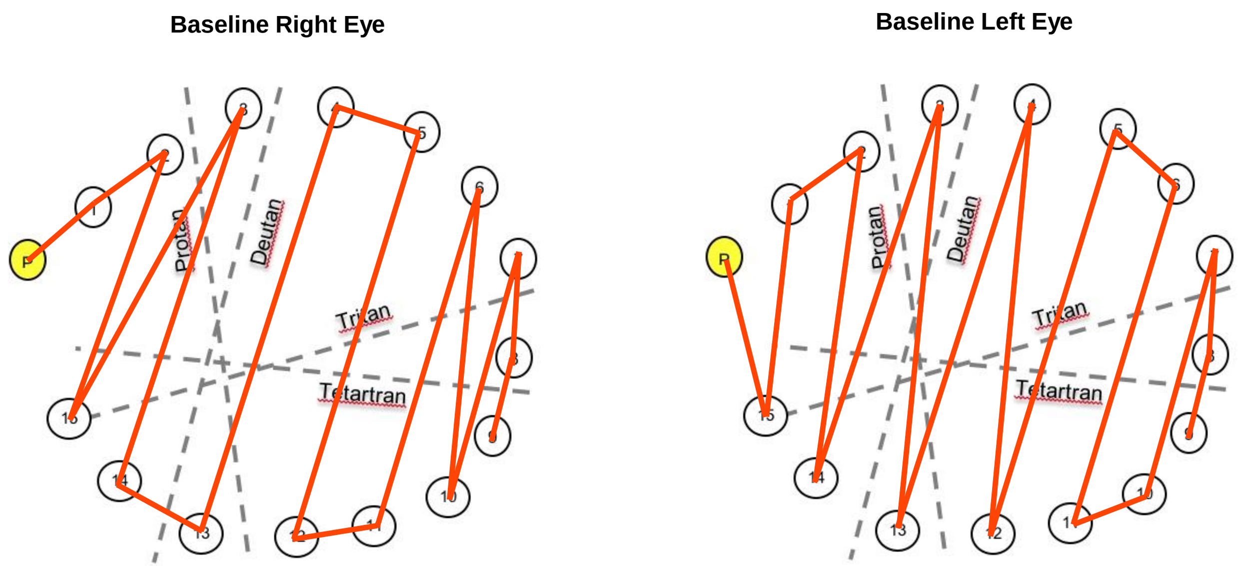

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Figure 5B

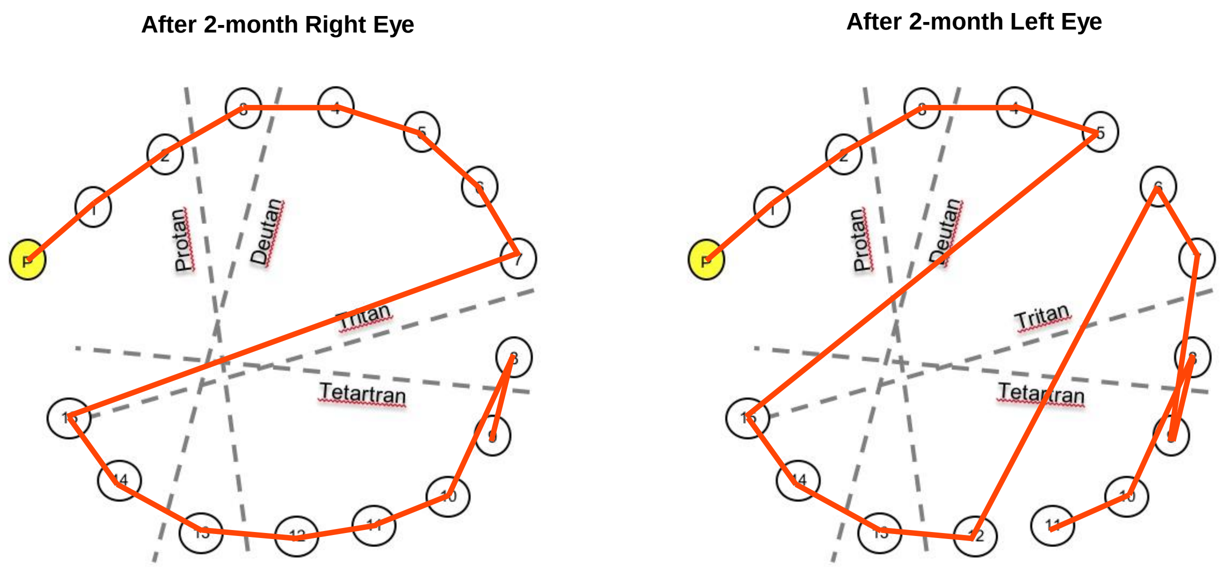

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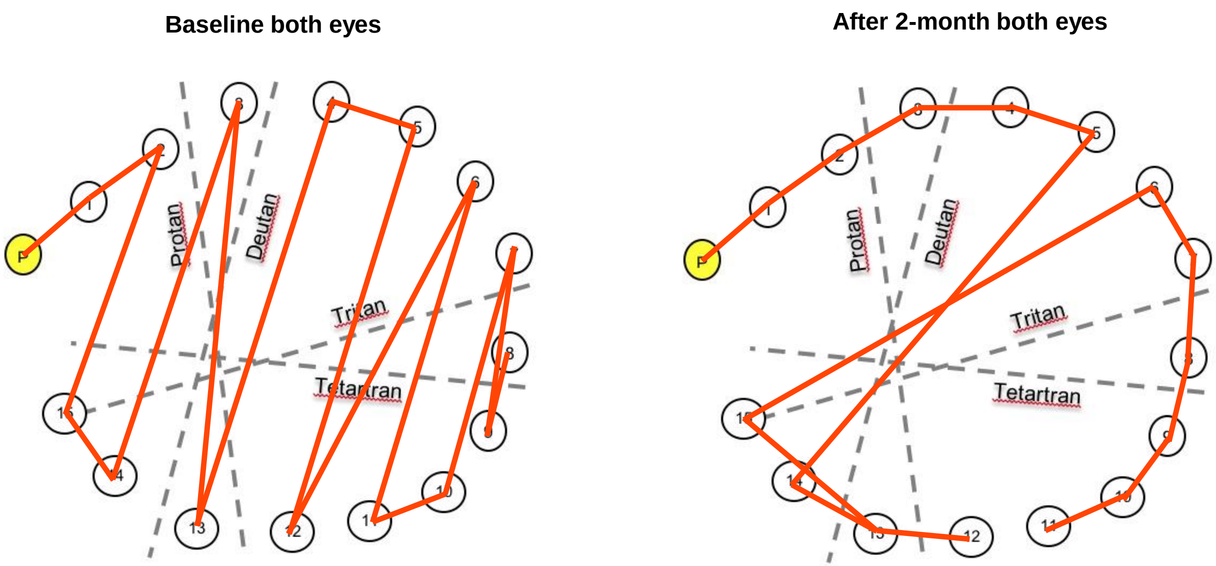
Figure 5C



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