The effect of feedback on luminance thresholds for peripherally presented stimuli*

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The effect of a central task on peripheral vision was determined by obtaining absolute luminance thresholds for peripherally presented stimuli. A competing central task was provided by interrupting the fixation light and requiring the S to reilluminate it. Data were obtained over five sessions, with feedback information provided on each trial. Thresholds were highest for the initial session and declined as a function of practice. The magnitude of the change depended upon the interruption rate. When central and peripheral stimuli compete for attention, priority is given initially to the central task, but, with practice, the differences are reduced.

Peripheral thresholds are usually obtained while the eyes are maintained in a reference position by gazing at a steady fixation point. With an increase in the eccentricity of the stimulated area, a number of visual functions are systematically altered. For the absolute threshold of the dark-adapted eye, threshold values fall as more peripheral regions are stimulated, reaching a minimum at about 18 deg, after which they rise steadily (Sloan, 1949). In general, sensitivity is closely related to the density of receptors. The absolute threshold follows the rod distribution (Campbell & Rushton, 1965). For visual acuity, discrimination is reduced steadily with increasing eccentricity, the function resembling the corresponding cone densities (Österberg, 1935).

There is extensive evidence, however, that such peripheral thresholds represent limiting cases which are characteristic only of well-practiced Ss tested under conditions in which the peripheral discrimination is the sole task in question. If the Ss are inexperienced, or if there is competition for attention, peripheral discrimination may be impaired. Both Low (1943) and Saugstad and Lie (1964) report that peripheral visual acuity increases with practice. Webster and Haslerud (1964) demonstrated that the accuracy with which Ss could report the presence of stimuli in the extreme periphery decreased when performance on a central task was improved by incentives (Barrick, Fitts, & Rankin, 1952), and under adverse thermal conditions when the perceptual load of a central tracking task was high (Bursill, 1968). Weltman and Egstrom (1966) reported that danger-induced stress produces a

marked increase in response time for peripherally presented signals, while Gasson and Peters (1965) found significant shrinkage of the visual field, as measured perimetrically, while concentrating on a demanding foveal tracking task.

Recently, Leibowitz and Appelle (1969) demonstrated, for a peripheral threshold task, that a slight modification of the standard testing procedure significantly raised peripheral thresholds. Specifically, the fixation light was extinguished randomly, and the S was required to reactivate it while peripheral threshold determinations were being made. Although their data were essentially identical to those of Sloan for standard testing with a steady fixation light, thresholds were increased by as much as one log unit with addition of the central task. They also report that peripheral thresholds improved with practice during the course of the study.

The purpose of the present study is to determine the influence of a competing foveal task, interruption of the fixation light, as a function of experience on the absolute peripheral threshold. In order to maximize the effect of practice, feedback regarding the S's responses was given continually throughout the training sessions. Such data are useful in assessing the extent of nonsensory factors on peripheral thresholds as well as the specific influence of training.

METHOD

Apparatus

The central fixation light and 12 peripheral stimuli were mounted in the horizontal plane on a perimeter encompassing a visual angle of 180 deg at a viewing distance of 70 cm. The circular stimuli, each 0.5 in. (1.27 cm) in diam and subtending 1.07 deg of arc, were mounted at visual angles of 20, 35, 50, 65, 80, and 90 deg on either side of the fixation point, which was provided by a red "grain of

wheat" bulb. Light for the peripheral stimuli was provided by General Electric electroluminescent panels. Their luminance output is proportional to the applied voltage with, over the ranges used, no significant change in spectral output. These sources respond rapidly to an application of voltage but decay relatively slowly. Pairs of Polaroid filters were mounted in front of the panels and adjusted so that the decay was not visible. Except for the fixation and stimulus lights, the room was in absolute darkness.

Procedure

The S was instructed to view the fixation light and to signal "left" or "right" whenever a light appeared in the periphery. Peripheral lights were activated randomly with respect to both order and time for a 1-sec duration. The interval between flashes was random, ranging between 15 and 30 sec. The S's head was positioned by a head- and chinrest, and vision was always binocular. All lights were at eye level.

The active central task was provided by extinguishing the fixation light at random intervals, governed by an electronic timing circuit and switching relay. The mean time the light was illuminated, which ranged between about 0.2 and 2.0 sec, was controlled by the adjustment of a bank of potentiometers. A relay selected among them and was activated by the S to reilluminate the bulb after it had been automatically extinguished. The S was provided with a pushbutton switch mounted at arm level and was instructed to keep the central light on as much as possible. Noise produced by the apparatus was masked by an air conditioner.

Two levels of difficulty were employed for the two experimental groups consisting of five Ss each. For one, approximately 28 presses per minute were required to keep the central bulb illuminated, while for the other, approximately 59 presses per minute were required. All Ss were requested, after 30 min of dark adaptation, to maintain fixation and to indicate when a light appeared in the periphery. In a single session, three thresholds for each of the 12 stimuli were determined, using the ascending method of limits. Each S was tested for five sessions at approximately 2-day intervals. In the first session, which was simply used to evaluate initial thresholds, no feedback was given. In the remaining four sessions, if S did not report seeing a peripheral light, both auditory and visual feedback were supplied. The S was told that he had missed a light on the left or right, after which illuminance

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Fig. 1. Log mean luminance thresholds as a function of stimulus eccentricity for five sessions. The Ss were required to maintain illumination of the fixation light, which was interrupted 28 times per minute.

Fig. 2. Log mean luminance thresholds as a function of stimulus eccentricity for five sessions. The Ss were required to maintain illumination of the fixation light, which was interrupted 59 times per minute.

of that stimulus was increased so that it was visible. Eye-movement data were recorded for the first and last trials for two Ss in each of the groups. Silver chloride electrodes were filled with (Redux) electrode paste and taped to the temporal side of the lateral angle of each eye. A grounding electrode plate was attached to the smooth part of the left forearm. A

bucking voltage eliminated the standing potential. Electrodes were able to stabilize during dark adaptation.

Performance on the central task was evaluated by two timers, one of which counted the number of times the S pressed the switch to illuminate the central light and the other to measure the amount of time the light remained

off. Luminance values were recorded in terms of ac driving voltage by a Simpson VOM and later converted to foot-Lamberts. The lights were calibrated on a relative basis with a photomultiplier, after which the absolute values were determined with a Macbeth illuminometer. Eye-movement data were recorded on a Bausch and Lomb VOM 7 recorder and later converted to the percentage of session time allotted to central fixation.

Subjects

The Ss were recruited from introductory psychology classes for the first session and were paid for the following four sessions. All were male with 20/20 vision, did not wear spectacles (although contact lenses were permitted), and were naive as to the purpose of the experiment.

RESULTS

The threshold data expressed as mean log luminance as a function of peripheral angle are plotted in Fig. 1 for the slower interruption rate and in Fig. 2 for the faster. For both rates, the initial session, in which no feedback was given, produced the highest thresholds. For the following two feedback sessions, the thresholds dropped steadily for both interruption rates. For the slower rate, no change is observed after the third session, while for the faster rate, there is a slight improvement for the fourth session. For both rates, the fifth session is almost the same as the fourth. Overall, the lowering of the threshold is much greater for the faster interruption rate, although they both eventually reach the same level, which is comparable to the data obtained by Sloan. It should be noted that the greatest improvement occurs for the near periphery. For the slow interruption rate, there is very little increase beyond 65 deg. For the fast interruption rate, improvement is greater for the near than for the far periphery. The magnitude of the reduction in threshold should also be noted. At 50 deg of eccentricity for the faster interruption rate, the final threshold is two log units lower at the final than it was at the initial session.

Analysis of variance reveals that the two interruption rates differ at the .05 level of significance ($df = 1/118$, $F = 3.94$). Sessions ($df = 4/72$, $F = 3.26$), eccentricity ($df = 11/198$, $F = 5.17$), and interaction between Ss and eccentricity ($df = 44/792$, $F = 2.32$) are all significant at the .005 level.

There is no difference between the reaction time to the interruption of the central fixation light for the two rates. The mean values were 0.582 sec for the slower rate and 0.675 for the

Table 1
Eye Movement Data Expressed as Percentage of Time the Eyes Were Positioned Centrally for Both Interruption Rates for the First and Last Sessions

Average Interruption Rate	Central Fixation	
	Session 1	Session 5
28 ipm	61.04%	75.10%
59 ipm	77.27%	76.89%

faster [$t(48) = 0.306$, n.s.]. No differences were obtained in reaction time over the five sessions [$t(18) = 0.398$, n.s.]. The eye-movement data expressed in terms of the percentage of time the eyes were positioned centrally are presented in Table 1 for the first and last sessions for the two interruption rates. None of the observed differences are significant, as determined by a t test. In general, the Ss spent about three-quarters of the time with their eyes centrally positioned, and one-quarter, searching.

DISCUSSION

The principal result of the present experiment, that peripheral discrimination is impaired by a simultaneously presented foveal task, is in agreement with a large number of previous studies using different methods of measurement and modes of discrimination. The generalization which emerges from this research is that when there is competition between foveally and peripherally presented stimuli, priority is given to

the foveal stimulus. In effect, the functional visual field and the physiological visual field are not identical. Experimental conditions which favor the physiological visual field are absence of competition for attention or stress and an experienced S. When these conditions do not obtain in the presence of competition for attention or stress, and particularly with inexperienced Ss, discriminations with respect to peripherally presented stimuli show a decrement. These general results are reflected in the concepts of Sanders's (1963) "functional visual field," Mackworth's (1965) (functional) "tunnel vision," and Piaget's concepts of "centration" and "decentration" (Vurpillot, 1959).

The present results are relevant when extending data from conventional laboratory studies to more complex situations in which the factor of attention plays a role. The fact that competition for attention produces a specifiable shift in apparent sensitivity is of fundamental importance in considering the functional performance of the visual system.

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