The extreme retinal periphery: Experimental evidence of specific function suggested by A. Yarbus for blind retina

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Issue

In 1975-80 A. Yarbus published ten articles presenting his thoughtful view on the whole subject of vision. Most part of these papers were devoted to color vision and introduced such original terms as "zero color" and "anti-color". In particular, Yarbus based his theory of color vision on the experiments with diascleral stimulation of the extreme periphery of retina. Experiments lead to the hypothesis that a narrow retinal ring running along the ora serrata could be considered as a **blind retina** having certain specific functions. The photoreceptors of this ring aren't designed for formation of local images being only stimulated by diffuse light scattered inside the eye. Their responses are used for estimation of average illumination characteristics aimed at general normalization of the perceived scene for color constancy.

Yarbus described his experiments with diascleral stimulation of the retina in the articles [1, 2] of the series mentioned above too shortly and without details. In these experiments sclera was illuminated with thin light ring (see Fig. 1).

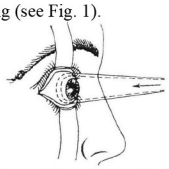

Fig. 1. Illumination of the sclera with thin light ring. Light ring is indicated with dashed lines. Note that cornea was not occluded. From [1].

Yarbus found that light ring placed near limb were not perceived at all, even when its intensity and spectrum were changed. But when ring diameter was increased, switching the ring on caused paradoxical darkening and changes in color of the perceived foveal visual images.

There is scarce and contradictory information on the very existence of this darkening. Fry&Alpern [4] denied it, though earlier, Shouten&Ornstein claimed that it existed [3]. Unlike Yarbus these authors used spot stimulation of the sclera. But technique of their experiments cause a lot of doubt. It seems reasonable to use spot sclera stimulation in view of contemporary concept of blind retina whose width differs substantially on nasal and temporal sides of the eye (see Fig. 2).

To test the validity of Yarbus' hypothesis we used both methods providing diascleral stimulation of the retina: ring illumination ("Ring") and spot illumination ("Spot") . In the "Ring" experiments we tried to reproduce Yarbus' experiments but with the cornea occluded. In the "Spot" experiments we tried to improve experimental technique described in [3, 4] in order to obtain unambiguous and reproducible results.

Purpose

Experimental investigation of paradoxical darkening of the perceived visual images in the conditions when the blind retina is selectively stimulated by light (illustrated by Fig. 2).

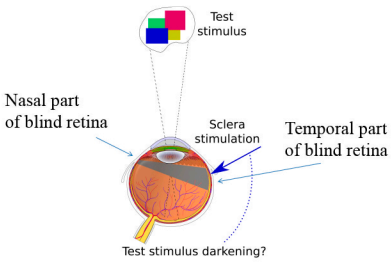

Fig.2. Principal scheme of the experiment. Does sclera stimulation produce paradoxical darkening of the foveal test stimulus? Blind zone marked with grey.

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Experiment setup

For the experiments with ring and spot diascleral illumination we used DLP video projector ViewSonic PJD6553w ("DLP") controlled by our original computer program. Distance between projector lens and subject's sclera was 60 cm. Sclera illumination level inside the spot and the ring was 10000 lux. Experimental room was darkened. All experiments were monocular. 6 subjects participated in experiments.

Ring stimuli

The subject laid on his back. Subject's eyelids were fixated with adhesive plaster. Cornea was occluded with a black cap placed over transparent contact lens. Caps of various diameters were used either occluding the whole cornea or leaving a narrow peripheral zone uncovered. Sclera stimulation was switched on/off manually.

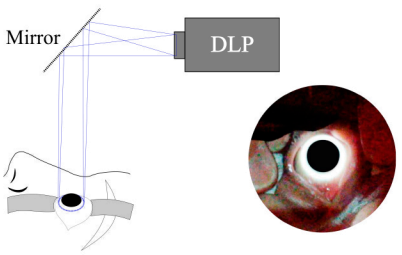


Fig. 3. Ring experiment setup.

Spot stimuli

Subject fixated the test stimulus positioned 30°-40° temporally or nasally while a small spot of light was projected onto the sclera near the limbus and moved to the corner of the eye and back along the horizontal meridian of the eye. Sclera stimulation was switched on/off every 5 sec .

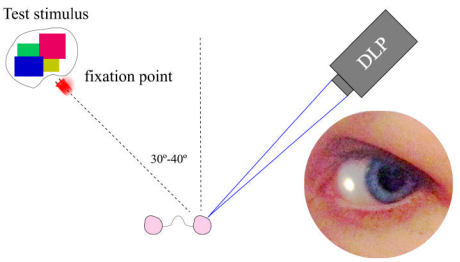


Fig. 4. Spot experiment setup.

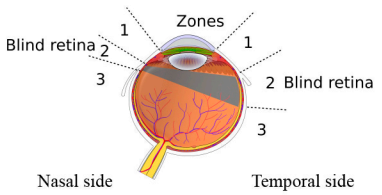
Predictions

We expected different effects depending on sclera zone stimulation.

Zone 1 – no retina under sclera – no change in perception

Zone 2 – blind retina under sclera – paradoxical darkening

Zone 3 – sighting retina under sclera – subject see spot on the side of the visual field opposite to the sclera stimulation side (photoreceptors are stimulated through sclera).



Results

"Ring" experiments

The ring width was about 1 mm. Without sclera stimulation subjects saw dark area in the center of the visual field and, in case of partial cornea occlusion - experimental room objects on the periphery.

Zone 1: subjects did not perceive stimulation switching on/off.

Zone 2: when stimulation was switched on, subjects reported blackening of central area and of objects on the periphery. When stimulation was switched off, subjects reported restoring brightness of central area and objects on the periphery. In case of total occlusion of the cornea, switching the ring on/off caused the perception of general darkening/lightening of the large central area.

Zone 3: with such experimental setup we could not stimulate this zone due to anatomical restrictions (the exposed area of the eye).

"Spot" experiments

The spot size was about 1 mm. We used three positions of the spot at different distances from limb.

Temporal side: near limb (zone 1); 5-7 mm (zone 2); 12-14 mm (zone 3).

Nasal side: near limb (zone 1); 5-6 mm (zone 2); 8-10 mm (zone 3).

Zone 1: subjects did not perceive the spot switching on/off, there were no evident change in perception of the test stimulus.

Zone 2: when the spot was switched on, subjects reported darkening of the test stimulus. When the spot was switched off, subjects reported brightening of the test stimulus.

Zone 3: when the spot was switched on, subjects reported no change of the perceived test stimulus and saw a bright image (usually of reddish color) on the side of the visual field opposite to the sclera stimulation side, as if the retina was stimulated by the light spot through the pupil.

Concluding remarks

– Our experiments showed paradoxical darkening of perceived visual images when stimulating sclera in the nasal and temporal zones 2. We suppose that the zones 2 correspond to a blind retina.

– Stimulation of the zones 1 and 3 produced quite different effects (zone 1 – no effects; zone 3 – no darkening, appearance of the bright image on the opposite side).

– The results obtained support the Yarbus' hypothesis about specific function of the blind retina zones at the temporal and nasal sides of the eye.

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According to the idea of Yarbus, a narrow retinal ring running along the *ora serrata* could be considered as a blind retina having certain specific functions. The photoreceptors of this ring aren't designed for formation of local images being only stimulated by diffuse light scattered inside the eye. Their responses are used for estimation of average illumination characteristics aimed at general normalization of the perceived scene. One prediction of this hypothesis is that selective light stimulation of the blind retina should cause darkening of the perceived visual images and changes in color. To test the validity of Yarbus's hypothesis, we used two methods providing diascleral stimulation of the retina. The subject had to describe the changes in visibility of the observed visual scene in the following conditions: (1) he/she fixated the test stimulus positioned 30-40º temporally or nasally while a small spot of light was projected onto the sclera near the limbus and moved to the corner of the eye and back; (2) he/she observed a peripheral part of the visual field left visible after occlusion of the pupil while the thin light rings of various diameters and brightness were projected onto the sclera around the iris. By both methods it was possible to find the conditions of paradoxical darkening of the visual field due to illumination of certain area presumably covering the blind retina. Stimulation of the adjacent areas produced quite different effects.
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TEASER

A.Yarbus put forward the hypothesis that a narrow retinal ring at *ora serrata* is behaviorally blind and serves for color constancy by estimating average scene illumination. One of the predictions of this hypothesis – paradoxical darkening of the visual field due to illumination of blind retina – was supported by our experiments.