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Improving validation of BCI-based CV assessment

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Objective: Our laboratory develops non-invasive brain-computer interfaces (BCIs) for assessing color vision (CV) and identifying CV deficiencies. These systems use steady-state visual evoked potentials (SSVEPs) to identify *metamers*—light sources with different spectral distributions that are the same color [1]—and are based on the theory that light sources that are metamers do not elicit SSVEPs. To validate CV assessments, experiments use the same visual stimulator to compare BCI- and behaviorally-identified metamers.

We compared the accuracy of two methods for behaviorally-identifying metamers. The first [2], *fixed luminance*, reduced the search space to a single dimension by limiting settings to those with equal luminance. The second, *variable luminance*, introduced a novel approach allowing participants independently adjust the stimulator settings in two dimensions. We hypothesized the variable luminance method would enable the identification of light sources that were closer to being metamers, and thus, elicit smaller SSVEPs.

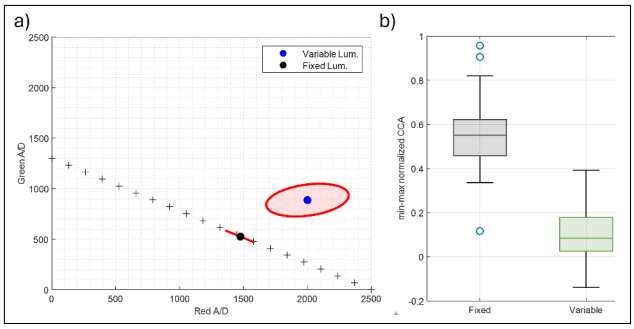

Figure 1: *Experimental results. a) Behavioral results . b) Comparison of min-max normalized SSVEPs for the two methods.*

Methods: 14 participants (6F) without CV deficiencies (FM-100 test [3] (mean $\pm$ SD: 40.6 $\pm$ 24.3)) participated (approved by the Stratton VA IRB) in behavioral experiments, 3 returned for BCI-based experiments (1F). The stimulator alternated between a monochromatic (590 nm) *amber* light source and a dichromatic (525 and 625 nm) *green* and *red* light source at 10 Hz. The luminance of the monochromatic light source was always fixed at 2400 D/A units.
Fixed luminance method – 20 stimulator settings (5 s/setting, 2 s ISI) were presented to participants in two orders (10 runs each). Order 1 – the dichromatic source initially emitted only green light (with equal luminance to the monochromatic light source), then gradually reduced green and increased red luminance, while maintaining constant overall luminance. Order 2 – reversed the sequence. Participants pressed a button to indicate the metamer; the final metamer was the median of the runs.
Variable luminance method – Participants controlled green and red luminances using 2 knobs and pressed a button when they identified the metamer; the final metamer was the median of 10 runs.
BCI-based experiments – 32 channels of EEG were recorded (g.tec; Brain Vision actiCAP). Four stimulator settings were presented (20 runs/setting): (1) Fixed luminance metamer, (2) Variable luminance metamer, (3) dichromatic source turned off (i.e., max SSVEP), and (4) constant amber (i.e., min SSVEP). SSVEPs were quantified using canonical correlation analysis (CCA) and min-max normalized.

Results: Metamers identified using the fixed luminance method (red: 1476, green: 526 A/D) elicited larger SSVEPs ($p < 0.001$) than the variable luminance method (red: 2001, green: 887 A/D) (Fig. 1).

Conclusion: The fixed luminance method for behaviorally-identifying metamers elicited smaller SSVEPs, suggesting these settings of the visual stimulator were more similar in color. An improved method for behaviorally-identifying metamers will enhance the development of BCI-based CV assessment systems.

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References:

[1] JJS Norton et al. BCI-based assessment of CV. *JNE*, 18(6):066024, 2021.
[2] M DiRaimo. Enhancing BCI-based CV assessment a new protocol for using SSVEPs to identify metamers. Master's thesis, Univ at Albany, 2023.
[3] Dean Farnsworth. The Farnsworth-Munsell 100-hue and dichotomous tests for color vision. *JOSA*, 33(10):568–578, 1943.

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