## A PILOT PERIMETRIC STUDY OF FAR PERIPHERAL COLOR VISION USING TWO SMARTPHONES

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Despite a significant number of investigations showing that, in conditions of a proper scaling test stimulus size and/or luminance, human peripheral retina can provide foveal-like color perception, some doubts concerning peripheral color vision are still common among visual scientists and ophthalmologists. Methodological and technical problems in creating conditions for a suitable stimulus presentation and adequate characterization of perceived images at the periphery of the visual field make it difficult to collect enough data and formulate comprehensive notion of the peripheral vision. Up to now, search for a simple technique allowing fast assessment of the peripheral vision capabilities seems to be rather pressing. In our pilot study, we tried to use identical smartphones (Samsung Galaxy S6 with AMOLED screen) both for test stimulus presentation and for quantitative evaluation of perceived images using color checker. The test stimuli (uniform color circles of 4-8° in diameter turning on/off each 1.5 s) were displayed on the smartphone attached to the platform moving along the perimetric arc to vary stimulus eccentricity. The second smartphone, displaying color checker circle, was fixed at the center of the perimeter arc. The hue and saturation of each test stimuli corresponded to one of the smartphone primaries (R, G, B). Hue, saturation, and luminance of the checker circle could be easily controlled by the subject employing mouse connected with the checker smartphone. The test stimulus and the checker circle were observed simultaneously in monocular viewing conditions. Subjects were three males and one female (30 - 75 years old) with normal color vision. The subject task was to make the appearance of the checker image as similar as possible to the appearance of the peripheral one adjusting hue, saturation, and luminance of the checker circle. Presenting color test stimuli at far periphery (temporal visual field, 60-95°), we have found that perceived peripheral images could be vivid and allowed matching in hue and saturation to the foveal checker image. The peripheral images preserved or changed their appearance with increasing eccentricity depending on the stimulus parameters and individual eye properties. For instance, in subjects IP and PN, at the maximal test stimulus intensities, the quantitative estimates of the perceived hue (according to the HSV color model) at the eccentricities of 60°, 80° and 95° were: 0→3→1; and 0→0→0 (for R); 126→76→81 and 121→30→135 (for G); 217→227→211 and 234→240→232 (for B), respectively. In the range 80-95°, perceived luminance could be very high, significantly exceeding the maximal possible level of the checker image. It was surprising that, in certain conditions, two of our subjects could perceive the red stimuli as certainly the green ones or see the two hues at once in one image. Transformation of the red image into the green one and back could be verified by means of moving the test stimuli along the perimetric arc repeatedly.

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RUSSIAN ACADEMY OF SCIENCES
INSTITUTE FOR INFORMATION TRANSMISSION PROBLEMS (Kharkevich Institute)

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INTERNATIONAL COLOUR VISION SOCIETY
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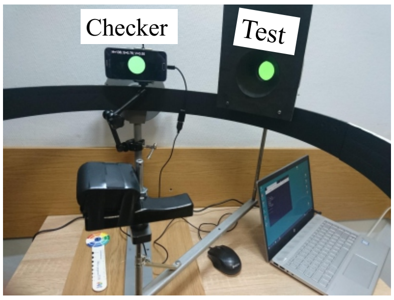
## Purpose

**The purpose** of this investigation was to find a simple technique for a quantitative assessment of peripheral color vision. Despite a significant number of investigations showing that, in conditions of a proper scaling test stimulus size and/or luminance, human peripheral retina can provide foveal-like color perception, some doubts concerning peripheral color vision are still common among visual scientists and ophthalmologists. Methodological and technical problems in creating conditions for a suitable stimulus presentation and adequate characterization of perceived images at the periphery of the visual field make it difficult to collect enough data and formulate comprehensive notion of the peripheral vision.

## Methods

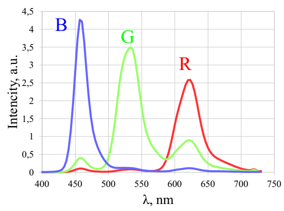
### Experimental setup

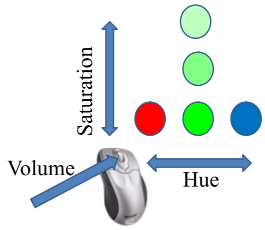



In our pilot study, we tried to use identical smartphones (Samsung Galaxy S6 with AMOLED screen) both for test stimulus presentation and for quantitative evaluation of perceived images using color checker. The test stimuli (uniform color circles of 4-8° in diameter turning on/off each 1.5 s) were displayed on the smartphone attached to the platform moving along the perimetric arc to vary stimulus eccentricity. The second smartphone, displaying color checker circle, was fixed at the center of the perimeter arc.

### Procedure

Smartphone primaries



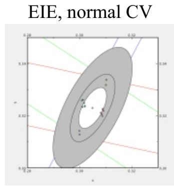




The hue and saturation of each test stimuli corresponded to one of the smartphone primaries (R, G, B). Hue (H), saturation (S) and luminance (Volume–V) of the checker circle could be easily controlled by subjects with a mouse connected to the checker smartphone. The test stimulus and the checker circle were observed simultaneously in monocular viewing conditions. The subject's task was to make the checker image as similar as possible to the appearance of the peripheral one adjusting hue, saturation, and luminance of the checker circle by means of moving the mouse. The quantitative estimates of the perceived colors were obtained according to the HSV color model and were displayed on the checker.

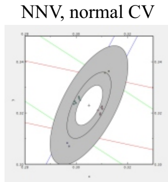
### Subjects

Subjects were three males and one female (30 - 75 years old) whose color vision (CV) was assessed with CAD (Colour Assessment and Diagnosis) test by City Occupational Ltd.

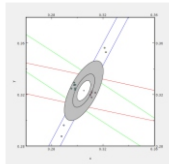
EIE, normal CV



NNV, normal CV

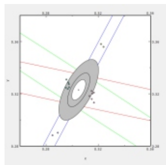


IPN



Diagnosis: normal RG color vision; deficient YB color vision

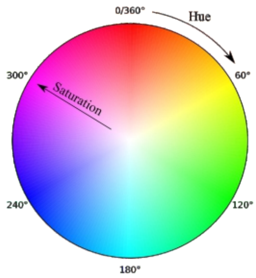
PPN



Diagnosis: potential deutan deficiency; deficient YB color vision; acquired deficiency likely

## Results

Some results of our preliminary investigation are shown here in tables and polar plots. Presenting color test stimuli at far periphery (temporal visual field, 60-95°), we have found that perceived peripheral images could be vivid and, in most cases, allowed matching in hue and saturation to the foveal checker image. Matching in perceived brightness (volume) was less reliable: the highest possible value V=1.0 was often insufficient for matching. With increasing eccentricity, the peripheral images preserved or changed their appearance depending on the stimulus parameters and individual eye properties (see the Tables 1, 2 and plots).




It was surprising that, in certain conditions, two of our subjects could perceive the red stimuli as certainly the green ones or see the two hues at once in one image. The data of one such subject (EIE) are presented in the two lower plots. At the intensity level 100 and the eccentricity 80°, a red stimulus was perceived as red-green and, at 95 °, - as green. Transformation of the red image into the green one and back could be verified by means of moving the test stimuli along the perimetric arc repeatedly. At higher intensity level, 255, transformation of red into green was not observed.

**Table 1. Subject IPN. Test 4 cm. (H-S-V)**

| Test | Eccentricity | | | | | |
|---|---|---|---|---|---|---|
| | 60º | | 80º | | 95º | |
| | L | Perceived image | L | Perceived imager | L | Perceived image |
| RED | 34 | Reddish flicker | 45 | Dark red flicker | 35 | Achromatic flicker |
| | 100 | 348-0.89-0.7 | 100 | 20-0.83-0.7 | 100 | 3-0.75-0.6 |
| | 255 | 357-0.86>1 | 255 | 0-0.8>1 | 255 | 3-0.76=>1 |
| GREEN | | | | | | |
| | 15 | Achromatic flicker | 15 | Achromatic flicker | 15 | Dark green circle |
| | 100 | 100-0.93-0.9 | 100 | 134-0.71-0.8 | 100 | 107-0.73-0.5 |
| | 255 | 120-0.92>>1 | 255 | 120-0.74>>1 | 255 | 106-0.72>1 |
| BLUE | | | | | | |
| | 20 | Bluish flicker | 20 | Dark bluish flicker | 30 | Dark blue flicker |
| | 100 | 230-0.7>1 | 100 | 223-0.8-0.5 | 100 | 222-0.8-0.6 |
| | 255 | 218-0.8>1 | 255 | 235-0.79>1 | 255 | 216-0.8>1 |

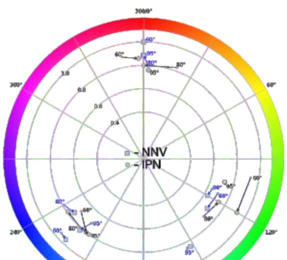


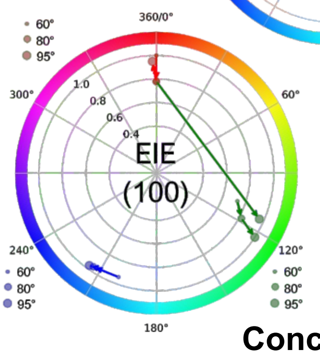

**Table 2. Subject NNV. Test 4 cm. (H-S-V)**

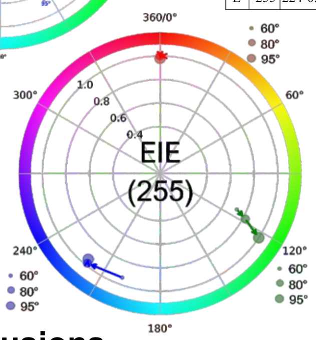
| Test | Eccentricity | | | | | |
|---|---|---|---|---|---|---|
| | 60º | | 80º | | 95º | |
| | L | Perceived image | L | Perceived imager | L | Perceived image |
| RED | 34 | Orange-red circle | 40 | Dark red circle | 35 | Achromatic flicker |
| | 100 | 0-1-0.6 | 100 | 3-0.79-0.6 | 100 | 1-0.88-0.8 |
| | 255 | 0-1-1 | 255 | 0-0.89>1 | 255 | 0-0.88>1 |
| GREEN | | | | | | |
| | 15 | Achromatic flicker | 15 | Achromatic flicker | 15 | Dark green flicker |
| | 100 | 115-0.7-0.3 | 100 | 114-0.64-0.8 | 100 | 154-0.85-0.4 |
| | 255 | 128-0.69-0.9 | 255 | 120-0.63>1 | 255 | 152-0.85-1 |
| BLUE | | | | | | |
| | 20 | Bluish flicker | 20 | Dark-bluie flicker | 30 | Achromatic flicker |
| | 100 | 228-0.95-0.5 | 100 | 240-0.79-0.9 | 100 | 219-0.71-0.4 |
| | 255 | 224-0.96-1 | 255 | 232-0.75>1 | 255 | 222-0.82>1 |

Comments to the Tables:

-The triplets of values in the cells of both Tables correspond to the values H, S, V chosen by the subjects as a result of matching. At low intensities of the peripheral stimuli, matching was impossible though subjects could perceive not only "something flickering" but also clear pale circular images.

-The signs >1 and >> 1 correspond to the cases when the peripheral image was perceived as very bright and the foveal image with V=1 (the maximum possible value) appeared to be too weak in comparison with it.




In many cases, far peripheral images were characterized by unusually high brightness making it impossible to obtain the foveal image matched to the peripheral one in V.

Matching in H and S was also not always possible, supposedly, because of relatively low precision of the smartphones as the devices for color coding and displaying.

## Conclusions

**(1) A simple setup with two smartphones designed for displaying and varying color test and checker images proved to be suitable for fast preliminary investigation of peripheral color vision providing consistent and reliable data.**
**(2) The quality and applicability of the set up as a measuring instrument could be improved by using more perfect color model and taking the devices with better color characteristics.**

Acknowledgments

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