Effects of target-field luminance, interstimulus interval, and target-mask separation on extent of visual backward masking*

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Three variables—target field luminance, interstimulus interval, and spatial separation of target and mask—were found to have significant effects on backward masking, in accord with predications from a model developed by Purcell, Stewart, & Dember (1968). Quantitative differences between the results of the present and the earlier (1968) study were attributed to a masking-by-flashes effect in the earlier study or, when considered in terms of receptive fields, to the involvement of different-sized receptive fields resulting from the difference in the size of the targets employed in the two studies. Further, the results of the present study provide an estimate of the radius of the inhibitory region for the detection system that is in close accord with such estimates from experiments using quite different procedures.

Purcell, Stewart, & Dember (1968) proposed that metacontrast is mediated by the mechanism of lateral inhibiton, as found in the *Limulus*. According to this model, upon presentation of the target stimulus (a black disk on a white surround, for instance), a differential in inhibition is established between the neurons serving the target area and those of the surround. The surround neurons fire at a higher rate than the target neurons and, hence, subsequently inhibit themselves to a greater extent. When the masking stimulus follows (a flash), the target neurons fire at a rate greater than the relatively more inhibited surround, resulting in a brightness reversal. The phenomenal appearance of the target area depends on a temporal averaging of the target as presented (i.e., black) and the reversed (i.e., brightened) target. Maximal metacontrast is achieved when this averaging process yields a target of approximately the same apparent brightness as the background, thereby rendering the target undetectable.

Two ways proposed to facilitate differential inhibition—and therefore metacontrast—are to use (1) high levels of target-field luminance, on the assumption that the brighter the target field, the greater the rate of firing and, hence, the greater the amount of inhibition generated, and (2) short interstimulus intervals (ISI), on the assumption that inhibition from the target's surround spreads laterally with time and, given sufficient time to spread, would decrease the target's susceptibility to brightness reversal.

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That greater target-field luminance renders the target more maskable has been confirmed (Purcell, Stewart, & Dember, 1969; Purcell & Stewart, 1969). Phenomenal brightness reversal and re-reversal have been related to the stimulus parameters of target field luminance and interstimulus interval (Purcell & Dember, 1968; Stewart, Purcell, & Dember, 1968). In addition, the concepts of "reversals" and "re-reversals" have formed the basis for an explanation of target recovery obtained when the standard masking stimulus is itself followed by a mask (Dember & Purcell, 1967; Robinson, 1966).

A third factor assumed to affect differential inhibition is a spatial one. Introducing a black figure near the black target serves to protect the target from the lateral inhibition spreading from the surround. The less the inhibition received from the surround, the greater the differential in inhibition and, hence, the more effective the masking. Within the disk-ring paradigm, it has been shown that increasing separation of the disk and ring reduces amount of masking (Cox, Dember, & Sherrick, 1969), presumably because as separation increases, the ring less effectively protects the disk from inhibition from the surround.

The present experiment was undertaken to replicate with improved methodology an earlier finding (Purcell, Stewart, & Dember, 1968) concerning the spatial effectiveness of the mask. The results of that study confirmed the prediction that the greater the differential inhibition, the farther the mask could be from the target and still have an effect on target detectability. The present experiment measured detectability of a thin target line at fixed distances from a masking bar, using a yes-no indicator coupled with a signal detection analysis.

SUBJECTS

Five female and five male paid college students with normal or corrected-to-normal vision served as Ss. The Ss were trained on all stimuli used in the experiments, receiving at least 200 trials on each of 2 days preceding the 10 experimental days.

STIMULI

The stimuli consisted of black paper fixed on white index cards. The target stimulus was slightly less than 2 min of arc wide and 36 min high and was vertically oriented. The masking stimulus was also 36 min high and extended horizontally from the center of the visual field to the left edge of the field. The viewing field was approximately 2½ deg square.

APPARATUS AND PROCEDURE

The stimuli were presented tachistoscopically (Scientific Prototype GB). Viewing was monocular. The target stimulus was attached to a plate that could be moved horizontally to one of four positions—0, 6, 12, or 18 min to the right of the masking bar. The stimuli were presented in the following order: dark fixation field, target, dark ISI, mask, dark fixation field. Ss were dark adapted for 5 min before each day's tasting. The dark fixation field, which served as the adapting field, was illuminated continuously by four dim peripheral red dots arranged in a diamond pattern to help the S fixate on the center of the field.

The duration of the target was established for each S individually on each day's testing by determining 90% correct detections with the target field luminance at 40 fL, and the target was followed immediately by a 100-msec blank masking flash of 40 fL. Mean target duration used was about 60 msec.

The three main variables of the experiment were: target field luminance, which was either 20 or 60 fL; ISI, which was either 0 or 50 msec; and separation between target and mask, which was 0, 6, 12, or 18 min. Mask conditions were constant at 40 fL field luminance and 100 msec duration.

Each S received 10 trials on each of the 16 conditions (2 luminances x 2 ISI x 4 separations) on each of 10 experimental 1-h sessions. Preceding the collection of the experimental data for each session, target duration was determined on the basis of 50 to 70 trials of target plus flash. Ss received the 16 conditions in random order, which was different for each day and

Table 1
Mean d' Scores for the 16 Conditions (N = 10)

	0 ISI				50 ISI			
	0 Min	6 Min	12 Min	18 Min	0 Min	6 Min	12 Min	18 Min
20 fL	1.06	1.81	2.59	2.73	2.27	2.91	3.17	3.07
60 fL	.79	1.66	2.11	2.35	1.85	2.64	3.05	3.11

for each S. Within each block of 10 trials, the schedule of target presentation was random with the restriction that the target would not appear on 0, 1, 9, or 10 out of 10 trials. Across the 10 days, the target was presented on 50 of the 100 trials for each condition.

On all trials, S initiated the stimulus sequence on signal from E. The S's task was to say "yes" or "no," as to whether the target was presented or not.

RESULTS

The false-alarm to hit ratios were computed and d' scores were obtained from the table in Appendix 1 of Swets (1964). The cases in which the false-alarm rate was .00 were raised to .01.

The means for the 16 conditions are presented in Table 1. In addition, the means for 20- and 60-fL target field luminances are 2.45 and 2.16, respectively; for 0 and 50 msec ISI, 1.89 and 2.76, respectively; and for O, 6, 12, and 18 min separations, 1.49, 2.26, 2.73, and 2.81, respectively.

A three-way analysis of variance with repeated measures on all factors was computed. All main effects reached significance at the .01 level or beyond. No interaction effect was significant.

DISCUSSION

That greater target field luminance and shorter ISIs reduce target detectability is in accordance with predictions from the Purcell et al model. Increase in target field luminance or decrease in ISI leads to greater differential inhibition, thereby facilitating brightness reversal and decreasing target detectability. Moreover, increasing separation of target and mask increased target detectability, as predicted. However, the spatial effectiveness of the mask in the present study does seem quantitatively different from that obtained by Purcell, Stewart, & Dember (1968). In that experiment the target was an extension of the masking bar; detection occurred when the S reported that the bar extended to the right of the midline of the stimulus field. Under some conditions, target extensions as great as 67.2 min (the maximum extention allowed by the apparatus) were undetectable. In the present study effects of the mask probably extend no farther than 12 or 18 min (percent correct detection for 0-, 6-, 12-, and 18-min separations was 69%, 79%, 86%, and 88%, respectively). Since target plus flash without masking figure yielded approximately 90% target detection, the values of 86% and 88% correct target detection most likely reflect masking effects of flash alone. It may be that in the previous study (Purcell et al, 1968), masking effects of flash alone contributed heavily to the apparently greater amount of masking obtained.

An alternative explanation for the quantitative difference between the results of the present study and the previous one can be offered in terms of the antagonistic action of receptive fields. Assuming that the target falls on the central excitatory region of a receptive field and the mask on the surrounding inhibitory region, the mask will cover less of the inhibitory region of the receptive field as the separation between target and mask increases. According to this conceptualization, increasing separation between target and mask releases the target from inhibition due to the mask's falling on the target's inhibitory region. The difference between the two studies can be attributed to the difference in the size of the targets used. A line target would be below threshold for a number of large-sized receptive fields, and, therefore, would involve only a subset of the possible receptive fields. The Purcell, Stewart, & Dember (1968) study employed targets of varying sizes, all of which were larger than those used in the present study, thus involving a different set of receptive field sizes.

From the results of the present study, it is possible to estimate the radius of the inhibitory region (assuming a Gaussian distribution) of the detection system to be between 12 and 18 min. This is in contrast to estimates of inhibitory regions from other metacontrast studies using discrimination rather than detection systems, which were found to be about 30 min (Fry, 1947) and 1 and 2 deg (Alpern, 1953; Weisstein & Growney, 1969). However, it is in close accord with estimates based on Mach bands (von Békésy, 1960) of 10 min and adaptation effects of large disks on smaller disks or ever smaller probes of about 15 min (Sturr et al, 1965; Sturr & Frumkes, 1968; Frumkes & Sturr, 1968) and 20 min (Westheimer, 1965, 1967).

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