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Exploring the Effect of a Notch Filter on Color Contrast Sensitivity in Color Normal and Color Deficient Young Healthy Adults – a pilot study

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INTRODUCTION

Color contrast sensitivity (CCS), an essential part of daily life, allows the observer to discriminate color differences, thereby facilitating interactions with the environment. CCS is believed to be mediated by differences in the stimulation of wavelength opponent channels across space (red-green and blue-yellow).

Arden et al first used a computer program to assess CCS in a high contrast setting. Subsequently, variations of this method have been used in research. CCS assessment has proven beneficial in the early diagnosis of a variety of disorders. Al Saeidi et al tested a computer program of CCS (Arden test) as a screening tool for diabetes. The designers of the Konan CCS test claim the test isolates the photopic cones in sufficiently high granular contrast for use in clinical trials.

Notch filters that increase separation of the long and medium wavelength cone spectral sensitivity curves are promoted to enhance color vision in congenital red-green color deficiency (CD). Opinions are mixed on the efficacy of these filters, likely due to individual variability of red-green CD.

Previous research from Kitchens, et al. investigated the changes in color perception induced by multi-notch filters (EF) in color normal and deficient humans. Using the Farnsworth 100 hue test, they showed that the EF may be useful for improving color discrimination, but only for some sections of the spectrum (Boxes 22-42, 43-63). The filters, however, do not create a normal color perception. **Currently unknown is the effect these notch filters have on color contrast sensitivity.**

PURPOSE

Our purpose was to explore the effects of a notch filter (Enchroma) on CCS in congenital CD and color normal (CN) subjects.

METHODS

This study adhered to the tenets of the Declaration of Helsinki, and all procedures were approved by the Southern College of Optometry (SCO) Institutional Review Board. Informed consent was obtained from each participant prior to collection of any data.

- 9 congenital CD and 4 CN young healthy adults aged 20-80 years old recruited from the student and staff population of SCO.
- Criteria for inclusion: no medications or known systemic conditions that could affect color vision, no ocular diagnosis that could affect CCS such as cataract, and BCVA at distance of 20/40/better OD, OS. Amblyopia was acceptable as long as targets were able to be discriminated.
- CCS for red (R), green (G), and blue (B) targets were measured for each eye using the digital color contrast test design (ColorDx, Konan Medical – **Figure 1**)
  - *Easy 4 button response, Landot C, "High Granularity, Photopic Cone Isolation"*

FIGURE 1: *ColorDx, by Konan Medical.*

- Testing performed monocularly, with OU tested for each subject, once for baseline and twice for each type of filter (ND, NF – spectral transmissions shown in **Figures 2a and 2b**)

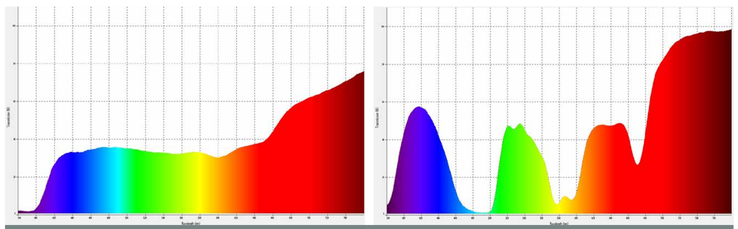

FIGURE 2: *Spectral transmission curves for the (a) neutral density and (b) notch filter used in this study. Overall transmission of both filters was approximately 30%.*

- With (NF – Enchroma, total transmission ~28%), with ND filter (total transmission approximately 28% and without(N) a notch filter at 50 cm with low overhead illumination and a 4-alternative forced choice staircase procedure (standard for the instrument).
- The difference between the red and green CCS results for N and NF conditions were compared between CN and CD subjects, grouped as follows:
  - *Between CN, Blue-Normal CDs (CD-BN: log CCS blue > 0.65), and Blue-Deficient CDs (CD-BD: log CCS blue <= 0.65);*
  - *Between CN, G-deficient CDs (CD-G), and R-G-deficient CDs (CD-RG).*

RESULTS

- **Table 1** shows the statistics for the Shapiro-Wilk test for normality. The results indicate that distribution of the data is nearly normal.

TABLE 1: SHAPIRO WILK TEST FOR NORMALITY

GROUP	R-G DIFFERENCE CHANGE FROM NO FILTER TO NOTCH FILTER (SW P-VALUE)	R-G DIFFERENCE CHANGE FROM ND FILTER TO NOTCH FILTER (SW P-VALUE)
Color Deficient, RE	0.052	0.083
Color Deficient, LE	0.24	0.416
Color Normal, RE	0.017	0.188
Color Normal, LE	0.082	0.767

- **Figure 3** shows the CCS for the (a) red, (b) green, and (c) blue targets under the 3 filter conditions (no filter, neutral density filter, and notch filter).
  - *One-way ANOVA for correlated samples showed a significant difference in mean CCS for all 3 targets across the 3 filter conditions for both the CD and CN subjects, except for the red target both eyes for CD subjects, red target LE for CN subjects, and green target both eyes for CD subjects.*
  - *Tukey HSD test revealed that the differences were between the ND filter condition and each of the other two conditions. The no filter and notch filter conditions were not significantly different from each other.*
  - ***Due to the difference in mean contrast sensitivity produced by the ND filter condition compared to the other two conditions, the ND filter condition was not used in the remaining analysis.***

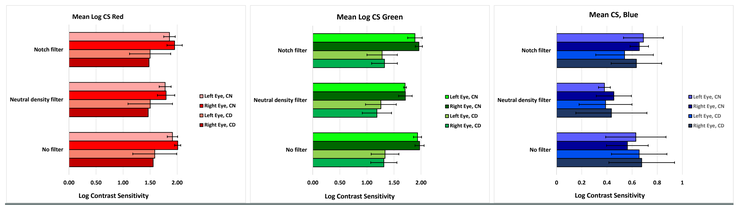

FIGURE 3: *Mean +/- standard deviation of color contrast sensitivity for the (a) red, (b) green, and (c) blue targets, grouped by filter condition. Data are shown separately for the right and left eyes and for the color deficient (CD) and color normal (CN) subjects. See text for details.*

- The difference in the CCS between the red and green targets (R-G dif) was calculated for the no filter and notch filter conditions for the CD and CN groups. The CHANGE in R-G dif was calculated as the absolute value of (R-G dif for the no filter condition – the R-G dif for the notch filter condition).
  - ***Two-tailed t-test for independent samples showed the mean change in R-G dif was significantly larger CD vs CN*** *for both RE (0.136 ± 0.13 vs 0.035 ± 0.01, p = 0.049) and LE (0.234 ± 0.12 vs 0.023 ± 0.03, p = 0.002) –* ***Figure 4****.*
- The CD group was subdivided into "blue normal" (BN – log contrast sensitivity for the blue target greater than 0.6 with no filter) and "blue deficient" (BD – log contrast sensitivity for the blue target 0.6 or less with no filter). The CHANGE in R-G dif was calculated and compared across the 3 groups (CN, CD –BN, and CD-BD).
  - ***One-way ANOVA for independent samples showed a significant difference in the mean CHANGE in the R-G dif between no filter and notch filter conditions across the 3 subject groups (p = 0.015). – Figure 5.***
  - *Tukey HSD test revealed that the* ***difference between CN and CD-BD group was significant at p < 0.05; the difference between CD-BN and CD-BD was significant at p < 0.05****; and the difference between CN and CD-BN was not significant.*

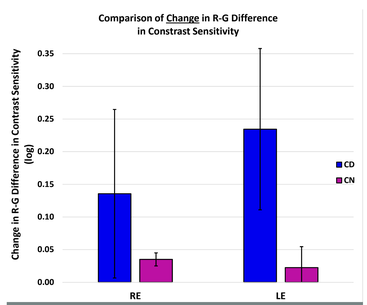

FIGURE 4: *Mean +/- standard deviation of change in the difference in red and green contrast sensitivity (R-G dif) is plotted for color normal (CN) and color deficient (CD) subjects. Data are shown separately for the right and left eyes. See text for details.*

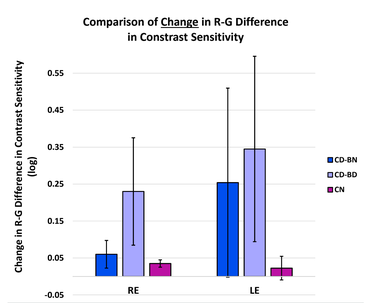

FIGURE 5: *Mean +/- standard deviation of change in the difference in red and green contrast sensitivity (R-G dif) is plotted for color normal (CN), color deficient with normal blue contrast sensitivity (CD-BN) and color deficient with low blue contrast sensitivity (CD-BD). Data are shown separately for the right and left eyes. See text for details.*

CONCLUSIONS

In this small group of young, healthy adult subjects with normal vision,

- The notch filter creates a greater change in the R-G dif for subjects who have congenital red-green color vision deficits compared to that for subjects with normal color vision.
  - *The subgroup of congenital red-green color vision deficient subjects who also demonstrated a lower CCS for the blue target with the instrument used in this study had a significantly different change in the R-G dif with the notch filter compared to that for subjects with normal color vision and to that for subjects with congenital red-green color vision deficits who demonstrated higher CCS for the blue target.*
  - *Whether these differences remain for targets of sizes different from that tested in this study remains unknown.*
  - *A factor that can contribute to difference in blue contrast sensitivity is the amount of macular pigment in the region tested with the stimulus; how the changed blue contrast sensitivity due to the presence of greater macular pigment would affect the change in R-G dif with the notch filter has not yet been tested.*

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