ASSESSMENT OF COMPENSATION AND SIMULATION FILTERS FOR COLOUR VISION DEFICIENCY

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INTRODUCTION

Compensation filters may improve perception in humans with Red-Green colour vision deficiency (CVD) whilst simulation filters may mimic CVD in colour vision normals (CVN). A previous study (Lillo et al. 2014) showed that Variantor simulation filters mimic protanopia in a discrimination task when tested only at pseudo-achromatic confusion axes. Studies (e.g. Gómez-Robledo et al. 2018) using EnChroma compensation filters (EnChroma, Berkeley, USA) have not found statistically significant improvements in colour vision. We aimed to assess effects of simulation (Variantor) and compensation (EnChroma) filters on perceptual performance in discrimination and colour naming tasks.

METHODS

Participants. 5 CVN participants performed tasks with and without Variantor filters; 10 CVN and 9 CVD (1 protanopic, 2 protanomalous, 4 deuteranopic and 2 deuteranomalous participants) with and without EnChroma filters.

Discrimination task. The CVA-UMinho test (Linhares et al., 2016) was carried out on a calibrated CRT monitor (GDM-F520, Sony Corp.) controlled by a ViSaGe-MKII (CRS). A square chromatic target (5°) was placed on an achromatic static luminance noise background (mean luminance=11 cd/m^2). Observers indicated the location of the square (right or left side). Noise dot luminances ranged randomly (6-16 cd/m^2). Target hues were presented along 16 hue axes, including the 6 protan, deutan and tritan confusion lines (Smith and Pokorny, 1975). Discrimination thresholds were measured on two separate occasions using a staircase procedure.

Naming task. The discrimination task was modified to present the target closer to screen centre for the 16 hue axes at 3 saturation levels (100, 66 and 33%). There were 144 trials (16 hues x 3 saturations x 3 presentations) for each measure, performed on two separate occasions. Participants named each target hue using one of the 11 basic colour terms in English (Lin et al., 2001). A response was deemed correct if it corresponded to the modal response of CVN participants not wearing any filter.

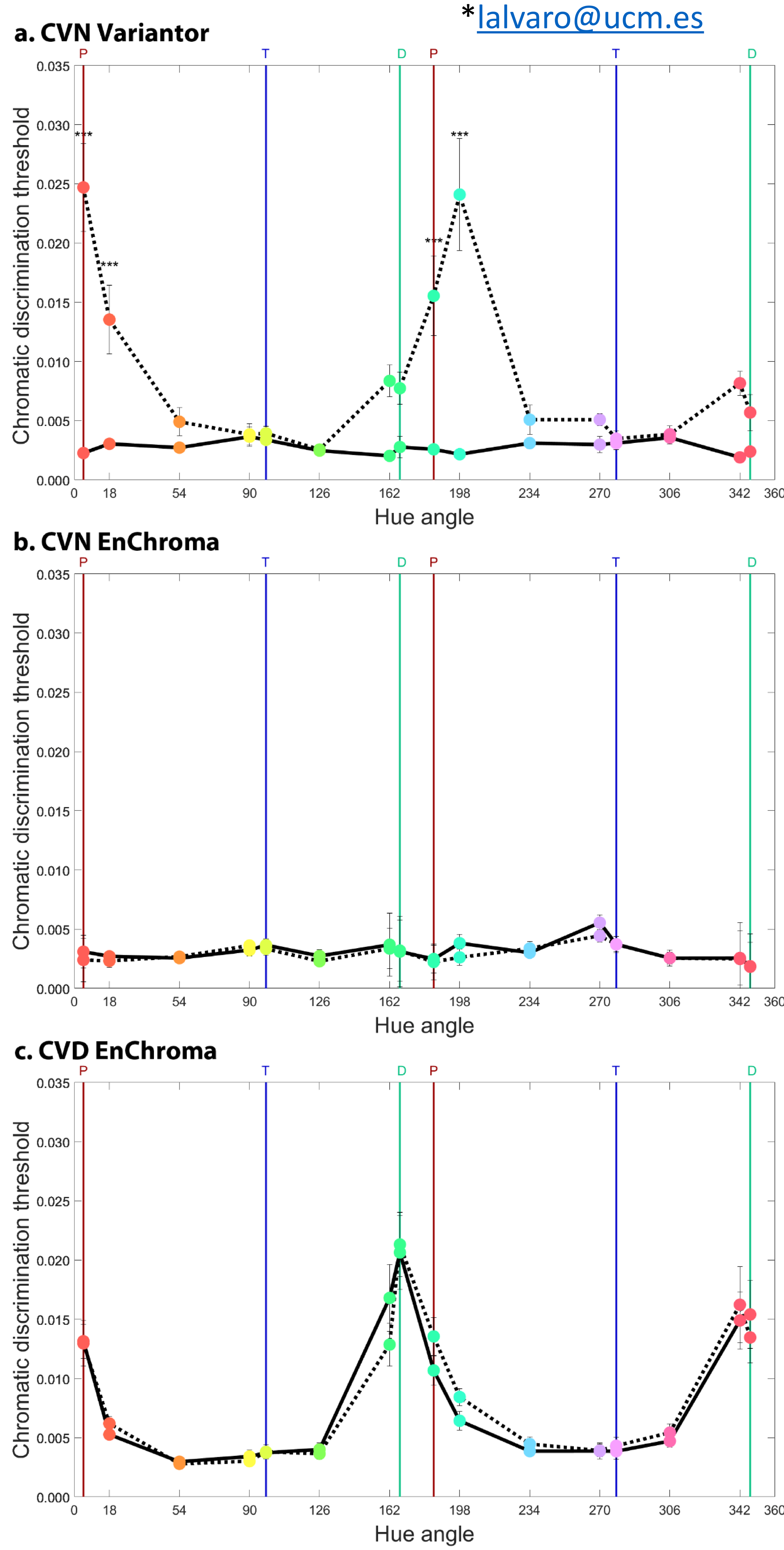

Figure 1. Discrimination thresholds (distance to colour of background in $u' v'$ units) without (solid) and with (dotted) filters. Vertical lines represent protan (red), deutan (green) and tritan (blue) confusion lines. Error bars show ±1 SEM.

CONCLUSION

Variantor showed expected protan-like losses. No significant improvement in colour discrimination or naming was demonstrated with EnChroma. Any red-green CVD compensation filter can introduce different cues which might result in improved discriminability for some hues (but degraded discriminability at others). To date, no study has demonstrated enhanced overall colour discrimination for persons with red-green colour vision deficiency when using compensation filters.

RESULTS

Summary. **Variantor** impaired discrimination near protan axes of confusion ($P < 0.001$, see *** in Fig. 1a) and reduced naming hit scores ($P < 0.001$, data not shown). **EnChroma** did not affect discrimination or naming for any participant group (nor CVD nor CVN) or hue (all $P > 0.05$).

Variantor. A two-way repeated measures ANOVA with filter (no-filter, Variantor) and hue (16 hues) on **discrimination** thresholds (Fig. 1a) revealed significant main effects of filter ($F_{(1,4)} = 87.94$, $P < 0.001$, $\eta^2 = 0.96$, worse discrimination with Variantor), hue ($F_{(15,60)} = 11.23$, $P < 0.001$, $\eta^2 = 0.74$) and filter*hue interaction ($F_{(15,60)} = 14.96$, $P < 0.001$, $\eta^2 = 0.79$). Tukey (HSD) post-hoc comparisons revealed that significant differences were only found (filter vs no-filter) for hues near protan axes of confusion ($P < 0.001$, see *** in Fig. 1a).

A one-way repeated measures ANOVA with filter (no-filter, Variantor) as the within-subjects factor on **naming** hit scores revealed a significant main effect of Variantor ($F_{(1,4)} = 128.46$, $P < 0.001$, $\eta^2 = 0.97$; 82.22±3.39% no-filter, 30.35±5.21% Variantor).

EnChroma. A three-way mixed-measures ANOVA with filter (no-filter, EnChroma) and hue (16 hues) as within-subjects factors and participant group (CVN, CVD) as the between-group factor on **discrimination** thresholds (Fig. 1b for CVN, Fig. 1c for CVD) revealed significant effects of hue ($F_{(1.77,30.20)} = 10.26$, $P < 0.001$, $\eta^2 = 0.38$), participant group ($F_{(1,17)} = 27.33$, $P < 0.001$, $\eta^2 = 0.62$, worse discrimination for CVD vs. CVN) and hue*participant group ($F_{(15,255)} = 11.94$, $P < 0.001$, $\eta^2 = 0.41$). There was no overall effect of EnChroma on discrimination thresholds ($P = 0.867$) nor were there significant filter*hue ($P = 0.256$), filter*participant group ($P = 0.353$), or filter*hue*participant group ($P = 0.196$) interactions.

A three-way mixed-measures ANOVA with filter (no-filter, EnChroma) and hue (16 hues) as within-subjects factors and participant group (CVN, CVD) as the between-group factor on **naming** hit scores revealed significant main effects of hue ($F_{(4.09,69.67)} = 9.19$, $P < 0.001$, $\eta^2 = 0.35$) and participant group ($F_{(1,17)} = 46.18$, $P < 0.001$, $\eta^2 = 0.73$, worse naming for CVD vs. CVN), but no significant effect of filter ($P = 0.962$) or filter*participant group ($P = 0.791$) interaction.

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