THE RAYLEIGH MATCH ON THE PERIPHERAL RETINA

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Recently, a widespread misconception that, at the periphery of the visual field, color perception is absent or poor, attracted attention of Tyler (2015, 2016), who emphasized that peripheral color vision is foveal-like if stimuli are scaled in accordance to eccentricity. This statement is based on the results of investigations using various methods, such as wavelength discrimination (van Esch et al., 1984), sensitivity to spatiotemporal color contrast (Noorlander et al., 1983), color discrimination thresholds (Nagy, 1993), etc. In this work we tried to characterize peripheral color vision on the basis of the Rayleigh match. For this purpose we developed a prototype free view alternating stimuli device consisting of stimulus box and arduino based control box. Stimulus box contains PCB with LEDs mosaic (green, red and amber LEDs with peak intensities at 520, 620, 590 nm respectively), first diffuse acrylic plate, second orange diffuse acrylic plate and exchangeable white diaphragms with 2, 3 or 4 cm circular window. Orange plate (used to avoid S-cones stimulation) shifts the green LED emission spectrum peak to 550 nm leaving the red and amber LED peaks untouched. The first field contains a mixture of red and green lights, the second field contains amber light. Fields alternate every 1.5 sec. RG knob on the control box varies relative amounts of the red and the green lights in the mixture field from 0 (only green) to 1 (only red) at constant brightness of 50 cd per square meter, AB knob varies intensity of the amber field. For foveal vision, the subject task was to eliminate perceived flickering using RG and AB knobs. Device calibration was performed with 10 normal trichromats; the individual RG match midpoints varied from 0.417 to 0.469; the accepted ranges boundaries were less than 0.005 from midpoint. For the peripheral color vision assessment the stimulus box was moved along the horizontal arc of the Förster type perimeter. Viewing distance was 30 cm, ambient light 200 lx. The stimulus box was located at the temporal side of the test eye, other eye of the subject was occluded. The task of the subject was to achieve match midpoint using RG and AB knobs while gazing at the central fixating point (red LED). Pilot study of the peripheral color vision was conducted with 3 subjects at the eccentricities of 20°, 40° and 60°. The main results were: (1) no peripheral color vision abnormalities for eccentricities up to 60° were found in any of our subjects; (2) for constant field size, all subjects demonstrated noticeable increase of RG ranges with eccentricity increase; (3) increasing field size with increasing eccentricity resulted in much less dependence of RG ranges on the eccentricity; for example, for one subject accepted RG ranges were: 0.500-0.525 (25°; 2 cm), 0.525-0.550 (40°; 3cm), 0.525-0.570 (60°; 4cm). We believe these preliminary results are in favor of the statement that peripheral color vision is foveal-like.

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Purpose

The purpose Recently, a widespread misconception that, at the periphery of the visual field, color perception is absent or poor, attracted attention of Tyler (2015, 2016), who emphasized that peripheral color vision is foveal-like if stimuli are scaled in accordance to eccentricity. This statement is based on the results of investigations using various methods, such as wavelength discrimination (van Esch et al., 1984), sensitivity to spatiotemporal color contrast (Noorlander et al., 1983), color discrimination thresholds (Nagy, 1993), etc. In this work we tried to characterize peripheral color vision on the basis of the Rayleigh match used in anomaloscope. Specifically we investigated match ranges dependence of stimulus size at different eccentricities.
We know only one work on peripheral color vision (Gordon, Abramov, 1977) where modified anomaloscope procedure was used, but they used similarity rates between fields.

Methods

Optical device

The development of the device was inspired by works (Bongard, Smirnov, 1958; Woods et al., 2005; Trukša et al., 2012). The device uses "silent substitution" principle. A prototype free view alternating stimuli device consists of the stimulus box and arduino based control box (Fig.1). Stimulus box (Fig. 2) contains PCB with LEDs mosaic (green, red and amber LEDs with peak intensities at 520, 620, 590 nm respectively), first diffuse acrylic plate, second orange diffuse acrylic plate and exchangeable white diaphragms with 2, 3 or 4 cm circular window. Orange plate is used to avoid S-cones stimulation. It shifts the green LED emission spectrum peak to 550 nm leaving the red and amber LED peaks untouched (for discussion of the green light spectrum position see (Pokorny, Smith, 1984)). The first field contains a mixture of red (R) and green (G) lights, the second field contains amber light (A). Normalized spectra of R, G and A lights are presented in Fig.3. Fields alternate every 1.5 sec. RG knob on the control box varies relative amounts of the red and the green lights in the mixture field from RG=0 (only green) to RG=1 (only red). With the help of spectrophotometer (X-Rite Eye One Pro) we programmatically equated brightnesses at RG=0 and RG=1 so that the RG knob varies hue at the constant brightness of 50 cd/m². AB knob varies intensity of the amber field. All three lights are controlled with 10-bit resolution.

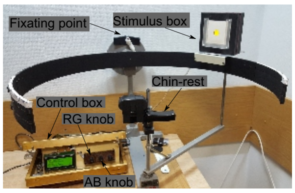

Fig. 1. General view of the experimental setup

Experimental setup

General view of the experimental setup is presented in Fig.1. For the peripheral color vision assessment the stimulus box was moved along the horizontal arc of the Fӧrster type perimeter. At the center of the perimeter arc fixation point (red LED) was placed. Viewing distance was 30 cm, ambient light 200 lx. Stimuli sizes were 2, 3 and 4 cm.

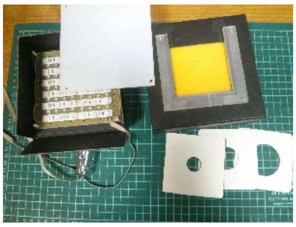

Fig. 2. Stimulus box disassembled

Subjects

Device calibration was performed with 10 normal trichromats. Also 2 protanopes and one deuteranomalous trichromat were measured. Main experiments were conducted with 2 subjects with normal color vision.

Procedure

The task of the subject was to eliminate perceived flickering using RG and AB knobs. For the device calibration the subject binocularly gazed at the center of the stimulus. In the main experiments the stimulus box was located at the temporal side of the test eye, other eye of the subject was occluded. Measurements were conducted at the eccentricities 25°, 40° and 60°. Subject was asked to achieve match point by turning RG, AB knobs while gazing at the central fixating point, but focusing attention on the flickering of the stimuli. After the match point was achieved, RG thresholds (ranges of the indistinguishability) were determined with respect to hysteresis.

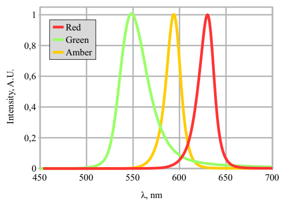

Fig. 3. Normalized spectra of the of the stimulus box channels R, G and A .

Results

Device calibration

It was found, that for foveal color vision it is not easy for subjects to determine which of the two fields is presented at the given moment, so experimenter helped the subject with sound signal. Some subjects reported occurrence of afterimages of various kind which complicated their task. The results are presented in Fig. 4. Individual RG match midpoints varied from 0.379 to 0.478; the accepted RG ranges boundaries were less than 0.005 from midpoint. We also present results of 3 subjects with abnormal color vision (BAV, BDA – protanopes and DAN – deuteranomalous trichromat). One of the subjects (PVD) reported that color vision of his left and right eyes differs, so we present his results for each eye: PVD_OD (RG=0,465;AB=285), PVD_OS (RG=0.471, AB=297).

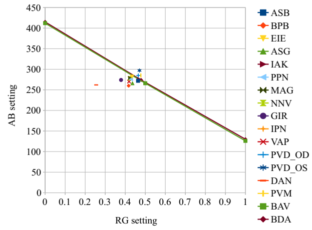

Fig. 4. Device calibration results

Main results

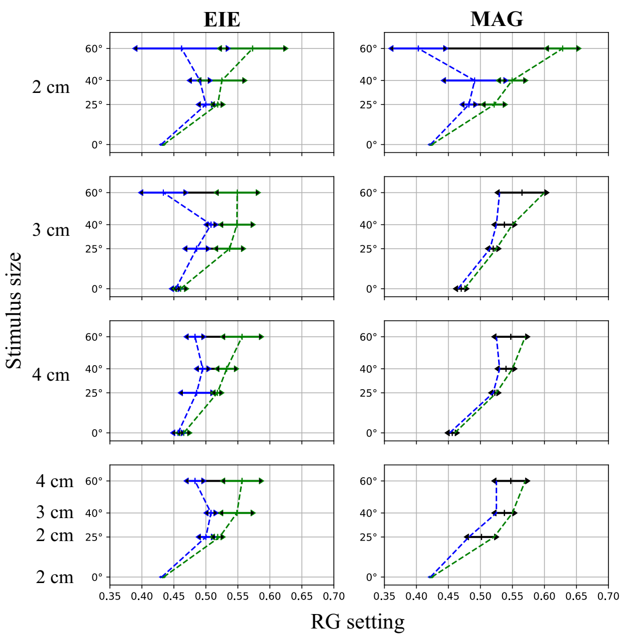

Fig. 5. RG ranges for two subjects EIE and MAG for eccentricities 25°, 40°, 60° and stimulus sizes 2, 3, 4 cm. Diagram in bottom row is combined of the 3 upper diagrams. Hysteresis effect is denoted by lines with arrows: blue for lower RG range and green for upper RG range.

It was found that setting of AB knob can be fixed equal to its setting for subject's foveal color vision estimated during calibration. So subjects turned only RG knob. We determined hysteresis in RG ranges by example of upper range determination: after subject reported that he achieved match point, he continue to increase RG until he noticed flickering; then he decreased RG until he stop to perceive flickering.

Diagrams in Fig. 5 show:
– There is noticeable shift of RG match points to the red when going from fovea to periphery which we attribute to macula optical filtering properties.
– Foveal match ranges (eccentricity 0°) increase with field size increasing.
– Contrary to the findings of (Gordon, Abramov, 1977) we see slight shift of the RG ranges to the protanomalous side with eccentricity increase (with stimuli sizes 1.5° and 6.5° at eccentricity of 45° those authors concluded that color vision on the periphery has slight indication of deuteranomaly).
– For constant field size increasing eccentricity cause RG ranges increasing and increasing hysteresis effect in RG ranges. This is especially dramatic in upper diagrams with stimulus size 2cm.
– Up to eccentricities to 60° there is no sign of color blindness even for small stimulus size 2 cm.

Conclusions

(1) No peripheral color vision abnormalities for eccentricities up to 60° were found in any of our subjects.
(2) For constant field size, all subjects demonstrated noticeable increase of RG ranges with eccentricity increase.
(3) Increasing field size with increasing eccentricity resulted in much less dependence of RG ranges on the eccentricity.
We believe these preliminary results are in favor of the statement that peripheral color vision is foveal-like.

Also it seems that the developed device can be useful for assessment of color vision due to its simplicity and extremely low cost.

Acknowledgments

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References

Bongard M.M., Smirnov M.S., Friedrich, L. (1958) The four-dimensional colour space of the extrafoveal retinal area of the human eye. In: Visual Problems of Colour, Vol. 1, pp. 325-330. London: H. ~I. Stationery Office.
Gordon J., Abramov I. (1977) Color vision in the peripheral retina. II. Hue and saturation. JOSA. V.67(2). P. 202-207.
Noorlander C., Koenderink J. J., den Ouden R. J., Edens B. W. (1983) Sensitivity to spatiotemporal colour contrast in the peripheral visual field. Vision Research V.23(1). P. 1–11.
Pokorny J., Smith V.C. (1984) Metameric Matches Relevant for Assessment of Color Vision. In: Verriest G. (eds) Colour Vision Deficiencies VII. Documenta Ophthalmologica Proceedings Series, vol 39. Springer, Dordrecht.
Trukša R., Fomins S., Ozoliņš M. (2012) Rayleigh Equation Anomaloscope from Commercially Available LEDs. Materials Science. V.18(2). P. 202-205.
Tyler C. W. (2015) Peripheral color demo. I-Perception. V. 6(6). P. 2041669515613671. DOI: 10.1177/2041669515613671.
Tyler C.W. (2016) Peripheral color vision and motion processing. Human Vision and Electronic Imaging. V.5. P. 1-5. DOI: 10.2352/ISSN.2470-1173.2016.16HVEI-138
van Esch J.A., Koldenhof E.E., van Doorn A.J., Koenderink J.J. (1984) Spectral sensitivity and wavelength discrimination of the human peripheral visual field. JOSA A. V. 1(5). P. 443-450.
Woods, R. L, Rashed, A. L, Benavides, J. M, Webb, R. H. (2005) A Low-power, LED-based, High-brightness Anomaloscope. Vision Research. V.46. P. 3775 – 3781.

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