POSITIVE AND NEGATIVE CHROMOSTEREOPSIS USING LED DISPLAYS

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Introduction

Chromostereopsis is visual illusion whereby the impression of depth is conveyed in two-dimensional colour images, usually of red-blue or red-green colors, but can also be perceived with red-grey or blue-grey images [1-3].

The **aim** of the present investigation is:
a) to study the binocular perception of colour images and the generation of an illusory chromostereopsis effect;
b) to determine the effect parameters by partial covering the eye pupils; and
c) to evaluate the minimum colour difference necessary to induce chromostereopsis.

Methods

We randomly presented trial images using two colored light sources (red and blue luminophores) on a DELL U2412M display with pixel pitch 0.27 mm. The distance to display was 0.8 m. Therefore displaying 1px comprises an angle around the visual limit of 1'. We used a series of trials – up to 30 presentations of each color difference pair (Fig.1). The observers' positive responses to the query *"Is the center part closer?"* were counted as "1" and summed. The psychometric curves were fit with a sigmoidal function (where the trial sample set number N was used as the ordinate). The sigmoidal function slope parameter σ was used to calculate the effect threshold $\mathbf{N_{Th}}$.

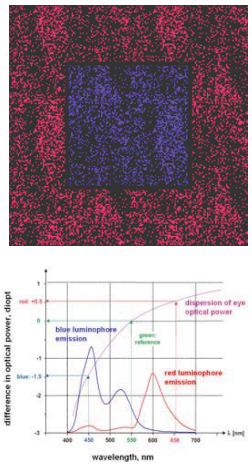

Fig 1. Stimulus presented on planar LED display. Central part 300x300 px, viewing area 600x600 px. Changes of eye optical power is presented below.

The set of trial colored image pairs were measured and their colors were fixed in the **CIE xyY** diagram. The threshold value $\mathbf{N_{Th}}$ was recalculated to determine the color difference threshold $\Delta\boldsymbol{\lambda}_{\mathbf{Th}}$ (sample N's central and surrounding color coordinates were projected towards the color gamut borders from the initiating point – point **O** in the **CIE xyY** diagram).

In order to diversify experimental conditions, we employed partial bilateral covering of the eye pupils that produces an additional type of retinal stereo disparity.

Results

Our experiments allow to determine minimum colour difference to observe chromostereopsis for the red-blue luminophore pair. Participants exhibited illusory depth perception while viewing planar colour images, demonstrating the binocular nature of this phenomenon. The way in which participants perceive chromostereopsis depends on their accommodation habits while viewing composite images, on the pupil size, and on the aperture shape. Figure 2 shows the psychometric curve of the results of the viewing trials set, similar to that in Fig.1. Employing sequences of image-pairs is sufficient to obtain data for a qualitative sigmoidal fit and to calculate the colour difference threshold (obtained value of colour difference threshold in wavelength metrics $\Delta\boldsymbol{\lambda}_{\mathbf{Th}} \approx$ 1nm).

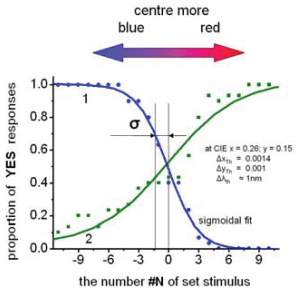

Fig 2. Psychometric curves to determine the threshold of colour difference to detect the induced colour stereoeffect. Curve for viewing with uncovered pupils (1), curve for viewing with lateral shielding (3) that shows the effect "polarity" switching. Data in insert correspond to viewing with uncovered pupils.

When the eye's pupils and lens do not possess circular symmetry, chromatic eye aberrations exert themselves in more complicated way. Figure 4 is the calculated point spread function of a half-covered eye viewing an in focus red display image and an unfocused blue display image (according to Fig.1). When red/blue ratio for colours of stimuli centre and of periphery is equal, then according to ***"Center-of-gravity"*** model [4] the stereo disparity value equals to 0. Deviation from this stimuli equivalence point gives a contribution to the ***"Center-of-gravity"*** model disparity value and chromostereopsis effect becomes recognizable.

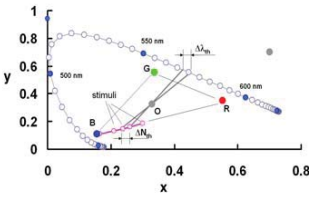

Fig 3. Stimuli on CIE xy chart and the way of presentation of the determined resolution threshold in the wavelength metrics.

Besides, the effect polarity: positive vs. negative switching – i.e., blue nearer than red and vice versa, occurs changing the lateral eye pupil covering. In our studies we observed the phenomenon - the pronounced switching of effect polarity. However the experimental points on the psychophysical curve in this case exhibited a larger deviation, at first, and the colour difference threshold at least doubled, subsequently. Such variance can perhaps be explained by the minimization of the pupil area and retinal illumination.

Discussion and conclusions

Chromostereopsis is an illusory optical effect which distorts retinal images of planar colour sources. Chromostereopsis distortion depends on image parameters, including symmetry, colour, and viewing angle, and on ambient luminance or retinal illumination.

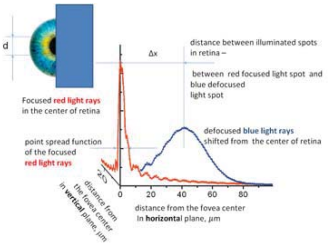

Fig 4. Retinal illumination at eye horizontal and vertical plane from a single display R+B pixel calculated from PSF function and its defocusing for blue emission. Calculations are done for half of pupil covered. Insert shows covering of eye pupils.

- Chromostereopsis can be characterized by the colour difference threshold $\Delta\boldsymbol{\lambda}_{\mathbf{Th}}$, the value that is sufficient to induce an illusory sense of depth - $\Delta\boldsymbol{\lambda}_{\mathbf{Th}} \approx$ 1nm.
- Measured threshold values are for red-blue computer display radiation determined at the difference equilibrium point **CIE x** = 0.26; **y** = 0.15 at stimuli averaged luminance **Y** = 3.9 cd/m2. These values result for trials wherein the participants' pupils are not obstructed in any way.
- Symmetrical bilateral screening of the participants' eye pupils allows for the reversal of the illusory effect - from blue in front of red to red in front of blue.

References

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