

# The fading of stabilized images: Eye movements and information processing\*

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Two experiments are reported which indicate that neural and photochemical satiation processes are inadequate to explain the fading of the stabilized retinal image. When eye movements are attempted over the stimulus, fading occurs more rapidly, indicating an information processing component in the disappearance of the image.

Each movement of the eye, whether voluntary, as in saccadic or smooth pursuit movements, or involuntary, as in ocular tremor, flicks, and drifts, brings the image of a visual target to a new locus on the retina. In the early 1950s, Ditchburn in England and Riggs in the United States developed an optical lever system which could eliminate the effects of eye movements on the locus of the image on the retina (Ditchburn & Ginsborg, 1952; Riggs, Ratliff, Cornsweet, & Cornsweet, 1953). The effect of elimination of eye movements is quite dramatic. Within a few seconds, the stabilized image of a target fades and finally disappears from the conscious percept. This phenomenon has been demonstrated many times since it was first reported (cf. Heckenmueller, 1965).

It is somewhat surprising to find that very little theoretical attention has been paid to the specification of the mechanism responsible for this phenomenal disappearance of the stimulus. The two most frequently cited explanations are rather peripheral in nature. The first involves photochemical satiation such as that described by Hecht (1937). This position maintains that, under conditions of constant illumination, the photoreceptive processes in the retinal receptive cells reach a steady state. Since the regeneration and breakdown rates have equalized, no further neural impulses are generated and the target disappears from consciousness.

An alternative proposal, suggested by Hartline's

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(1940) observations and elaborated by Ratliff (1965) and Arend (1973), is based on the fact that the visual system seems to predominantly respond to temporally transient stimulation. Most fibers in the optic nerve respond to the onset or offset of stimulation, and there is little response to invariant stimulation. Without eye movements to shift the image over new receptors, the temporal transients normally available at the contour are not present. Thus, contour information is not being continually forwarded to the higher centers, and the stimulus fades. Further evidence for this position comes from the fact that if the stabilized image is now flickered (in order to restore the temporal transients) the faded image immediately reappears (Cornsweet, 1956; Ditchburn & Fender, 1955). Similarly, if slight motion or tremor is introduced, the target again reappears (Ditchburn, Fender, & Mayne, 1959; Krauskopf, 1957; Riggs & Tulunay, 1959).

Since the photochemical satiation and the neural transient arguments both depend upon relatively peripheral satiation processes, they are inadequate explanations of the findings of Krauskopf and Riggs (1959) and Cohen (1961), who have demonstrated binocular interactions in the disappearance of the stabilized images. Such findings would argue for a more central locus for this perceptual effect.

The theoretical treatments which have suggested central processes that might account for the disappearance of the stabilized image have, for the most part, been an extension of the satiation notions discussed above. Thus, Krauskopf and Riggs (1959) hint at possible central neural adaptation, and Cohen (1961) suggests field satiation such as that proposed by Kohler and Wallach (1944), to account for figural

aftereffects. Hebb (1963) extends the field satiation hypothesis to include the fatigue of cell assemblies due to continued stimulation. Unfortunately, these theoretical positions do not seem to fare well in the light of available data. For instance, Campbell and Robson (1961) used the shadows of the retinal capillaries as a stabilized image. They report that "The capillary shadow can be seen for a much longer period if moved across the retina at certain amplitudes and the frequencies but, even so, these moving shadows also ultimately disappear and never reappear spontaneously [p. 12P]." Coren (1971) reports that a rotating stabilized image also tends to disappear for most observers, but that the time to disappearance is 10 to 20 times longer than for a stationary stabilized target. In these paradigms, although the locus of the retinal image is decorrelated with eye movements, new retinal receptors are continually being stimulated, since the image is in constant motion. The image motion should insure that temporal transients are available at the contour. Under these conditions, it seems unlikely that satiation of neural processes, whether central or peripheral, can explain the disappearance of the stimulus.

Data pertinent to the involvement of central information processing in the fading of the stabilized image has emerged from EEG recordings made while observing a stabilized target. It has long been known that attending to the presence of any visual image will tend to block the appearance of alpha waves (cf. Jasper, Cruikshank, & Howard, 1935). It is thus not surprising to find that the disappearance of the stabilized image is usually accompanied by the appearance of alpha waves (Gerrits, 1967). It is interesting to note, however, that Lehmann, Beeler, & Fender (1965) have reported that the onset of these alpha waves *precede* subjective report of the fading of the stabilized image. If the E physically manipulates an equivalent nonstabilized image and causes it to fade out, the observer reports the disappearance of the image *before* the alpha wave train appears in the EEG. Similar findings have been reported by Keesey and Nichols (1967). It is almost as if the percept were being actively blocked by some central mechanism. This would also accord with Keesey and Nichols's (1969) report that induced changes of the EEG are accompanied by changes in the visibility of the stabilized image.

Other lines of inquiry also seem to suggest that information processing mechanisms may be involved in the disappearance of the image. A steadily increasing fatigue of a neural or cortical mechanism would predict that the image would first lose clarity. Next there should be a patchy disappearance of random portions of the contour which spreads to the whole figure. Although there is fading of the image, as it disappears, it does not randomly fragment.

Organized portions of the figure, parallel lines, whole sides of outline forms, etc., seem to vanish as units (Evans, 1965; Pritchard, Heron, & Hebb, 1960), even when all possible slippage of the image is eliminated by use of afterimage procedures of stabilization (Bennet-Clark & Evans, 1963; Evans, 1966; Evans & Wells, 1967). In addition, more meaningful targets remain visible longer than meaningless targets (Pritchard et al, 1960). Such organized disappearance suggests higher level processing rather than random local satiation.

A hint as to what type of central mechanism may be involved comes from a behavioral analysis of the effects of image stabilization. Effectively, image stabilization breaks the correlation between the eye movement and the retinal position of the visual image. Thus, no ocular response has any effect on target locus. It is well established that eye movements are used by Ss to check, verify, and modify the percept. Thus, free eye movements across an illusion figure have been observed to result in a reduction in the apparent magnitude of some visual illusions, while steady fixation results in little change (Coren & Hoening, 1972; Festinger, White, & Allyn, 1968). In an illusion of extent, such as the Mueller-Lyer, this is probably due to the fact that the eye initially overshoots when attempting to fixate the vertices of the apparently longer portion of the illusion and undershoots on the apparently shorter portion. A corrective flick must now be made to place the image of the vertex on the fovea. The direction and extent of the flick give an indication of the direction and extent of the illusory distortion (Festinger et al, 1968; Judd, 1905; Stratton, 1908). The percept is then corrected on the basis of this error information, resulting in illusion decrement. Similarly, we might imagine an observer trying to interact with the stabilized image. No attempt to shift the point of fixation would have any effect on the locus of the retinal stimulation. This might soon lead the central information processor to conclude that the target is not actually out in the environment at all, since no ocular response seems correlated with the retinal image. Such a conclusion might result in a cessation of overt or perceptual responding to the image, as suggested by Festinger, Burnham, Ono, and Bamber (1967). Most probably, the S would simply cease to extract information from the stabilized array. Either of these events would result in the disappearance of the stimulus from consciousness. This might be the same mechanism which protects our conscious perception from being continually swamped by the presence of shadows from "floaters" in the vitreous humor, or the constantly shifting, pulsating shadows of our retinal capillaries lying on top of the retina. Since no overt ocular response causes any change in the nature of the stimulation from these sources, they are soon eliminated from the percept. Information about them

is no longer extracted and entered into consciousness.

If this analysis is correct, we ought to be able to control the rate of fading of the stabilized image by controlling the nature of the observer's interaction with the stabilized image. If he does not attempt to explore the image, we would expect it to persist longer than if he actively engages in attempted eye movements over it. This latter behavior would rapidly provide him with information which indicates that the image is completely decorrelated with his eye movements. Such decorrelation usually implies an entopic rather than an environmental stimulus, and generally such images are eliminated from conscious perception. The experiment reported below attempted to test this hypothesis.

## EXPERIMENT I

### Method

**Stimulus and Apparatus.** There are several important methodological problems which must be considered. To begin with, one would like to eliminate all possibility that any observed fading of the stabilized image will be due to neural or photochemical satiation. This is best done by having the image oscillating or rotating across the retina, while stabilized relative to eye movements. As noted above, Campbell and Robson (1961) and Coren (1971) have reported that such targets also disappear, although with a considerably longer latency.

A problem arises when the observer makes overt eye movements in attempting to interact with the stimulus. Most contact-lens or optical lever systems of image stabilization are subject to slippage, especially in the presence of large eye movements (Barlow, 1963). Although afterimage stabilization is free of this difficulty, one cannot, of course, generate a continuously moving afterimage. A stabilized target which circumvents these difficulties is Haidinger's brushes. Ratliff (1958) mentioned the use of this entopic stimulus as a stabilized image. Coren (1971) has specified the factors affecting its production and visibility, and demonstrated that data produced with the Haidinger's brush target is comparable to that produced by other methods of image stabilization. The image is rendered visible by flooding the eye with linearly polarized blue light. The phenomenal impression is of a dark propeller or hourglass-shaped target on a blue field. The target is probably caused by the radial orientation of the crystals of the macular pigment in the foveal region, which results in stronger absorption of linearly polarized light on the axis approximately perpendicular to the plane of polarization. By rotating the plane of polarization, we rotate the target about the center of the fovea. The target is close to 4 deg on its longest dimension, and hence is large enough for most experimental purposes. Since we are looking at a structural feature of the eye, it is perfectly stabilized. There is no opportunity for slippage of the image despite the presence of eye movements, since there are no attachments to the eye.

To produce the Haidinger's brush, Ss monocularly viewed a projection screen through a Wratten No. 47 (blue) filter and a rotating sheet of Polaroid (No. 328). The Polaroid was rotated at a constant speed of 360 deg/sec. The field luminance was 1.5 log fL. These stimulus conditions have been shown to produce the optimally visible image of the Haidinger's brush (Coren, 1971; Coren & Kaplan, 1972). Four dots spaced 1 deg apart horizontally and 2 deg apart vertically delineated a rectangular central area in the field.

**Procedure.** Sixty paid volunteers, with normal visual acuity, served as Ss. Each was randomly assigned to one of three eye-movement conditions. A *fixation* condition was used to provide Ss with the minimum amount of information about the

decorrelation between the target and eye movements. Fixation Ss were instructed to stare at the center of the rotating black propeller (the Haidinger's brush pattern). This is a very easy task, since the center of the target is centered on the fovea. To the extent that the S is not emitting voluntary saccades, little information about the decorrelation between eye movements and image locus is available. In the *relevant* eye-movement condition, the S was instructed to attempt to fixate the outer wing tip of one blade of the rotating array and to track it around in its movement. Since the center of the image is stabilized on the center of the fovea, this is an impossible task. Each time the S attempts to fixate the wing tip in order to track its rotation, the entire image appears to jump in the direction of the movement. The S is thus engaged in a saccadic chase of the wing tip across the field. His eye movements never alter the locus of retinal stimulation, and he can never alter his point of fixation relative to the image. Under these conditions, the observer ought to rapidly learn of the decorrelation between his eye movements and the image.

It seemed desirable to introduce a control condition to account for any effects due to the mere presence of eye movements. Electrooculographic recordings of eye movements on pilot observers indicated that, under the relevant eye-movement instruction, observers tended to emit saccades of a median magnitude of about 1 deg with a median intersaccade interval of about 1 sec. Based on these values, an *irrelevant* eye-movement condition was included. It was a control for the effects of simple, nontarget-directed eye movements on the appearance of the image. In this condition, an auditory click was generated at the rate of 1/sec. With each click, the S was to move his eye from side to side using the marked central rectangle in the field as a guide. The S was thus emitting voluntary eye movements, but these were not directed towards active interaction with the stabilized image. Under these conditions, we might expect more information about the decorrelation between the eye movements and retinal locus to be picked up than in the fixation condition, but less than in the relevant eye-movement condition.

All Ss observed the propeller target under one of the three eye-movement conditions. If the target disappeared, they were told to look into the central portion of the field (marked by the rectangle of dots). If the target was still not visible, they were to depress a telegraph key. This provided a record of the time to disappearance to the closest 0.1 sec. If the target did not disappear after 360 sec of viewing, the session was terminated and the S was assigned a score of 360 sec.

### Results and Discussion

It was predicted that the disappearance of the stabilized image would be faster if the observer actively attempted to interact with the target. Such attempted interactions would provide the perceptual centers with an indication that changes in the locus of the image on the retina were uncorrelated with eye movements. A stimulus which cannot be interacted with is not behaviorally relevant. It is not likely to represent a normal environmentally generated stimulus. Given this behavioral irrelevance, it is not necessary for the target to be represented in the conscious percept. Thus, the image should apparently fade from view.

In the relevant eye-movement condition, the observer is attempting to shift his point of fixation over the target in order to track the rotation. The retinal stabilization makes all such efforts unsuccessful. This means that the observer quickly learns of the decorrelation between eye movement and image movement, thus resulting in rapid fading of the

image. In the fixation condition, since no voluntary saccades are attempted, little information about the decorrelation is available and the percept should persist longer in consciousness.

The mean time to disappearance was 92.7 sec for the relevant eye-movement condition, 114.1 sec for the irrelevant eye-movement conditions, and 140.1 sec for the fixation condition. These values are statistically reliable, with  $F = 3.91$ ,  $df = 2/59$ ,  $p < .05$ . It appears that when the observer actively attempts to respond to the stimulus array, only to find out that he cannot interact with it, the stimulus seems to be stricken from consciousness. This occurs more rapidly than when no responses are attempted.

It is interesting to note that the stabilized pattern still disappears even in the fixation condition, where we might expect little fading to occur. This fading may well be analogous to that observed by Evans and Piggens (1963), who found that even a bright nonstabilized figure that is steadily fixated against a dark background often fades and will frequently fragment. Riggs et al (1953) notes that continued starting at fine lines may result in their apparent disappearance, although wider lines tend to persist. With steadily fixated figures, the most likely area of disappearance is centered around the point of fixation (Hunt, 1964; Schuck, Brock, & Becker, 1964). Since the brush pattern is clearly steadily fixated and is centered on the fovea, it seems reasonable to hypothesize that the observed fading of the moving stabilized image is (at least partially) accounted for by this mechanism. It may be of value to separate such satiation effects due to prolonged viewing from those due to stabilization and the resultant effect of decorrelation between eye movements and image locus. To effect such a separation, Experiment II was conducted.

## EXPERIMENT II

### Method

**Stimulus and Apparatus.** The stabilized Haidinger's brush target, produced in the same manner as in Experiment I was again used as the stimulus. In addition, a nonstabilized control figure was provided. This control figure was an image of the Haidinger's brush, superimposed on a sheet of clear acetate which subtended a visual angle of 3 deg 45 min. This is the median size of the figure, as measured by Coren (1971). This image could be rotated at the same speed as the actual brush figure, and was viewed through the same blue filter used in the production of the brush pattern.

**Procedure.** Forty paid volunteers with normal vision served as Ss. Each was assigned to one of four viewing conditions. A *fixation* condition, a *relevant eye-movement* condition, and an *irrelevant eye-movement* condition were used, as in Experiment I. An additional *control* condition in which Ss fixated the center of the rotating nonstabilized image was also employed.

In order to provide information about the time course of the fading, a magnitude-estimation procedure was employed (Stevens, 1956). The first figure viewed was assigned a clarity value of 100. All subsequent judgments were made relative to this first value. Ss were auditorially cued to look into the center of the field and to judge the clarity of the Haidinger's brush pattern at 15-sec

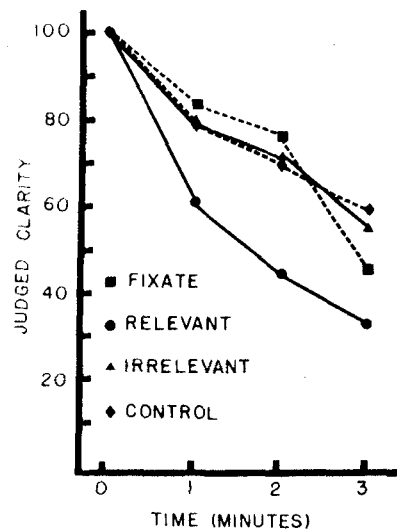


Fig. 1. The judged clarity of the stabilized retinal image plotted as a function of viewing time for the three eye-movement conditions and the control stimulus in Experiment II.

intervals. Coren (1971) and Coren and Kaplan (1972) have successfully used this procedure to establish conditions affecting the phenomenal clarity of the brush pattern. Clarity estimates were then pooled to obtain the mean clarity per minute over an inspection period of 180 sec.

### Results and Discussion

Figure 1 shows the results of this experiment. To begin with, all Ss, regardless of viewing condition, see the image fade somewhat during the inspection period. This fading is significant with  $F = 3.50$ ,  $df = 2/39$ ,  $p < .05$ , and probably represents the same sort of fatigue process which results in loss of clarity of any steadily fixated figure. The effect of viewing conditions is also significant ( $F = 3.43$ ,  $df = 3/39$ ,  $p < .05$ ).

The figure shows that this is entirely due to the more rapid rate of disappearance in the relevant eye-movement condition. The other three viewing conditions all lie virtually on top of one another. Contrasts among the viewing conditions reveal that the fixation, eye-movement, and control conditions are significantly different from the relevant eye-movement condition, but that none are significantly different from each other.

These results seem to imply that the fading observed in the fixation and irrelevant eye-movement conditions is not dependent upon having the image stabilized. Only the condition where eye movements are attempted over the stabilized figure results in more rapid disappearance of the stimulus. The fading is more rapid than would be expected on the basis of steady fixation alone. This is supported by the fact that the fixation condition and irrelevant eye-movement condition, although employing stabilized images, fade at the same rate as the nonstabilized, steadily fixated target. This data calls into question

the significance of Campbell and Robson's (1961) and Coren's (1971) report of the fading of a continuously moving stabilized image. Neither of these studies employed a nonstabilized control condition. Thus, their observed disappearances might be independent of image stabilization. It is, however, important to recognize that the Haidinger's brush target is a low-contrast configuration. The rate of rotation used here is equivalent to stimulating a single receptor at the rate of 8 Hz. As Keeseey (1973) has pointed out, such conditions might favor a loss in target visibility.

The more rapid disappearance of the target under the relevant eye-movement condition seems to imply that fatigue or satiation cannot alone account for the fading of the stimulus under stabilized viewing. Some additional mechanism seems necessary to account for these data. This additional mechanism may well involve information-processing strategies selectively used by the higher centers to eliminate those stimuli which are not behaviorally relevant from the conscious representation of the visual world.

The essence of image stabilization is the decorrelation between the primary response to visual stimulation (eye movement) and any change in the pattern of stimulation. Thus, the observer cannot successfully interact with the stimulus pattern. This is the same situation which characterizes most entopic phenomena, such as Maxwell's spot, floater's in the vitreous, or shadows of retinal capillaries. All of these manifest the same noninteractive quality. Although they are present in the incoming visual array, they do not have relevance for our behavioral coordinations in the external environment. Thus the perceptual system soon comes to ignore such features of the stimulus input even if they are continuously in motion, as in the pulsations of the retinal capillaries. The visual channels are thereby cleared for the processing of stimulation which may have pertinence to behavioral exchanges with the environment. Any viewing or practice condition which accelerates the processes of information concerning the decorrelation between eye and image movement seems to hasten the disappearance of the stabilized target.

In sum, one of the reasons that the stabilized image fades from consciousness is because the observer's interaction with the stimulus leads the higher centers to conclude that the image is not part of the behaviorally relevant environment. This results in a cessation of information processing from the stabilized stimulus.

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