AFTER—IMAGES*

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EDRIDGE-GREEN (1945) has described some experiments on the persistence of vision, which appear to him to give evidence (*a*) that the rods are not percipient elements but gland-like structures, secreting visual purple; (*b*) that the cones are not stimulated directly by light but indirectly by the decomposition products of visual purple; (*c*) that visual purple is secreted into a space filled with fluid, in which the tips of the cones are immersed; (*d*) that under certain circumstances relative movement can take place between this fluid and the tip of the cones. The writer has repeated and extended Edridge-Green's experiments in order to test the validity of the above conclusions.

It would appear that Edridge-Green did not differentiate between foveal and extra-foveal vision. Thus he mentions a strip of white paper (3 in. x $\frac{1}{4}$ in.) placed on a black-board, and describes the fate of the positive after-image resulting from a quick glance at the strip of paper, but omits to state the distance he viewed it from. In another experiment he mentions the after-image due to a red flower seen at a distance of 3 metres; in this instance it is reasonable to assume that it was cone-vision which predominated over rod-vision. The importance of distinguishing between the two kinds of vision is brought out forcibly by a variation of Bidwell's well-known experiment.

Methods

A disk of white cardboard, one half of which is painted black, has a small hole (1 cm. diameter) drilled in that boundary where white follows black on rotating the disk. A steel mirror to which is clamped a red filter is placed behind the disk. A small bright filament lamp is placed in front of the disk so as to illuminate it, and is so adjusted that the filament can be seen in the mirror when the aperture is in the correct position. The hue will, of course, be red. A wedge is forced between the mirror and the filter so that reflections at the two surfaces of the latter cannot interfere with the observations. If the observer is at such a distance that the image of the filament does not subtend at the eye an angle larger than 1·5°, the hue will remain red even if the motor-driven disk is rotated. However, if the observer fixates a point 3 or 4 cm. to one side of the image, the hue changes to green. This colour can also be observed on increasing the visual angle by a lens during direct fixation.

It is thus seen that, at least as far as negative after-images are concerned, a difference must be made between foveal and extra-

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foveal vision. Further, if (*a*) were correct it might be expected that the intensity of the red sensation would be diminshed extra-foveally, without any marked change in hue taking place.

The next experiment was designed to test the movements of after-images. A black cardboard disk had a small hole (about 1 cm. diameter) drilled into it, and was fixed to the motor as before. On the far side the aperture was covered with white translucent paper which was illuminated with a microscope lamp. The observer sat at a distance of about three feet from the disk, and electrically controlled the flashing of the light brought about by the passage of the aperture in front of the lamp. There was the faintest background illumination, rendering fixation possible. To test Edridge-Green conclusion (1946) regarding the function of the eye-muscles in effecting the disappearance of the after-image by exerting pressure on the eyeball, the eyes were moved after the flash had taken place, care being taken that no light should fall on the exposed parts of the eye; these as all other observations were monocular. When vision was foveal the after-image disappeared instantaneously: this is in agreement with Edridge-Green's result. When, however, vision was extra-foveal movement of the eyes did not affect the after-image. Of the red, green, and yellow filters used, the last rendered the observation of the effect more easily than the other two, probably on account of the higher luminosity.

In another set of experiments an ordinary torch was used for stimulation. It was focused so as to form a beam as nearly parallel as possible. The bulb and its reflector were viewed in a dark room, the appearance being that of a bright ring surrounding a dark one, at the centre of which there was the small bright filament, which formed an admirable fixation point. Red, yellow, and green filters were used, giving similar results, provided the brightness was not too intense. For example, when the filament had been fixated from a distance of about five feet for roughly $\frac{1}{4}$ to $\frac{1}{2}$ minute, and the torch was turned off, the positive after-image of the *reflector* appeared immediately, but that of the *filament* could not be seen at all. (This explains the apparently rapid disappearance of the after-image in the first part of the previous experiment.) When the light in the room was switched on, the after-image of the reflector of course, became negative, and that of the filament remained invisible. In order to determine whether the after-image moved relatively to the retina the point of intersection of two thin black lines was fixated. Owing to the tendency to look at the after-image—naturally with the fovea—it appeared to move: it follows that it seemed to move in the direction in which the eye was turning. However, by making a great effort in fixating a given point in the visual field, the observer could not detect any movement of the after-image. As soon as he relaxed his concentration the after-image moved. Repeating the experiment one evening when tired, the observer found it impossible to keep the after-image still.

Edridge-Green also mentions the distortion (" bulging ") of the after-image when the closed eyes are rotated right or left. The after-image which he used for this experiment was due to the strip of paper mentioned above.

The present writer repeated the experiment, viewing the strip from about two feet, but could not obtain a conclusive result. On another occasion, however, he viewed a complex object consisting of a gothic window in a church. The window, illuminated by the sun from the far side, subtended an angle of about 7° at the observer's eye. On closing the observing eye, he could see an exact positive after-image of the window; it became negative on opening it, positive on closing the eye again, etc. Details could be detected in this image which had escaped the observer's attention in the original, but were subsequently found to be there. It should be noticed, however, that the fixation point, a yellow cross on a red background, could not be seen in the after-image. The writer moved his eyes about, and found that the image became deformed only when its general dissolution had become advanced.

The long and detailed persistence of this large image would be unlikely if the retinal fluid moved relatively to the receptors. The fact that the coloured fixation area could not be seen is in agreement with the observations made by other workers (Duke-Elder, 1932). Its importance in connection with colour-matching is obvious.

These results are at variance with Edridge-Green's conclusions, in particular with his statement that the cones are stimulated indirectly by the decomposition products of the photochemical fluid (visual purple) and not directly by light. On the contrary, they suggest that in cone-vision the response is more rapid than in rod-vision. They also suggest that the persistence of the stimulating action is greater in the latter.

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