Spatial factors in masking with black or white targets[1]

JOSEPH F. STURR[2], *SYRACUSE UNIVERSITY*
THOMAS E. FRUMKES[3], *QUEENS COLLEGE OF THE CITY UNIVERSITY OF NEW YORK*

Two masking experiments were carried out. In the first, duration thresholds were measured for a 10 min black test disc paired with a larger concentric black mask, ranging in size from 15 min to 2 deg. The stimuli were tachistoscopically presented centrally, or at 2 deg or 6 deg in the left binocular field. As mask diameter increased, test threshold decreased in a negatively accelerated function, which approached an asymptote below *the unmasked condition. All functions are similar with systematic upward shifts for more peripheral stimulation. In Experiment 2, threshold luminance was adjusted for a 1 deg, 5-msec test flash paired with a 250-msec, 34-mL mask, ranging from 1 deg to 6.2 deg in diameter. Stimuli were presented in Maxwellian view at 7.2 deg in the right eye nasal field. Results were similar to Experiment 1, except that the asymptote is significantly* above *the control condition. Both experimental results support a border inhibition hypothesis.*

It has commonly been found with photopic, foveal or parafoveal stimulation, that masking is greater when a larger concentric masking stimulus approaches the size of a test stimulus (Werner, 1935; Crawford, 1940; Kolers, 1962; Battersby & Wagman, 1962). We have recently confirmed this result at four retinal positions, with black stimuli against a lighter background (Sturr, Frumkes, & Veneruso, 1965). In all cases, we found that a decrease in mask size produced a monotonic *increase* in test threshold, and greater masking occurred as stimuli were presented more peripherally. The slopes of these peripheral masking functions (plotted as a function of mask diameter) were much less steep than those in the fovea, indicating differential spatial influences at different retinal regions. For the fovea, the threshold of the test target paired with the largest (30 min diameter) mask was *below* that for the unmasked condition, suggesting summation or facilitation.

We subsequently attributed this facilitatory effect to the white afterimages of the large black mask (Sturr & Frumkes, 1966). These afterimages improved visibility by providing greater contrast than the original grey background. More recently, Streicher and Pollack (1967) have also interpreted our data along these lines. In order to eliminate afterimages, they restricted their design to backward masking. However, their dependent variable (test-mask interval) allowed for no control condition (i.e., test with no mask). Therefore, it is impossible to conclude from their data whether or not facilitation took place. Despite other design differences, their results were similar to ours in showing that masking increases as intercontour distance decreases.

In Experiment 1[4,5] of the present investigation, we included a broader range of mask sizes at three retinal positions, to determine if this "facilitatory" effect is peculiar to the fovea, and if the slope differences described above extended beyond the particular range of targets previously employed. In this experiment, the stimulus situation remained as identical as possible to that of our earlier study (i.e., the use of black targets, binocular view, tachistoscopic stimulus presentation, and duration thresholds). In Experiment 2, conducted at a later date, stimuli were presented monocularly in Maxwellian view at one retinal position. We specifically wished to determine which of the previously obtained effects of mask size could be demonstrated with light flashes and luminance thresholds.

EXPERIMENT 1

Methods

The apparatus was identical to that reported earlier (Sturr et al, 1965). Stimuli were presented binocularly by means of a Gerbrands tachistoscope, either centrally, or at 2 deg or 6 deg in the horizontal meridian of the left visual field. The test stimulus was a 10 min black disc, while the nine black masking targets ranged from 15 min to 2 deg in diameter. The masking targets and fixation crosshair were displayed upon a white transilluminated glass screen, and the test target upon a grey field, both combined by a half-silvered mirror to appear concentrically in one field.

The adapting field, fixation target, and mask were continuously exposed except when the test target was presented. The temporal interval between test and masking target was fixed. The duration of the test was adjusted for threshold. For the control condition (i.e., the measurement of RT or resting threshold), only the adapting field and fixation cross were presented prior to and following test target exposure. There was a variable 5- to 10-sec interval between stimulus presentation trials. The data were collected using the method of limits with alternating ascending and descending trials. A minimum of eight trials distributed over at least two separate sittings were employed for threshold determination. Four observers were used, three of whom had considerable previous experience in psychophysical judgments.

Results

Figure 1 illustrates data for Experiment 1. For each function, change from resting threshold (RT) is plotted on the ordinate, masking target diameter on the abscissa. The horizontal dashed lines above and below zero on the ordinate represent the average deviation of the resting threshold data. This measure of variability for the other data points was approximately ±10 msec. Functions

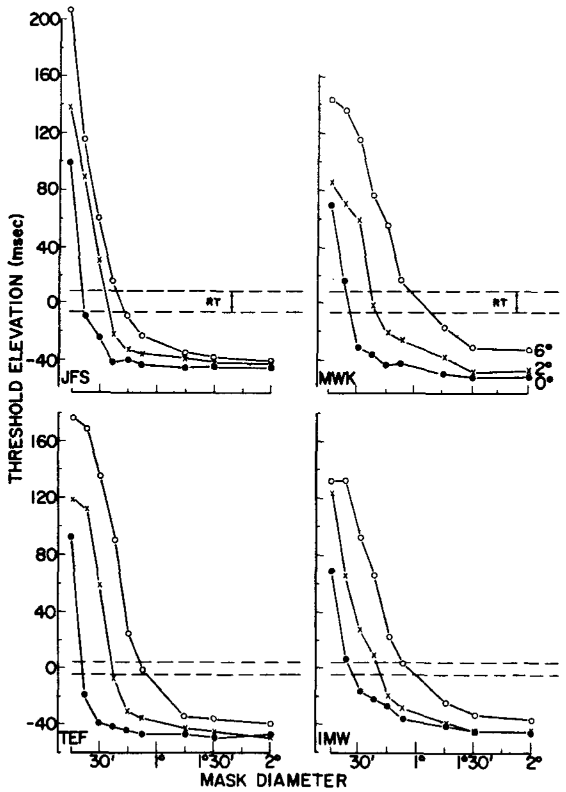

Fig. 1. Masking functions for black targets. Ordinate: change from resting threshold (RT) in milliseconds. Abscissa: masking target diameter in degrees. Horizontal dashed lines represent average deviation of RT data. Closed circles: central stimulation (0°), x's: 2°, and open circles: 6° in periphery.

with the closed circles indicate central stimulation, the x's 2 deg, and the open circles, 6 deg.

In general, similar functions can be seen for all observers. At all retinal positions, TF threshold decreases according to negatively accelerating functions, approaching asymptotes *below* RT. A systematic upward shift in the functions can be observed with more peripheral stimulation. Although our previous study (Sturr et al, 1965) indicated a slope shift in the upper portions of the functions from fovea to periphery, only two observers (TEF and IMW) clearly showed this in Fig. 1. The interpretation of these upper portions is difficult because of the use of duration thresholds, as discussed below.

Discussion

The results of Experiment 1 are in agreement with previous studies employing dark figures (Werner, 1935; Kolers, 1962; Sturr et al, 1965) which demonstrated that as mask size decreases, test threshold increases. This supports hypotheses such as Werner's (1935) emphasizing the importance of proximity of target borders in masking. The possible underlying physiological mechanism might involve lateral inhibition (Ratliff, 1965). The systematic increase in masking with peripheral stimulation parallels the neuroanatomical arrangement in the retina, as has been pointed out earlier (Sturr et al, 1965).

Figure 1 indicates that the obtained masking functions approach asymptotes below control level. In connection with this, the incidental subjective impression of all four observers should be noted. Presentation of larger masks, particularly in the periphery, produced clear and in some cases, prolonged white negative afterimages. This adds substance to the previous conclusion that the facilitatory effect can be attributed to the white afterimage enhancing the contrast between the test stimulus and grey background (Sturr & Frumkes, 1966; Streicher & Pollack, 1967). With light flash, rather than dark target stimulation, and with foveal or parafoveal photopic conditions, test flash threshold decreases as a concentric masking flash increases in size (Crawford, 1940; Battersby & Wagman, 1962; Frumkes & Sturr, 1967). However, no facilitatory effect has been observed except for threshold flashes preceding large masking fields by approximately 100 msec (Sperling, 1965). Under such conditions where no facilitation is observed, is the same smooth function obtained? One of the purposes of Experiment 2 was to answer this question.

A second purpose of Experiment 2 was to overcome some of the methodological shortcomings involved with tachistoscopic presentation of stimuli. One limitation of this technique is the use of duration thresholds, which are hard to interpret beyond the limits of temporal reciprocity (approximately 100 msec), where changing duration is *not* equivalent to increasing or decreasing luminance. Since the resting threshold was approximately 40 msec, the meaning of "threshold elevation" for durations greater than 60 msec is not precise. In Experiment 2, this criticism is overcome by the use of brief light flashes and luminance thresholds measures.

The presentation of the mask before and after the test stimulus also makes it difficult to determine whether backward, or forward masking account for the above results. We therefore restricted Experiment 2 to forward masking. Since the second experiment was carried out in another laboratory at a later date, the spatial parameters, although similar, were not identical to those of Experiment 1.

EXPERIMENT 2

Methods

Stimuli were presented to the right eye by means of a Maxwellian view optical system to be described more fully in a subsequent publication. Two independent channels which provided test and masking flashes (TF and MF, respectively) individually focused the source image upon electronically pulsed shutters. Rise and fall time for stimuli was approximately 1¼ msec. Variable apertures controlled the size of TF and MF, and balanced neutral density wedges enabled fine adjustment of luminance. A third channel provided an adapting field and central fixation cross. The observer saw this cross upon a steady 40 deg adapting field of 2 mL, upon which TF and MF were superimposed.

The 5-msec, 1 deg diameter circular test flash was presented at 7.2 deg in the horizontal meridian of the right eye nasal field. The 250-msec, 34-mL concentric mask, ranged in diameter from 1 deg to 6.2 deg. TF and MF were pulsed synchronously at either their onset or offset. Two trained observers were used in this study. One of them (TEF) was also used in Experiment 1.

Thresholds were obtained after the observer was dark-adapted for 5 min and subsequently exposed to the adapting field for 1 min. The paired flashes were then presented once every 4 sec to the observer who adjusted TF luminance for threshold. For the control condition (i.e., resting threshold or RT), only TF was presented. A minimum of 12 readings distributed over at least two separate sittings were obtained for each threshold determination. RT was checked at the beginning of every experimental session.

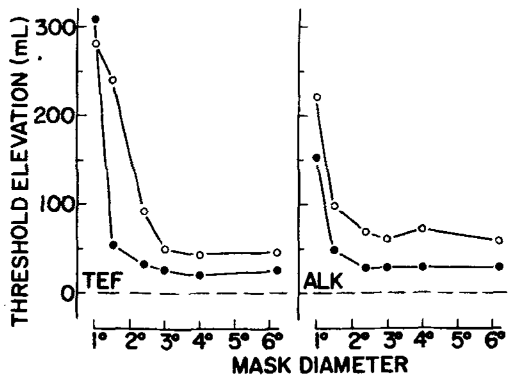

Fig. 2. Masking functions for light flashes at one retinal position (7.2 deg). Ordinate: change from resting threshold in millilamberts. Abscissa: masking target diameter in degrees. Horizontal dashed line represents RT. Open circles: simultaneous onset of paired flashes; closed circles: simultaneous offset.

Results

The means of all data points collected in this experiment are shown in Fig. 2. Change from resting threshold is plotted along the ordinate in millilamberts, MF diameter in degrees of arc along the abscissa. Resting threshold is indicated by the horizontal dashed line. Simultaneous flash onset measurements are indicated by open circles, offset data by closed circles. The average deviation for all data points including RT was approximately 0.07 log mL. TF threshold monotonically decreases as mask diameter increases, approaching an asymptote *above* RT. This occurs both when paired flashes are presented synchronously at onset or offset. The onset condition produced higher threshold, confirming results of Battersby and Wagman (1962).

Discussion

The smooth, negatively accelerated functions obtained with luminance thresholds are remarkably similar to those obtained with duration measures in Experiment 1. However, no facilitation was observed. We have previously suggested that the effects of mask size can be interpreted in terms of either total general energy summation, or inhibition at borders (Sturr, Frumkes, & Veneruso, 1965). According to the first interpretation, it would be predicted that larger masking targets produce more "noise" and hence more test flash energy is required for detection. On the other hand, a contour inhibitory hypothesis predicts that the magnitude of inhibition is an inverse function of the distance between target edges. Clearly, both experiments tend to support this latter viewpoint. There nevertheless exists the possibility that total energy might also play a role under other stimulus conditions. For example, in a recent report Westheimer (1967) employed much smaller foveal, photopic stimuli and obtained a non-monotonic function with MF diameter variation. With a 1 min test target, decrease in mask diameter below 5 min resulted in a *decrease* in test threshold. These complex effects have also been demonstrated for conditions where more neural convergence occurs, i.e., farther in the periphery and under dark adaptation (Crawford, 1940; Westheimer, 1965; Teller et al, 1966; Frumkes & Sturr, 1967).

From the present data, we conclude that the distribution of energy along target borders is a very crucial variable in visual masking. The evidence presented from this type of study, as well as those altering shape (Werner, 1935; Pollack, 1965) size of MF, or size of TF (Streicher & Pollack, 1967) indicate that inhibitory interactions are involved.

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NOTES

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2. Address: Department of Psychology, Syracuse University, Syracuse, N. Y. 13210.

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4. Experiment 1 was carried out at Syracuse University while T.E.F. was a U.S.P.H. Predoctoral Trainee in Physiological Psychology. Experiment 2 was carried out at Queens College where T.E.F. is a U.S.P.H. Postdoctoral Fellow.

5. The results of Experiment 1 were presented at the April, 1966, meeting of the Optical Society of America in Washington, D. C.

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