grams of the monocular and binocular vernier acuity thresholds (75% correct level) for both subjects. As may be seen in Fig. 3, the vernier acuity thresholds of the twin with normal vision are lower with binocular (5.6 sec arc) than with monocular (8.3 sec arc) viewing conditions. This difference is statistically significant (t = 2.61, df = 10, p < 0.05). For the monocularly deprived twin, the monocular (nondeprived eye) and binocular vernier acuity thresholds are essentially the same (7.1 and 7.3 sec arc, respectively). Comparison of the deprived twin's monocular thresholds (nondeprived eye) with the normal twin's monocular thresholds indicates no statistically significant difference (t = 0.897, df = 10, p > 0.30). Therefore the resolution capability in the nondeprived eye of the one twin is not superior to the corresponding eye in the other twin.

Discussion. Our results do not support the conclusion by Freeman and Bradley that human amblyopes exhibit significantly higher-than-normal vernier acuity in the nondeprived eye. The vernier acuity thresholds of the present study are consistent with those reported by Westheimer and are lower than those obtained by Freeman and Bradley. Since it is known that practice influences vernier acuity, the difference between our findings and those of Freeman and Bradley could be due to the fact that these investigators used untrained subjects and a smaller number of trials to determine thresholds. Furthermore, the subjects in the Freeman-Bradley study were not a homogeneous population but rather consisted of strabismic amblyopes, anisometropic amblyopes, and subjects with other monocular anomalies. Our investigation of identical twins with equivalent optical properties (except in the deprived eye) and equal practice opportunities provides a high degree of comparability of the deprived and control groups. In our study of monocular deprivation in humans we did not find statistically significant improvements in vernier acuity in the nondeprived eye.

We thank Mark J. Mannis, M.D., and Ellen R. Matsumoto, O.D., for clinical ophthalmic examination of the subjects, Ian M. Schiller, M.D., for assistance in performing ultrasound measurements, and Tony Lee for serving as a diligent psychophysical observer.

From the Departments of Ophthalmology and Psychology (L. M. C.), University of California, Davis, Calif. Supported in part by National Eye Institute grant EY-03424 (to C. A. J.). Submitted for publication Jan. 28, 1982. Reprint requests: Chris A. Johnson, Ph.D., Department of Ophthalmology, University of California, Davis, Calif.

Key words: monocular deprivation, vernier acuity, identical twins

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Saccadic suppression under conditions of whiteout. LORBIN A. RIGGS and KAREN A. MANNING.

We have measured the impairment of vision that accompanies a saccadic eye movement under whiteout conditions. Translucent plastic diffusers were fitted around the
eyes to provide a luminous field without perceivable contours. Visual sensitivity of three subjects was tested by means of 10 msec luminance decrements of variable amplitude. We found that sensitivity was lower, by 0.7 to 1.1 log unit, when the eyes were making 16° saccades than when they were at rest. Comparable amounts of saccadic suppression occurred under more usual Ganzfeld conditions. We therefore conclude that such minimal contours as are present in the Ganzfeld—fixation guides, minor surface blemishes, and the blurred outlines of the subject's nose and brow—have little effect on suppression. These results are consistent with the hypothesis that a centrally originating inhibitory process accompanies the initiation of the saccade. (Invest Ophthalmol Vis Sci 23:138-143, 1982.)

Volkmann and Latour measured the impairment of vision for brief test stimuli presented during a saccade. This phenomenon, amply confirmed by others, has come to be known as saccadic suppression. It has been cited as evidence for a process originating centrally in the visual system that inhibits vision for a brief interval of time before, during, and after the eye movement. Various authors have questioned the central interpretation, however. They propose that some or all of the impairment of vision may arise from purely retinal processes instead. As the eyes move, the images of the fixation points and the edges of the visual field are swept across the retina. Indeed, MacKay and Brooks and Fuchs have reported that externally produced image motion of this kind may result in a momentary visual impairment, even when the eyes are steadily fixating. However, these studies involved the displacement of test spots, stripes, or edges of the field that are effectively eliminated in the present experiments. Brooks et al. made use of a "2.2° defocussed, circular strobe flash" to test for saccadic suppression against varying backgrounds of front- or back-illuminated screens supplied by a slide projector. Psychophysical "yes-no" judgments were made to estimate test-spot thresholds by the use of one or more flash intensities against backgrounds of 1.0, 0.0, −1.0, and −2.0 log footlamberts. Under these conditions a 15° saccade or an equivalent background displacement resulted in a threshold elevation of up to 0.7 to 0.8 log unit at the highest background luminance, declining progressively until little or no suppression was found at the lowest luminance. Other studies have found, however, that substantial amounts of suppression remain when tested with near-dark and completely dark backgrounds. A near-dark background was also used in a recent study that showed substantial amounts of blink-related suppression. The aim of the present experiment is to eliminate the fixation guides and other contours that could provide retinal image motion during a saccade and to measure the extent of saccadic suppression that remains.

It is true that careful investigators have tried to minimize retinal contours by the use of wide-field conditions and thin, extrafoveal fixation guides. But one may always insist that even thin lines, plus any inhomogeneities on the surface of the Ganzfeld, may constitute sufficient contours for stimulation of the retina during a saccade. Consequently, we have equipped our subjects with full-field diffusers that effectively eliminate all contours in the visual field. Our thought is that this change should have no effect on centrally induced impairment that might occur in the usual Ganzfeld situation.

Materials and methods. We have found that a snugly fitting diffuser for each eye can easily be made by cutting a section of the right shape from an egg-shaped milky plastic material (the container for "L'Eggs" hosiery). This can be trimmed to fit in such a way that no gap is left between the skin and the plastic. Thus the entire visual field, including the outlines of the nose and cheek, is obscured. Taped to the face with bits of transparent cellulose
Figs. 2 to 4. Results for three subjects with the four experimental conditions. Each point represents the proportion of 30 or more correct judgments (on a probability scale) at a particular stimulus amplitude (ΔI/I, on a logarithmic scale).

Fig. 2. Results for subject K. A. M.

Fig. 3. Results for subject L. A. R.

tape, the diffusers are large enough to be worn with comfort yet small enough to fit within the orbital cavity surrounding each eye. Fig. 1 shows the diffusers being worn by a subject.

We wished to provide uniform luminance throughout the field by illuminating the diffusers from all possible directions. This was accomplished by positioning the subject's head at the center of the Ganzfeld bowl described in a previous report. The luminance of the field provided by the diffusers was held constant at 6.9 foot-lamberts at all times except for a 10 msec decrement of variable amplitude used for a test stimulus. Despite these precautions, no claim can be
made that the result is complete uniformity of light over the entire retina. Shadows of intraocular blood vessels or other structures must actually be present, but these remain constant with completely diffuse illumination and our subjects report total "whiteout" after putting on the diffusers and adapting to directionless illumination by the Ganzfeld. There is no visible change when the eyes make saccades except when the test decrements are perceived. In fact, subjects are at a loss to observe the extent of their own saccades and must be coached on the basis of the recorded electro-oculogram (EOG) to keep them at the appropriate value. The scene is thus quite different from that of more typical Ganzfeld conditions, in which the eyes move within a frame of reference that is provided by fixation guides, small surface blemishes, and the subject's own nose and cheeks.

The amplitude of each saccade was monitored by the use of EOG electrodes located on the skin just outside the temporal margins of the diffusers. The EOG deflection was first displayed and measured on the face of a storage oscilloscope while the subject was not wearing the diffusers and could make use of two fixation guides that were 16° apart, one to the right and the other to the left of center. After the diffusers were put over the eyes, the experimenter continued to monitor each saccade and could coach the subject to maintain their size at approximately the same value as before.

A trigger circuit was used to present the test stimulus at the moment of sudden change in the EOG due to the onset of the saccade. Alternatively, the experimenter could present a stimulus manually when the eyes were at rest. The test stimulus consisted of a 10 msec decrement (ΔI) in the prevailing illumination (I) of the Ganzfeld. A psychophysical threshold was found by varying the decrement in equal steps of log (ΔI/I).

We wished to compare the results under whiteout conditions with those obtained in the Ganzfeld as used previously with fixation guides. Thus we determined a threshold for the detection of decrements under each of four conditions: with diffusers on (1) while the eyes were at rest and (2) while the eyes were making a 16° saccade; and with diffusers off (3) while the eyes were looking straight ahead at the surface of the Ganzfeld and (4) while the eyes were saccading from the right fixation guide to the left. Luminance was kept constant for viewing with and without the diffusers. This was accomplished by partially masking the fluorescent tube sources that were used to illuminate the Ganzfeld whenever it was to be viewed without the diffusers.

Thresholds were determined by a two-alternative forced-choice procedure used in previous studies to minimize the effects of observer bias. In brief, the subject hears two auditory signals 3 sec apart. One signal is accompanied by a 10 msec decrement of the prevailing luminance. The occurrence of a decrement after one or the other signal is randomized, and the subject is asked to indicate which of the two signals was accompanied by the stimulus. A minimum of 30 such judgments...
are made at each of four or five randomized amplitudes to ascertain the proportion of correct choices as a function of the amplitude of the decrement. These proportions range from chance (0.5) to certainty (1.0) as the size of the decrement increases. By means of a least-squares fit, the point of 75\% correct judgments is estimated and the corresponding value of \( \Delta I/I \) is taken as the threshold. In the saccade conditions, the subject makes a saccade at each of the two signals, and a decrement is triggered by one or the other of the saccades. In the conditions where the eyes are at rest, the experimenter presents the decrement at the time of one or the other of the signals.

**Results.** Figs. 2 to 4 display the proportion of correct judgments made by the three subjects under the four experimental conditions. It is clear that in both cases a larger decrement was required for correct detection during a saccade as compared with the resting condition. The presence or absence of the diffusers made relatively little difference.

Saccadic suppression is appropriately measured by the difference in \( \log (\Delta I/I) \) for 75\% correct detection in the saccade condition as compared with the resting condition. This suppression was 1.06, 0.69, and 1.11 log units for subjects K. A. M., L. A. R., and D. J. U., respectively, with diffusers on. Suppression with ordinary Ganzfeld viewing was 0.93, 0.79, and 1.24 log units for the same subjects.

**Discussion.** We have found saccadic suppression amounting to about 1 log unit under whiteout conditions in which little if any retinal stimulation is caused by the saccade. Under more usual Ganzfeld conditions, we find comparable amounts of suppression. Earlier studies involving saccades of similar amplitude and fields of similar luminance have also yielded comparable amounts of suppression. Retinal explanations of saccadic suppression, however, would predict substantially less suppression under our whiteout conditions.

By the process of exclusion, then, we have added new evidence that the execution of a saccadic eye movement is accompanied by a central inhibitory process that interferes with the perception of stimuli occurring at that time. This conclusion is similar to one that has been advanced to account for the fact that blinks are accompanied by a partial failure to perceive the blackout caused by the eyelids. Blinks and saccades are thus conceived to produce self-induced visual effects that need to be suppressed if we are to maintain subjective stability of the visual world.

The exact nature of neural suppression must remain a mystery until definitive physiologic studies can be carried out. In the meantime we must not make the mistake of assuming that a single process must account for the effect. The evidence that retinal masking and other peripheral processes are at work is overwhelming when tests are performed under conditions that emphasize the movement of contours over the retina. But no less impressive is the present evidence that when such contours are minimized, a major amount of saccadic suppression still remains.

From the Hunter Laboratory of Psychology, Brown University, Providence, R. I. Supported by National Eye Institute grant R01 EY03169. Submitted for publication Oct. 20, 1981. Reprint requests: Lorrin A. Riggs, Ph. D., Hunter Laboratory of Psychology, Brown University, Providence, R. I. 02912.

**Key words:** decremental stimuli, saccadic suppression, Ganzfeld, eye movements

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