

Title AFTER-IMAGE MOTION AND THE EYE'S KINESTHETIC SENSE

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The visual sense of position, as distinguished from motion, is of interest to biologic control science. Phenomena of voluntary displacement of the visual after-image tell us something about this.

An after-image originating on the retina (as seems reasonable to accept) would not be expected to move as closed eyes are rotated.

The contrary is observed. The after-image moves in the direction of motion of the eye -- i.e. left if the eyes are turned left, and similarly for other vertical, angular, or horizontal motion. We note what appears to be a fact without a science.

In exploring this phenomenon the following can be noted, if one pays careful attention to the experienced phenomena. We may interpret the modalities of vision relating the retinal image to the sensory function of three reference systems  $R_1$ ,  $R_2$ , and  $R_3$ , pertaining to eye-head, head-body, and body-gravitational frames.

- (1) The black oval field seen in front of the eyes with both eyes closed is most intensely black in the center, is wider than it is high and gradually fades into nothing (which is not black) towards the edges.
- (2) The image on each retina in ordinary vision is, as it were, "projected" onto a two dimensional space which we may call inner "sensory screen" for the lack of a better concept, and moves on this. We may say that this "screen" is also the locus of all possible retinal images.
- (3) This locus is stationary with respect to the head and moves as the head is turned.
- (4) When seeing with one eye the unused black portion of the oval field (pertaining to the closed eye) is inhibited from view, and nothing is experienced in its place.
- (5) An after-image on one closed eye may at times be seen in the visual field of the other open eye (i.e. only the black field of the closed eye is inhibited). The after-image may be seen at will or not, depending on whether one "looks" through both eyes or not.
- (6) When the head is turned without eye motion, the "screen" moves with respect to the environment, but the retinal images are stationary with respect to the "screen". This can be best noticed with closed eyes and an after-image which remains stationary in the field of view as one turns the head. If the eyes are moved but the head is stationary the screen is stationary and the retinal image moves.

(7) Therefore, the writing on a moving object such as a piece of paper moving to and fro in front of the eyes can be made to appear relatively stationary (and thus legible) if tracked by head motion but not by eye motion.

(8) If one moves both the head and the eyes but keeps the eyes looking at a fixation point, the after-image remains stationary with respect to the visual scene.

(9) If the eye is displaced manually (externally without eye-muscle effort) the room appears to tilt (which does not happen for voluntary eye, head or body displacement) but the after-image remains stationary with respect to its previous position in visual space. Note that tilting the head in the opposite direction will not right the tilted room. We may call this form of displacement a disturbance function with respect to position reference.

(10) The tilted or displaced image is suppressed after some time (of the order of one minute). If both eyes are simultaneously displaced both image may be suppressed after some time and nothing external is seen. (Certain flowing patterns appear -- there is temporary blindness). Under such conditions an after-image obtained before suppression still may be seen.

It seems that the observed displacement of the visual after-image on what we have called the "sensory screen" is an indication of a kinesthetic sense of the eye.

What is meant by the kinesthetic sense of the eye can be understood if one thinks of an imaginary fly sitting on the retina and moving with it. The sense for the position of the fly is analogous to the experience of the moving after-image.

If the organization of man is subject to evolved design principles then it would seem that all our senses may have a form of double data processing including (a) the quality and intensity of sensation (b) the body spatial origin of the sensation. In the case of the eye this sense appears to have developed further since (1) the visual image is not felt at the retina but is projected outward (2) the visual image on the retina itself has spatial aspects so that mode (b) becomes another order of spatial sensorium, whose role is to eye position what the kinesthetic sense is to hand position. The motion of the after-image with eye rotation is one clue that such a sense exists.

This auto-tracking ability even allows a man to observe his own nystagmus - a rather obfuscating biologic advantage.