

The Eyes Have It: Exposure Times and Saccadic Movements in Visual Half-Field Experiments

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Several tachistoscopic visual half-field experiments using exposure times in excess of 150 msec have been reported and arguments have been put forth justifying this procedure. An experiment was done investigating visual field accuracy under conditions where eye movement was allowed, following parafoveal exposure. Two control experiments were done to evaluate the viewing conditions. When eye movement is permitted, accuracy in both visual fields reaches 100%. It is concluded that visual field differences found with exposure times greater than 150 msec are due to the active cooperation of the subjects and not due to the justifications advanced by experimenters using long exposure times. © 1985 Academic Press, Inc.

A majority of experiments on human cerebral lateralization differences in the processing of visual perceptual information use the same basic experimental procedure. Subjects with normal vision are exposed to a display system capable of showing information for brief intervals, ideally with millisecond accuracy. A subject is told to maintain fixation on a defined point in the field of view and is given practice at the designated task. Stimuli are then shown, usually randomly, in parafoveal vision to the left or right of this fixation point thus insuring that the information

This work was supported by funds from the Committee on Research, University of California, Berkeley. Send correspondence and requests for reprints to: Curtis Hardyck, Institute of Cognitive Studies, University of California, Berkeley, CA 94720.

is initially received in the contralateral hemisphere. The subject then produces an appropriate verbal or manual response as measured by reaction time or accuracy. The assumption is made that randomness of stimulus presentation to the right or left is sufficient to insure that the subject maintains the fixation desired by the experimenter.

Exposure times in this type of experiment may range from a few milliseconds to 150–180 msec. Usually exposure times do not exceed these limits since onset time to initiate a saccade is in the range 150–180 msec. Thus, to insure that visual input is restricted to one visual-field cerebral hemisphere, an upper limit of 150 msec is usually observed.

There are, however, a small subset of experiments that use exposure times ranging up to 800 msec. Usually, such long exposures are necessary when the stimuli to be shown are of such complexity that an unacceptably high error rate is produced with the conventional upper limit of 150 msec (Klatzky, 1970, 1972; Klatzky & Atkinson, 1971; Moscovitch, Scullion, & Christie, 1976; Marzi & Berlucchi, 1977; Strauss & Moscovitch, 1981; Sergent & Lorber, 1983). The arguments offered for the use of these longer exposure times have two basic forms:

(1) Reaction times are measured from the onset of the stimulus at which time the information is received by only one hemisphere. It is implied that even though the subject may move his eyes toward the stimulus, it was at least initially presented intrahemispherically. Thus, observed differences in reaction times within hemifields may be safely attributed to cerebral lateralization differences (Strauss & Moscovitch, 1981; Moscovitch et al., 1976).

(2) Visual half-field differences for given types of stimuli obtained with longer exposures are similar to differences found in experiments with shorter exposure durations. Thus, the longer exposures do not reduce observed behavioral differences (Strauss & Moscovitch, 1981; Moscovitch et al., 1976; Klatzky & Atkinson, 1971; Klatzky, 1972; Sergent & Lorber, 1983).

Despite the post hoc nature of these justifications, long exposure durations per se are not a methodological problem provided that eye movements are strictly monitored as with an eye-movement system (Reuter-Lorenz & Davidson, 1981). However, such controls are not always utilized. Frequently, the self-reported compliance of the subjects with the fixation instructions is the only proof available to the experimenter.

We questioned both the validity of these arguments and the controls on fixation that have been imposed and designed an experiment with three conditions in which visual half-field differences were examined in parafoveal vision relative to foveal orienting. In Condition 1, the subject was allowed to view the stimulus foveally after first perceiving it in parafoveal vision. This method of first presenting the stimulus peripherally and then allowing the subject to fixate directly on it provides a direct

test of the stability of visual half-field differences when stimulus exposure is deliberately divided between peripheral and foveal presentation. Conditions 2 and 3 were control conditions in which both presentations of the stimulus were shown in parafoveal vision. In Condition 2, two exposures of 25 msec separated by a 400-msec interval were shown, controlling for the dual exposure aspect of Condition 1. In Condition 3, the subject oriented to a parafoveal exposure of 25 msec, then reoriented to the center fixation point and received a second 25-msec exposure, thus controlling for the physical orienting present in Condition 1. If visual-field response differences for stimuli viewed entirely within a visual field are not distinguishable from responses to stimuli where eye movements allow both a parafoveal and a foveal viewing, the justifications for long exposure times can be accepted, at least on pragmatic grounds.

MATERIALS

Our basic pool of items consisted of 150 five-letter words and an equivalent number of nonwords. Words were taken from the word norms published by Toglia and Battig (1978) and were rated high on imagery, concreteness, meaningfulness, and familiarity.¹ Nonwords were pronounceable, nonhomophonic to actual English words, and constructed in accord with English orthographic rules. All stimuli were constructed with 24-point Helvetica letters, photographed with Kodak technical Pan film, and mounted on 2 × 2 slides. The use of this film allows a high-contrast light image against a black background. When projected the inner edge of each item was located 2.25° of visual angle from a central fixation point. The items subtended 1.8 to 2.0° of horizontal visual angle. Illumination level of the room as measured at the display screen was 5.14 cd/m² between trials and 8.57 cd/m² during the stimulus presentation.

APPARATUS

Items were back projected on a screen located 152 cm from the subject. Projection was done using Kodak Ektagraphic self-focusing projectors with Uniblitz shutters having a rise and fall time of approximately 2–5 msec. A fixation point was provided by two special 3-v bulbs with focusing lenses producing a display similar in appearance to X in the center of the screen. The subject sat in an armchair modified to hold a head-positioning device adapted from a Tektronix oscilloscope viewing hood. This served to fix head position while allowing the subject to speak.

A remote eye-movement monitoring system (Gulf & Western 1994s) was located 38 cm from the subject. Responses were made by push-button switches held in each hand and activated with the thumb.

SUBJECTS

Nine subjects were recruited from introductory Psychology classes, being told at the time of recruitment that they would be paid at the rate of \$3.50/hr for their participation. At the time of recruitment, all potential

¹ Mean and standard deviation values for the word ratings are as follows: Imagery ($M = 5.71$, $SD = 0.36$). Concreteness (5.76, 0.40), Meaningfulness (4.55, 0.51), Familiarity (6.06, 0.39).

subjects filled out a brief questionnaire asking about handedness, handedness of immediate relatives, the wearing of eyeglasses or contact lenses, and whether English was a first language. Persons who were left-handed or with left-handed relatives and persons who lacked English as a first language were not asked to participate.

PROCEDURE

At the beginning of the session, subjects were asked to wear the glasses or contacts normally used for reading and were then tested for acuity on a Bausch & Lomb Ortho-rater. Subjects scoring less than 10 correct (equivalent to 20/20 vision) on the acuity test were paid for one hour but not used in the experiments. Following acuity testing, subjects were seated in the experimental room and the procedure explained. To begin, subjects fixated on the center of the screen, the eye-movement monitor was aligned, and the digital X and Y coordinates of eye position for the fixation point X were determined and supplied to a PDP-11 computer. Subjects were told that letter strings would appear randomly to each side of the fixation point for 50 msec, but would not appear if they were not focused on the central fixation point. When the item appeared, they were to press a designated switch if they thought the item to be a word and the other if they thought it not to be a word.

Subjects were then given 40 practice trials on items not included in the experimental set. The sequence of trials was controlled by a PDP-11 computer interfaced with the eye tracker. The digital coordinates taken at the time the eye monitor was aligned with the subject fixating were compared with the digital coordinates sampled by the eye monitor prior to exposure of the stimulus item. Eye position was sampled every 16.7 msec. Our procedure required five successive samples of eye position to be within 0.25° of visual angle of the X and Y position for fixation as determined at alignment before the test item was shown. Such a precaution insured that stimuli would not be shown in the course of a rapid scanning movement across the fixation point. When this criterion was satisfied at the onset of a trial, the fixation point disappeared as the letter string was shown for 50 msec. The average intertrial interval was 6–7 sec, but was longer if the subject was not fixating within the defined area since stimulus presentation was delayed until sampling of eye position indicated appropriate fixation. In addition to the computer sampling, the experimenter was able to observe the subject on three television monitors showing the subject's left pupil as monitored by the eye monitor, the head position of the subject, and the scene as viewed by the subject, complete with cross-hair display showing the subject's eye fixation. When the subject responded, the computer restored the fixation point, advanced the slide projector, and resumed examination of eye-position data prior to displaying the next item.

A total of 400 trials was run for each subject with a brief rest given midway. Eye position and calibration were carried out prior to each block of 200 trials. The first block of 200 trials was to establish a baseline of performance within the visual half fields. The second block represented the experimental condition.

As mentioned earlier, the total pool of items consisted of 150 words and 150 nonwords. Items were repeated once in the course of an experiment, but were balanced so that no item ever reappeared in the same visual field. Slides used within a 200-trial block were varied, so that two orders of presentation of an equal number of words and nonwords were used. Three subjects participated in each condition. In addition to accuracy measures, reaction times in milliseconds were taken from the end of the stimulus exposure until a response was made.

In the Orienting condition, after the determination of the baseline visual-field performance, a second series of judgments were undertaken in which the subject initially received a peripheral exposure of 25 msec located 2° of visual angle to the left or right of fixation. Immediately upon seeing the first exposure, the subject initiated a saccade to the area where the item had been exposed and was given a second exposure of 25 msec. Timing of the second exposure was controlled by the computer monitoring the subject's eye position and initiating the second exposure when the eye monitor indicated the saccade had halted within the area of the first exposure. Following this second exposure, the subject responded by a manual button press with his decision. A total of 200 trials were run for each subject, 100 trials blocked to the right and 100 to the left. If brief foveal viewing of stimuli such as may occur under long exposure times does not affect responses to stimuli initially shown parafoveally, we would expect accuracy and reaction-time measures to be statistically indistinguishable from the baseline condition where viewing is entirely parafoveal.

As a check on the effects of foveal orienting, two control conditions were run. In the Fixed condition, three subjects, following determination of the random right-left presentation baseline as in the Orienting condition, received 100 trials in each visual field, each trial consisting of two 25-msec exposures separated by a 400-msec interval. This condition allowed examination of the dual exposure aspects of our experiment while removing the confound of foveal viewing.

In the Return condition, subjects, again following determination of the random baseline, received 100 trials in each visual field where an exposure was shown peripherally for 25 msec. Following this exposure, subjects oriented to the peripheral placement of the stimulus (marked by a + which appeared after the exposure of the item and so placed as not to cause any possible masking) and then returned their gaze to the central fixation point at which time another 25-msec exposure was provided in

the same visual field as before. This condition allowed us to examine any effects specific to ocular orienting movements.

At the end of the experimental session, the results of each of the 200-trial blocks were shown to the subject and the summary results interpreted. The subject was also told about the purpose of the experiment and the relation of the experiment to other work done earlier. Subjects then filled out a handedness questionnaire and a family history of handedness inventory. This was done as an additional check on our earlier questionnaire given at the time the subjects were recruited.

RESULTS AND DISCUSSION

As can be seen in Fig. 1 substantial visual-field differences in accuracy are present in the baseline trials in which stimuli were presented randomly to either visual field for an exposure time of 50 msec. The right-visual-field advantage for lexical decisions under these conditions where the stimulus is a word is to be expected and has been reported before (Chiarello, Dronkers, and Hardyck, 1984; Cohen & Freeman, 1978). In addition, the same visual-field difference is seen in the experimental phases of the Fixed and Return conditions where peripheral exposure is still maintained even though the conditions of foveal orientation and dual exposures of

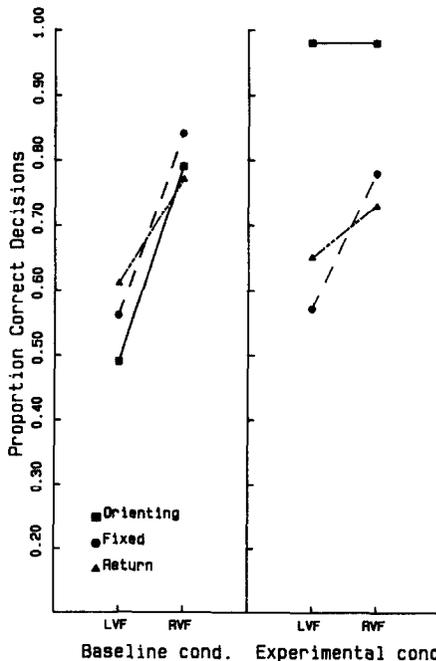


FIG. 1. Accuracy rates for the three viewing conditions in baseline and experimental trials.

stimuli were introduced. Therefore, it seems reasonable to conclude that the conditions of eye movements or of dual stimulus exposure have no effect on visual-field performance.

In the experimental trials of the Orienting condition where foveal viewing occurs, a different pattern of results emerges. Any visual-field advantage previously established in the baseline trials vanishes and the level of accuracy rises literally to 100%, since subjects were aware of their errors and reported them immediately to the experimenter. Thus, accuracy of judgment is perfect under conditions where the subjects receive a foveal glimpse of stimuli originally shown parafoveally.

A repeated-measures analysis of variance with factors of condition (baseline, experimental) and visual field (RVF,LVF) for the Orienting condition produced significant main effects of condition ($F(1, 2) = 57.41$, $p = .01$) and interaction effects of condition \times visual field ($F(1, 2) = 23.41$, $p = .04$). The same analysis for the Fixed condition revealed a significant main effect for visual field ($F(1, 2) = 35.80$, $p = .02$). The analysis for the Return condition indicated only a borderline effect for the condition \times visual-field interaction ($F(1, 2) = 14.30$, $p = .06$).

Although our results are quite convincing as regards accuracy measures, the possibility of reaction times remaining relatively unaffected has to be considered. Since many of the long exposure experiments used reaction times as the measure of lateralization differences, it is necessary to show that reaction times are also affected by foveal orienting. In Fig. 2, the reaction times for our three conditions are shown.

Reaction-time changes from baseline to experimental conditions are in close accord with the accuracy results. All conditions show similar reaction times for the baseline measures, ranging from 1170 to 1360 msec, with only small differences between groups. For the experimental measures, the difference between the group allowed to orient and the two control groups is almost 500 msec. The difference between the average performance on the baseline measure and the experimental measure for the orienting group is 695 msec, with the corresponding difference for the control conditions (averaged over both conditions) equal only to 105 msec. Analyses of variance for reaction times indicated no statistically significant effects for any condition.

It is interesting to note that the tendency toward a RVF-LH advantage still persists in this orienting group, although this difference is quite small and does not reach an acceptable statistical significance level in either baseline or experimental conditions. It is peculiar that it should exist at all, particularly in light of the fact that the Orienting condition requires that subjects look directly at the stimulus. Given the 100% accuracy in performance on this task, it hardly seems likely that the 25 msec of parafoveal viewing would outweigh the 25 msec of foveal presentation to produce a RVF-LH tendency. A more plausible explanation would

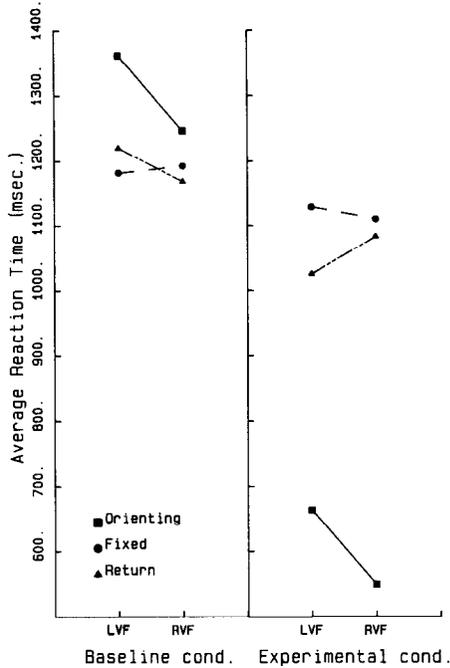


FIG. 2. Reaction times for the three viewing conditions in baseline and experimental trials.

be a response bias for right-handers to react more quickly to stimuli appearing on the right side of the screen. Such biases exist, as Bryden (1978) has demonstrated.

The implications for visual half-field experiments are quite clear. Stimuli exposed for longer than the time taken for saccadic movements run the risk of either producing a response bias or losing potential visual-field differences, unless eye movements are adequately controlled. Any experiment in which stimuli are shown for more than 150 msec reporting visual-field differences has subjects who are actively cooperating with the experimenter in maintaining central fixation. Such a process is not difficult, as has been demonstrated by other studies (Chiarello, 1985), where subjects are able to control their eye movements without much effort or training. However, the assumption that exposure times in excess of 150 msec can be used without monitoring of eye position is not a defensible one and experiments requiring longer exposure times should not be done without control of fixation.

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