ADVANTAGES AND SHORTCOMINGS OF USING A CONTACT LENS WITH AN IMPLANTED OCCLUDER IN THE ASSESSMENT OF PERIPHERAL COLOR VISION

Elena Iomdina[1], Olga Selina[1], Galina Rozhkova[2], Alexander Belokopytov[2], Egor Ershov[2], Ilia Nikolaev[3] and Peter Nikolaev[2]

[1] Moscow Helmholtz Research Institute of Eye Diseases, Russia

[2] Institute for Information Transmission Problems (Kharkevich Institute), Moscow, Russia

[3] Moscow State University, Faculty of Physics, Russia

Corresponding author: iomdina@gmail.com

Retrospective overview of publications available on peripheral color perception shows that there are practically no behavioral studies demonstrating real capabilities of peripheral vision as such and its linkage/cooperation with central vision. In particular, it seems important to obtain behavioral and psychophysical data on "pure peripheral vision", i.e. to investigate visual perception "switching central vision off". For this purpose, we decided to use contact lens with an implanted occluder in the hope to overcome some of the principal deficiencies of commonly employed techniques. When peripheral vision is studied, visual attention is usually divided between the peripheral test stimulus and the fixation stimulus at the center of the visual field. Such unnatural and uncomfortable conditions inevitably cause substantial difficulties in the assessment of potential capabilities of peripheral vision. Firstly, central fixation means forced limitation of the test stimulus image drift over the retina, whereas, for optimal perception of the peripheral stimuli, the drift should be enhanced (Yarbus & Rozhkova, 1977). Secondly, voluntary stabilization of the eye position deteriorates natural oculomotor activity, preventing normal saccadic movements that usually occur several times per second. Thirdly, at the cognitive level, mental resources are divided between the two tasks thus decreasing quality of the peripheral stimulus analysis. In our pilot investigation, we used contact lens with an implanted opaque occluder overlapping the pupil area and completely excluding central vision (shading the area of 60-80° in diameter). In total, our experiments confirmed significant benefits of this technique for studying peripheral vision capabilities. The subjects with an occluder on the contact lens demonstrated a significantly decreased tendency of turning the eye to foveate the peripheral stimulus since such turns were useless. Despite perceiving a large dark area at the center, the subjects could observe the periphery of the visual field without discomfort. They could walk freely around the rooms and corridors recognizing furniture and people. In general, the perceived scenes (under illumination of about 250 lx) were similar to the normally observed ones excluding some low contrast fragments and unsaturated colors. One of the subjects reported that he perceived the surroundings almost as in normal viewing conditions but felt himself as "looking through the iris but not through the pupil". Among the shortcomings of our technique the following three seem to be the most essential. (1) The size of the shaded area depends not only on the occluder diameter but also on the individual eye optics and the ambient luminance indicating the necessity of additional measurements for proper describing viewing conditions. (2) One of the critical parameters determining the size of the shaded area is the pupil diameter that is permanently changing during observation and depends on physical parameters of the scene and the emotional content of the stimuli. The amplitude of possible "pupil pulsations" has to be taken into consideration. (3) The lens can slip over the cornea changing the position of the occluded area in the visual field; such slippage should be prevented or taken into consideration.

Partially supported by RFBR grant 19-015-00396A.

ADVANTAGES AND SHORTCOMINGS OF USING A CONTACT LENS WITH AN IMPL ANTED OCCLUDER IN THE ASSESSMENT OF PERIPHERAL COLOR VISION

Elena Iomdina[1], Olga Selina[1], Galina Rozhkova[2], Alexander Belokopytov[2], EgorErshov[2], Ilya Nikolaev[3], PetrNikolayev[2]

[1]Moscow Helmholtz Research Institute of Eye Diseases, Russia

[2]Institute for Information Transmission Problems (Kharkevich Institute) Russian Academy of Sciences, Moscow, Russia

[3]Moscow State University, Moscow, Russia

E-mail: gir@iitp.ru

INTERNATIONAL COLOUR VISION SOCIETY

RIGA 2019

PURPOSE

The purpose of this research was to develop a simple method for studying capabilities of human peripheral vision in conditions close to natural. Retrospective overview of publications available on peripheral color perception shows that there are practically no behavioral studies demonstrating real capabilities of peripheral vision as such and its linkage/cooperation with central vision. In particular, it seems important to obtain behavioral and psychophysical data on "pure peripheral vision", or "vision without a fovea", i.e. to investigate visual perception "switching central vision off". For this purpose, we decided to use contact lens with an implanted occluder in the hope to overcome some of the principal deficiencies of commonly employed techniques.

TECHNICAL APPROACH

When peripheral vision is studied, visual attention is usually divided between the peripheral test stimulus and the fixation stimulus at the center of the visual field. Such unnatural and uncomfortable conditions inevitably cause substantial difficulties in the assessment of potential capabilities of peripheral vision.

Firstly, central fixation means forced limitation of the test stimulus image drift over the retina, whereas, for optimal perception of the peripheral stimuli, the drift should be enhanced (Figure 1; data from Yarbus & Rozhkova, 1977).

Secondly, voluntary stabilization of the eye position deteriorates natural oculomotor activity, preventing normal saccadic movements that usually occur several times per second.

Thirdly, at the cognitive level, mental resources are divided between the two tasks thus decreasing quality of the peripheral stimulus analysis.

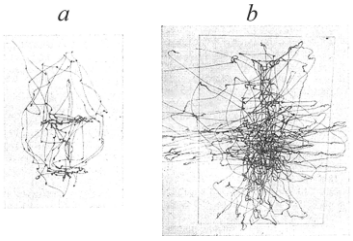
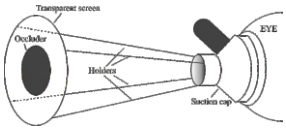
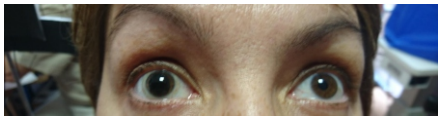


Figure 1. Eye movements in the course of looking at the same portrait without (a) and with (b) occluder on the suction cap of the type shown below.



In our pilot investigation, we used contact lens with an implanted opaque occluder overlapping the pupil area and completely excluding central vision (shading the area of 60-80° in diameter).



RESULTS

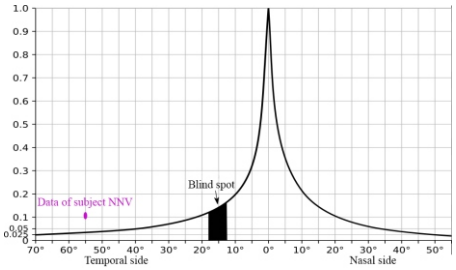
In general, our experiments confirmed significant benefits of the technique developed for studying peripheral vision capabilities. The subjects with an occluder on the contact lens demonstrated a decreased tendency of turning the eye to foveate the peripheral stimulus since such turns were useless. Despite perceiving a large dark area at the center, the subjects could observe the periphery of the visual field without discomfort. They could walk freely around the rooms and corridors recognizing furniture and people. In general, the perceived scenes (under illumination of about 250 lx) were similar to the normally observed ones excluding some low contrast fragments and unsaturated colors. One of the subjects reported that he perceived the surroundings almost as in normal viewing conditions but felt himself as "looking through the iris but not through the pupil".

Quantitative assessment of our technique advantages was carried out in two series of experiments:

(1) Computer-aided measurement of peripheral visual acuity using modified 3-bar targets and tumbling E stimuli (incorporated into original software TIP-TOP).

(2) Estimation of diascleral light contribution to color constancy.

The first results of both series appeared to be promising.



(1)The data obtained in subject NNV with the occluder covering up to 55° temporally were: **0.115-0.119** for the modified 3-bar targets, **0.098-0.088** for tumbling E, i.e. the range was **0.09-0.12 (**if the results were rounded off). These results are shown near the classical curve of Wertheim (1894) who conducted the measurements of his own peripheral visual acuity ***after several weeksof training*** At the same eccentricity 55°temporally, the result of Wertheim obtained with the small test grids made of wire was **0.033**.

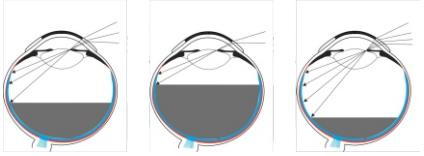
(2) As concerns the second experimental series, it is impossible to present its results briefly. In accordance with our predictions, most noticeable color transformations with changing diascleral light contribution were observed in the cases of red test stimuli. In more details these results are published in (Rozkova et al., 2019).

Among the shortcomings of our technique the following three seem to be the most essential.

(1) The size of the shaded area depends not only on the occluder diameter but also on the individual eye optics and the ambient luminance indicating the necessity of additional measurements for proper describing viewing conditions.

(2) One of the critical parameters determining the size of the shaded area is the pupil diameter that is permanently changing during observation and depends on physical parameters of the scene and the emotional content of the stimuli. The amplitude of possible "pupil pulsations" has to be taken into consideration.

(3) The lens can slip over the cornea changing the position of the occluded area in the visual field; such slippage should be prevented or taken into consideration.



CONCLUSION

In studies of human peripheral vision, application of contact lens with implanted occluders seems to be very promising but require thorough control and description of experimental conditions and individual visual characteristics of subjects

Acknowledgments

We are greatly indebted to Ekaterina Kruttsova for technical assistance, and to our colleagues – Maria Gracheva, Svetlana Rychkova, Nadezhda Vasilyeva and Anna Kazakova who were always ready to participate in our experiments.

Partially supported by RFBR grant 19-015- 00396A

References

Jordan, T. R., McGowan, V. A., & Paterson, K. B. (2012). Reading with a filtered fovea: The influence of visual quality at the point of fixation during reading. *Psychonomic bulletin & review, 19*(6), 1078-1084.

Lingnau, A. (2004). *Seeing without a fovea?: Eye movements in reading and visual search with an artificial scotoma* (Doctoral dissertation).

Rayner, K., & Bertera, J. H. (1979). Reading without a fovea. *Science, 206*(4417), 468-469.

Rozhkova GI, Iomdina EN, Selina OM, Belokopytov AV, Nikolayev PP. Contribution of the marginal peripheral retina to color constancy: evidence obtained due to contact lens with implanted occluder. *SensSist* 2019;33(2):113-123. doi:10.1134/S0235009219020082

Yarbus, A. L. & Rozhkova, G. I. (1977). The peculiarities of perceiving visual objects at the periphery of the visual field. In: *Sensory systems*. Leningrad: Nauka, 1977. P. 64-73

Wertheim, T., & Dunsky, I. L. (1980). Peripheral visual acuity. *Optometry and Vision Science, 57*(12), 915-924.