

SACCADIC OMISSION: WHY WE DO NOT SEE A GREY-OUT DURING A SACCADIC EYE MOVEMENT

FERGUS W. CAMPBELL and ROBERT H. WURTZ

The Physiological Laboratory, University of Cambridge, Cambridge CB2 3EG, England;
and The National Institute of Mental Health, Bethesda, Maryland 20014, U.S.A.

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Abstract—We investigated why we have no perception of a smeared image resulting from the reduction in contrast (grey-out) occurring at the retina during saccadic eye movements. By turning on light in the experimental room only during the eye movement, we were able to show that this grey-out was perceived as a smeared image of the visual scene. However, when the experimental room was illuminated before and/or after the saccade as well as during the saccade, perception of the grey-out was obliterated. During a period of fixation, perception of a blank image comparable in duration to an eye movement could also be eliminated by a preceding or following clear image. We conclude that lack of perception during saccadic eye movements made in normal contoured environments results primarily from the visual "masking" effect of a clear image before and/or after the eye movement acting on the grey-out during the eye movement. This "saccadic omission" is entirely a visual phenomenon and is far more powerful than the usually studied elevation of visual threshold for detection of a flash, "saccadic suppression."

INTRODUCTION

Our vision is interrupted several times a second by rapid eye movements (saccades) made from one point in the visual field to another. During these saccades the visual world sweeps across the retina and should produce a period of smeared vision lasting from 25 to about 100 msec depending on the size of the saccade (Robinson, 1964; Westheimer, 1954). Yet we normally do not see this smeared image of the visual scene generated by the eye movement.

This lack of perception is easily demonstrated by attempting to see one's own eye movements in a mirror, as described by Dodge (1900): "It was then we chanced on the observation that when the head was held perfectly still we could never catch our own eyes moving in a mirror. One may watch one's eyes as closely as possible, even with the aid of a concave reflector, whether one looks from one eye to the other, or from some more distant object to one's own eyes, the eyes may be seen now in one position and now in another, but never in motion." If one looks at a colleague's eyes in the mirror, one can easily see his eye movements.

Most of the work since Dodge (1900, 1905) and his contemporaries has concentrated on eliminating the smeared image occurring during a saccade in order to reveal the existence of any central inhibition associated with the eye movement. Attempts to quantify any such effect by testing the elevation of threshold for detecting a brief flash of light during a saccadic eye movement have generally found rather small effects, usually less than 0.5 log units (see review by Matin, 1974). This elevation of threshold has been named "saccadic suppression" (as cited by Zuber and Stark, 1966) but would be more accurately described as saccadic attenuation, and it is certainly not adequate to explain our lack of vision during an eye movement.

In addition, we think these experiments on saccadic suppression fail to deal with a central problem of

vision during eye movements: Why are we unaware of the physical event occurring at the retina—a grey-out which should result in perception of a smeared visual scene? By grey-out we mean a decrease in the contrast of an image due to its movement across a retina which integrates over time. This is analogous to the image on photographic film when the camera is moved over a wide angle while the shutter is open. The problem is thus not one of an elevation of threshold or reduction in sensitivity during eye movements—a saccadic suppression—but an elimination of this perception which we will refer to as a saccadic omission.

The present experiments demonstrate that this saccadic omission can result from the presence of a clear image before and/or after a saccade acting on the grey-out during a saccade. Such "masking" effects have been suggested previously, and experimentally demonstrated by Matin, Clymer and Matin (1972). From our experiments we conclude that in a contoured visual environment the "masking" of the grey-out by the clear image is the primary factor eliminating perception during saccadic eye movements, that is, in producing the saccadic omission.

METHODS

We made it possible to light the visual scene in front of a subject only during an eye movement. The light source used was a repetitive xenon flash which enabled us to turn on and off a bright light within several msec of a trigger pulse. The flash tube was run at such a rate that it was perceived as a steady light. We adjusted the intensity of the light so that a 100 msec period of flashes was seen as having a luminance of 3 cd/m².

The subject sat in a darkened room and made saccades from one small red fixation light (from a light-emitting diode) to another placed 20° or 30° away in the horizontal plane. This configuration of fixation lights produced eye movements that were stable in duration and time-course as long as the subject remained alert.

Horizontal eye movements were recorded using electro-oculograms (EOG) derived from two silver-silver chloride electrodes (Beckman, Miniature Biopotential) pasted to the cleaned skin at the outer canthus of each eye. This signal was displayed on a storage oscilloscope and also differentiated for use as a trigger for turning on the light during the saccades. The duration of any period of light and the frequency of the component flashes were recorded by a silicon photocell in front of the flash tube and were displayed on the second channel of the storage oscilloscope. The temporal relations between the saccadic eye movement and the stimulus were determined from the storage oscilloscope for each trial.

The light stimulus, consisting of the repetitive flashes at 1 kHz, was usually set to fill the duration of the saccade. To obtain a period of light after the end of the eye movement the duration of the triggered light stimulus was simply extended by up to 200 msec beyond the end of the saccade. A period of light just before the saccade was obtained by adding, to the constant period of light filling the duration of the saccade, another period of light synchronized with the onset of one of the fixation lights. This period of light came on after a delay to allow for the reaction time of the subject. Only those trials were used in which the reaction time placed the light period just before the eye movement.

A further set of experiments used a sequence of stimuli while the subject fixated. In these experiments the successive stimuli were from two xenon flash tubes each flashing at 320 Hz. The flash tubes were used as the light source for two slide projectors whose beams were combined using a beam-splitter and then back-projected onto a ground-glass screen. The apparent luminance was adjusted to be 3 cd/m², and matching of slight color differences between the tubes was aided by inserting a yellow (minus blue) filter in the beam.

RESULTS

Grey-out due to eye movement

We first confirmed that it was possible to see clearly during an eye movement. In a dark room a subject fixated a light on the left; a second light then came on 20° to the right and the subject made a saccade to it. This eye movement took 50–70 msec after the subject's reaction time (see Fig. 1, insert). The EOG of the eye movement triggered the repetitive xenon flashes illuminating the scene before the subject. In this initial experiment the scene consisted largely of the usual bank of oscilloscopes, oscillators and recording apparatus found in the laboratory. Highlights, such as very reflective parts, were covered with black tape. As the subject began a saccade, the light in the room was turned on within about 10 msec after onset of the eye movement, and left on for a duration of 5 msec or less (1–5 flashes). The room was seen clearly no matter where in the 50–70 msec eye movement the period of light occurred. This, of course, is not surprising since the light was brief enough to minimize any smearing of the image across the photoreceptors of the retina.

We then turned on the light and left it on for the 50–70 msec duration of the saccade. After each eye movement, the subject was asked whether the scene appeared as smeared or sharp. In every instance the subject said promptly that the scene was smeared, that is, it was greyed-out and appeared strikingly different from the clarity produced during the short exposure described above. This smeared appearance

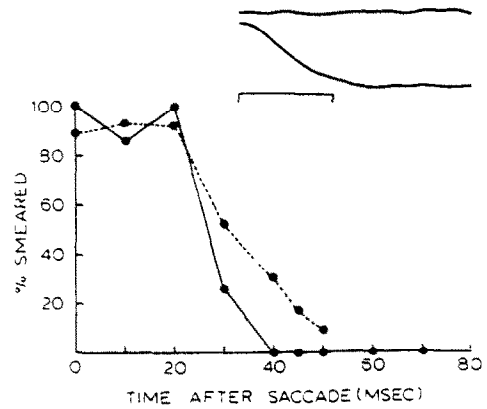


Fig. 1. Transition of smeared to clear image as the period of light extends beyond the end of the saccade. A 50 msec period of light was on during the eye movement on every trial. Ordinate shows percent of time the subject (FWC) reported that the image was smeared. The abscissa shows the duration of the light after the end of the eye movement. Circles connected by solid lines show the percent of the time the subject saw the scene as smeared as he looked around the laboratory room. (Circles connected by dashed lines show percent of time the subject saw a smeared image of his moving eye as he looked at his eyes in a mirror.) Inset shows an oscilloscope sweep of the EOG of a saccade used to trigger a 50 msec period of light during the eye movement indicated by the bracket. Line above saccade shows EOG level before the saccade.

is what would be expected physically as the retina 'sweeps' over the scene at a peak velocity of at least 500–600°/sec.

As we extended the duration of the light beyond the end of the eye movement, the amount of smearing that the subject reported became progressively less. The permitted responses were smeared, slightly smeared, and sharp. These responses were assigned values on a linear rating scale and are summarized as percent smeared in Fig. 1. The circles connected by solid lines in Fig. 1 show the percentage of the time that the scene was reported as smeared against the time the light was left on beyond the end of the eye movement. The end of the eye movement was determined on each trial by inspecting the trace of the EOG on the storage oscilloscope. This allowed for the slight variability in the duration of each saccade (the error in determining the end of the saccade was about ± 5 msec). At least three trials in random order were made for each duration of light shown on the abscissa of Fig. 1.

By the time the light extended 40 msec beyond the end of the eye movement the subject reported a clear scene 100% of the time. It is important to note that the subject did not perceive a smeared image followed by a sharp image but instead reported only a single percept even though the 50 msec of grey-out was still physically present. Furthermore, he was not aware that the duration of the light varied in different trials until the light extended more than 80–100 msec beyond the end of the eye movement.

A second subject reported essentially the same absence of smearing when the light extended beyond the end of the eye movement. The same effect was observed with saccades 5°, 10° and 20° long. We also repeated the same experiment with glow-modulator

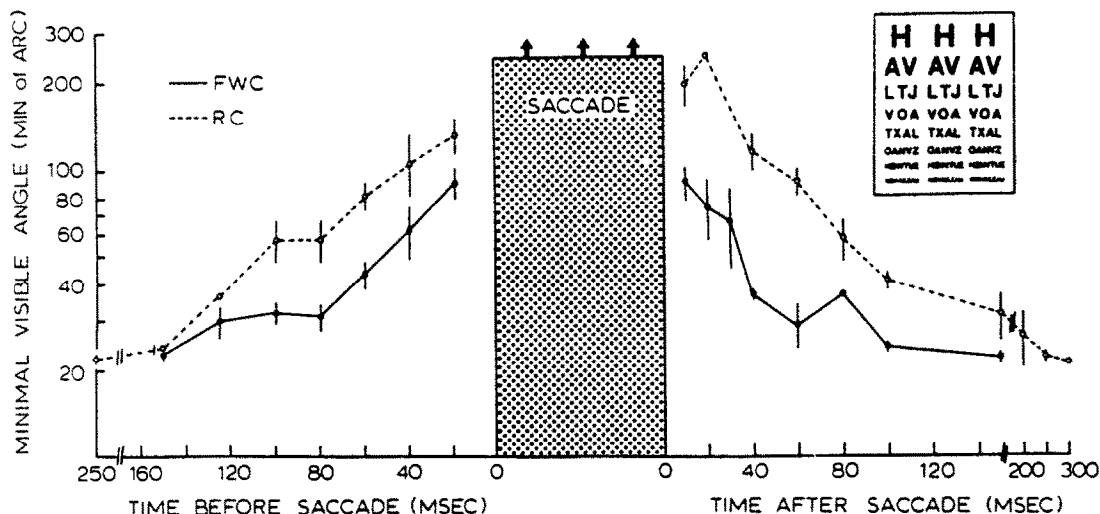


Fig. 2. Effect of a clear image before and after the smeared image during a saccade. The ordinate shows the minimal visible angle seen on the Snellen test charts; a logarithmic scale is used. Abscissa shows the time the period of light extended before or after the eye movement. Vertical line at each point is the standard error; where no line is shown the standard error is smaller than the symbol used. The stippled area indicates the period of light during a 30° saccade, and upward pointing arrows above stippled area indicate that not even largest visible angle on the chart could be seen during the saccade.

tubes instead of the repetitive xenon flashes. We could only illuminate a small portion of the visual scene due to the low light output of the glow modulator tubes but the results obtained were the same: a smeared percept when the light was on only during the eye movement and a clear image when the light extended 50–100 msec beyond the end of the eye movement. From these observations, we conclude that the sharp static image on the retina after the eye movement obscures the presence of the grey-out produced by the eye movement.

We then returned to the original observation that one does not see one's own eyes move when they are viewed in a mirror. Each author viewed his own eyes in a mirror at a distance of 20 cm (although the distance was not critical) when the eyes were illuminated only during the eye movement, as in the above experiment. Now during the eye movement the black pupil and dark iris were seen as an elongated blurred patch, and the bright corneal reflection was seen as a shorter bright streak. The effect of increasing the duration of the light beyond the end of the saccade as the eye movement was viewed in the mirror is shown by the circles connected by a dashed line in Fig. 1. As the duration of the light increased, the frequency of seeing the blur declined in close agreement with the preceding experiment. Again, in this case only one percept was seen with long light durations; the subject was not aware of the grey-out during the saccade which preceded the sharp image seen during fixation.

These experiments establish that the presence of a static and therefore clear image of a scene obscures the presence of a preceding grey-out even when the grey-out lasts as long as 50–70 msec. This raises the question of whether a clear image before the eye movement has a similar effect.

Pre- and post-saccade effects

In order to quantify the degree of smear more objectively, we measured visual acuity during and after saccades. Our rationale was that the greater the effect of the grey-out, the lower the visual acuity should be just before or just after the eye movement.

The subject made a 30° saccade between two fixation lights. Three copies of a conventional Snellen test chart were used to fill the space between the fixation lights (as illustrated in the inset of Fig. 2). The subject could raise and lower the chart so that any line he chose was on the level of the fixation lights. As the chart was viewed from a distance of 1.2 m rather than the standard 6 m the angle subtended by the letters was five times larger than conventional use. Therefore, the range of acuity covered varied from $21'$ – $250'$.

Figure 2 shows the results of these experiments for two subjects. The ordinate is a logarithmic scale of the visual acuity in minutes of arc. The abscissa is duration of the light in msec plotted on a linear scale. On the right is the effect of light durations obtained by extending the light after the end of the saccade; on the left is the effect of durations of light before the start of the saccade. The blank section between the two scales represents the duration of the light during the eye movements which was set at 70 msec for subject FWC and 80 msec for subject RC. The data for the periods before and after the eye movements were collected in separate sessions. In each session the order in which different durations of light were presented was randomized. Each point represents the average of three judgements. Each judgement was the final result of at least ten presentations of the stimulus which allowed the subject enough trials to move the test chart up and down in order to determine the lowest line which could be read.

As was found when viewing the room in the same conditions, the perceived image was so smeared that even the large letters subtending 250' were not readable when the light was on only during the eye movement. (The vertical arrows during the period of the eye movement indicate that the data cannot be plotted on the scale.)

On the right hand of Fig. 2 the graph shows that the subject can read smaller and smaller letters on the Snellen chart as the duration of the light extends for longer periods beyond the end of the saccade. An exposure of as little as 100 msec after the eye movement produced nearly maximal acuity for subject FWC at the light levels used in this experiment.¹ The duration of the light after the eye movement did not in itself affect acuity: brief duration still permitted the bottom line of the test chart to be read.

On the left of Fig. 2 the results show that if the light was turned on before the eye movement, the longer the light was on, the lower on the chart the lines could be read. Again, visual acuity reached nearly maximal levels when the light was on about 100 msec before the saccade. Although there are some differences between the shape of the curves obtained with light before and after the eye movement, the results show that light both before and after the eye movement is effective in obscuring the smeared image.² It is important again to emphasize that there was only one percept and that the subjects did not report a blurred percept followed or preceded by a clear one for any of our exposure times, short or long.

We conclude from these experiments that a clear static image either immediately before or after the eye movement obscures the grey-out occurring during the eye movement, although this grey-out is still physically present.

We then determined whether a period of grey-out would be acted on by a clear image in the absence of any eye movements. To do this we projected a blank white scene for 50 msec onto a screen while the subject fixated on the screen and preceded or followed this by a clear image of a Snellen test chart. As in the case of eye movements, maximum acuity was attained when a period of 50–100 msec of the clear image either preceded or followed the blank period. Since the clear image obscures the blank image in the absence of large eye movements, the effect of a clear image on a blank or a grey-out is not dependent on the occurrence of the eye movement but rather is a characteristic of the visual system.

¹ Differences in the slope of the curves of the two subjects are probably due to differences in accommodation. Subject FWC was a presbyopic uncorrected myope who viewed the screen at his uncorrected far-point. However, RC was a young corrected myope who focused for a distance beyond the screen. Due to the short duration of the flash there was insufficient time for her to accommodate for the distance of the screen. This point was overlooked at the time of the experiment but was checked later and found to account for her lower overall acuity.

² The judgment before the eye movement was more difficult to make since it could not be made on successive trials if early or late occurring saccades produced an unusual duration of light preceding the eye-movement. The exact shape of the curve, therefore, may not be significant.

The characteristics of this visual interaction are considered in detail in the following paper (Corfield, Frosdick and Campbell, 1978).

DISCUSSION

Our experiments have shown that we always see a smeared image during an eye movement if illumination of the environment is limited to the duration of the eye movement. However, the presence of a clear image before or after the eye movement eliminates perception of the grey-out even though it is still present at the retina. The shift from perception of a smeared image to a clear image can be made simply by turning a knob controlling the relative duration of clear and smeared images. We therefore suggest that in a normal contoured environment the primary mechanism for eliminating the smeared image must be this visual masking effect with central factors having negligible influence.

This effect can also be demonstrated independently of saccadic eye movements when a clear image precedes or follows a 50 msec blank image during a period of fixation. The effect of a clear image on a blank or smeared one is thus a functional characteristic of the visual system and is not dependent on the physical motion of the eyeball or its accompanying neuromuscular activity. We will discuss these observations in relation to saccadic suppression and corollary discharge, visual masking, and possible physiological correlates.

Saccadic suppression and corollary discharge

Helmholtz (1910) was probably the first to suggest that a central mechanism operates during an eye movement. He suggested that the stability of the visual world in spite of frequent eye movements was dependent upon a discharge from the motor system to the sensory system, and that this input allowed the sensory system to compensate for the shifted image. This motor-related discharge, which has subsequently been referred to as a corollary discharge (Sperry, 1950) or an efference copy (von Holst, 1954) has also been suggested as a way of eliminating vision during saccadic eye movements. Holt (1903) also proposed a "central anaesthesia" initiated by movement of the eye muscles to account for this lack of vision. Our experiments rule out any corollary discharge or central anaesthesia as the primary mechanism for eliminating vision during eye movements for the following reasons: First, we have demonstrated that the smeared retinal image can be seen during an eye movement when the light is on only during a saccade and, of course, brief stimuli falling on the retina are seen clearly. A potent corollary discharge should eliminate any such perception. Second, this perception of the smear can be eliminated by simply extending the duration of the visual stimulus beyond the beginning or end of the eye movement. This is a temporal visual manipulation, and any corollary discharge should be equally active in both the case where the smear is seen and the case where it is not. Finally, a stationary blank flash preceded or followed by a clear image is obscured by the clear image and this occurs entirely independently of any eye movement at all. While these points do not argue against

the concept of a corollary discharge (which might prevent the world from appearing to move, as Helmholtz suggested), they indicate that such a discharge is unnecessary to account for the lack of visual perception during eye movements in a normal contoured visual environment.

Both Dodge (1900, 1905) and Woodworth (1906) emphasized the blurred or "fused" image which must occur during a saccade, but much of the subsequent experimental work has deliberately eliminated the blurred image. In order to reveal the existence of a central inhibitory mechanism which might be obscured by the effect of a smeared image, Volkman (1962) measured the threshold rise of a small test target, briefly pulsed and therefore sharp, added to a background before, during, or after a saccade. This experiment, and subsequent ones (see Matin, 1974, for review) have generally revealed a small elevation in the threshold for detecting a flashed target. This change in threshold is so slight that neither Dodge nor the present authors would have been able to detect it in their experiments, and it certainly would not account for our failure to see the grey-out of an eye movement, as indicated by Volkman (1962): "The present results suggest some characteristics of the magnitude and the time course of the inhibitory effect. They suggest, first, that the magnitude of the effect is not large. The moving eye required a stimulus flash of about 0.5 log unit greater luminance than did the fixating eye in order to detect the flash or to recognize words when they were presented by the flash. The finest gratings which could be resolved by the moving eye were about 1.4 times as coarse as the finest ones resolved by the fixating eye. When one considers the ranges of luminance and stimulus-detail which we encounter every day in the visual scene, differences of these magnitudes are not impressive. It is doubtful whether central inhibition alone can account for the phenomenal 'continued clear vision' which occurs under a wide variety of circumstances. Instead, the fact that we do not notice stimuli which arrive during eye movements under normal circumstances must be attributed largely to retinal smear, which serves to decrease the photochemical effect of stimulation."

We have in fact found that this comparison of retinal smear during the eye movement and the clear vision after the eye movement is essential to understanding our failure to see the grey-out of a saccade. It should be noted, however, that other mechanisms must account for our lack of vision during micro-saccades since the velocity of these saccades is not high enough to produce a retinal smear.

The slight rise in threshold for detection of brief stimuli presented during eye movements has been referred to as "saccadic suppression" (as cited by Zuber and Stark, 1966). The saccadic suppression studies leave open the question of whether the perceived luminance of the background and the test spot are decreased, or whether the background appearance remains constant and the contrast sensitivity of the visual system is decreased. Volkman, Riggs, Moore and White (1978) have made an important contribution by using a grating of variable contrast as the test stimulus, thus measuring contrast sensitivity during saccades. The maximum reduction in contrast sensitivity found by Volkman *et al.* (1978) is 0.5 log units. For the medium range of spatial frequencies (around 3 c/deg) the visual system has a contrast sensitivity as low as 0.5%.

Thus, the total range of contrast sensitivity for these important spatial frequencies is 200:1 or 2.3 log units range. It is clear that a change of only 0.5 log units lasting for less than 100 msec (Volkman *et al.*, 1978) is a minor one. Even if the decrease in contrast sensitivity during a saccade were much greater it would be of little importance. Consider an image either completely greyed-out due to its high velocity on the retina, or an image partly smeared and therefore of low contrast. Clearly if one decreases the contrast sensitivity of the eye it will do nothing to an image which is already of zero contrast, and little to an image of low contrast.

Until Volkman *et al.* (1978) established that the change in sensitivity of the eye is in the domain of contrast sensitivity, much of the literature suggested that this change of sensitivity took the form of dimming the visual scene during a saccade, such as indeed happens physically during blinks. But we can be fully aware of every blink we make because of the dramatic decrease in retinal illumination. This experience is quite unlike that found with saccades: if there was a substantial decrease in light sensitivity during a saccade it would be perceived as a dimming of the visual world. It is thus vitally important that little or no gain change occurs in the visual system during a saccade. The elimination of the grey-out by the clear image before and after the eye movement avoids any such change in the gain of the visual system: there is an omission of the perception of the grey-out; a saccadic omission, not a slight increase in threshold; a saccadic suppression.

Visual masking

This saccadic omission is of course a visual masking phenomenon in that one visual stimulus obscures another one. Backward masking or meta-contrast has been suggested previously as the mechanism producing the elevated detection threshold called saccadic suppression (Alpern, 1969; Mackay, 1970; Grusser, 1972; Breitmeyer and Ganz, 1976). Mackay (1970) demonstrated that such an increase in threshold occurs even if remote contours in the background are moved in the absence of any eye movement. Subsequent experiments have confirmed and extended this effect (Mitrani, Meteff and Yakimoff, 1971; Brooks and Fuchs, 1975; Mateeff, Yakimoff and Mitrani, 1976) although the experiments do not exclude some residual effect of eye movement (Riggs, Merton and Morton, 1974). These masking effects, like saccadic suppression, have generally been only about 0.5 log units of threshold elevation. However, where a patterned background has been used (Brooks and Fuchs, 1975) the effect is substantially greater.

The effect of the stimulus after the eye movement on the smeared image during the eye movement was first studied by Matin *et al.*, (1972). In these experiments a slit of light against a black background was illuminated during a 4° long saccade. As the duration of the illumination extended 100 msec beyond the end of the saccade the stimulus was seen as it was by the fixating eye; no smear was then reported. Matin *et al.* (1972) suggested that a "temporally backward and spatially lateral inhibition (metacontrast) occurs when the duration of the flash is long enough to permit sufficient temporal integration of illumination in the period after the saccade to develop a 'mask'." They went on to suggest that for saccades occurring in more complex environments masking might be more effective and that forward as well as backward masking might occur. The present experiments show that the masking effect is the primary factor in a

complex environment as long as the image during the saccade is smeared or greyed-out; a clear image during a saccade is easily perceived. In addition we have found that forward masking is just as effective as backward masking.

In summary, our view of the importance of the smeared image during an eye movement and the action of the clear image before and after in obscuring the smear represents a return to the views of Dodge in 1900: "Moreover, it must be remembered that the duration of the eye movements is very short, for movements of 10° certainly not more than 60 msec, and possibly less than half that. It will be seen at once that the equalizing stimulation during the movement of the eyes scarcely covers the duration of the most pronounced after-effect of the intense stimulation at the preceding fixation pause; while the interference of the intenser stimulation of the succeeding fixation would make the faint stimulation hardly perceptible, even if it had no after-effect of the previous fixation, and no central inhibition to overcome in establishing itself." However, Dodge later went on (1905) to suggest that attention was also a significant factor in the lack of perception during eye movement, an addition we think is not necessary.

Neurophysiological correlates

The salient point of our experiments is that no oculomotor or proprioceptive signal is needed to eliminate perception during saccadic eye movements. We would expect, instead, an interaction within the visual system itself. Wurtz (1969 a,b) first investigated the response of neurons in the monkey visual system (presumably similar to that in man) to visual stimuli during eye movements. He found that cells in visual cortex (area 17 or striate cortex) responded to retinal image movement in the same manner whether the movement was produced by movement of the eye or the stimulus, and thus there was no evidence of a corollary discharge. Büttner and Fuchs (1973) also failed to find a significant modulation of activity of lateral geniculate cells in the monkey in association with saccades made in the dark. These neurophysiological results are consistent with our psychophysical conclusion that a corollary discharge need not be involved in saccadic omission. However, Wurtz (1969b) also found that many neurons did discharge during an eye movement. But since, in these experiments, the stimulus was present on the receptive field of the cell during the eye movement but not before or after the eye movement, these results are more comparable to our psychophysical experiments in which a smear was seen during the eye movement—presumably due to activation of an assembly of similar receptive fields. In subsequent experiments where the stimulus was on the receptive field of the cell before and after the eye movement, the cell did not respond to the stimulus during the eye movement (Judge and Wurtz, 1977). These results are comparable to the present psychophysical experiments when a clear stationary scene was present before and after the eye movement and the grey-out was not seen.

Several recent studies have shown a slight modulation of activity of cells in the geniculo-striate pathway of monkeys (Duffy and Birchfield, 1975; Bartlett, Doty, Lee and Sakakura, 1976). This indication of an

extra-visual input is not in conflict with the previous results of Wurtz (1969a,b) since to see this input requires averaging over many trials whereas the previous results rested on a trial by trial analysis. That non-visual effects can be seen on such a trial-by-trial basis is demonstrated in the monkey superior colliculus (Robinson and Wurtz, 1976) where cells receive an extra-retinal input that eliminates the response of these cells to stimulus movement resulting from an eye movement (although these cells probably play no role in saccadic suppression). The slight physiological effects seen with averaging at the striate cortex are reminiscent of the slight 0.5 log unit elevation of visual threshold of saccadic suppression. Taking the neurophysiological and psychophysical experiments together, our hypothesis would be that the inability to see the grey-out during a saccade (saccadic omission) results from interaction within the visual system and depends on no extra-visual input; this is comparable, at a psychophysical level, to the results at a physiological level (Wurtz, 1969a,b). The slight elevation in detection threshold (saccadic suppression) might be comparable to the slight modulation of cortical activity which requires averaging over several trials to be clearly established (Duffy and Birchfield, 1975; Bartlett *et al.*, 1976).

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