Backward masking of visual targets with internal contours¹

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Detection thresholds were obtained using a staircase procedure coupled with a forced-choice indicator response to test the hypothesis that a visual target would become increasingly less susceptible to backward masking as the amount of its internal contour increased. Relative maskability of each of several targets was expressed as a ratio of threshold under masking to threshold under nonmasking conditions. The hypothesis was confirmed, some earlier results were verified, and an unanticipated backward "facilitation" effect was indicated for the target with the most extensive internal contour (a disk composed of 16 black and white segments).

In a classic study on what is now commonly referred to as backward masking, Werner (1935) investigated, among several other variables, figural properties of the target stimulus. The finding most pertinent to the present paper was that stimuli with internal contours were especially hard to mask, compared with the homogeneous black disk typically employed in Werner's many experiments.

We have been engaged in a program of research devoted to replication and extension of various aspects of Werner's work, using a forced-choice indicator response instead of the phenomenal reports on which Werner relied. The forced-choice indicator is achieved by adding a second ring to the single masking ring typically used by Werner. The target is centered in one of the two rings on a given trial, with target location randomized over trials, and the S's task is to indicate target location simply by saying "left" or "right."

In a previous experiment (Sherrick & Dember, 1969), the role of internal target contour was investigated by comparing the maskability of a homogeneous black disk with that of targets composed of black and white hemidisks. As anticipated, the half-black, half-white target was less readily masked than an all-black target.

The present experiment was designed primarily to see if quantitative variation in internal target contour would be reflected in extent of masking. To this end, targets were prepared consisting of 2, 4, 8, and 16 black-white segments in addition to the standard homogeneous target. Since the stimuli were presented on a gray

background, it was possible to use both a black and a white target disk as well as masking rings that were either black or white. Moreover, to assess possible differences in target detectability per se, independently of target maskability, detection data were collected in the absence of the masking stimulus. Finally, as a consequence of pilot research, we employed a "stair-case," or "up-and-down," psychophysical method instead of the less sensitive constant-stimulus method used by Sherrick & Dember (1969).

SUBJECTS

Two male and two female paid college students with normal or corrected-to-normal vision served as Ss. The Ss were trained on all stimuli used in the experiment, receiving 180 trials on each of 2 days before the collection of the experimental data.

STIMULI

The target stimuli were black and white ink drawings on gray paper that reflected half of that reflected by the white ink. The six basic target stimuli consisted of two homogeneous disks, one black and one white, and four half-black and half-white disks having 2, 4, 8, or 16 alternating black and white segments. In addition, the two-segmented disk had four orientations, with black on the left, right, top, and bottom halves; the four-segmented disk had two orientations, an arrangement of alternating black and white segments and the reverse of this. Each S received only one of the two-segmented orientations and two Ss each received only one of the four-segmented orientations during the entire experiment in an effort to counterbalance for possible effects of relative positions of black and white. All

Fig. 1. Target stimuli used, including variations of the two- and four-segmented disks. All stimuli were the same size in the actual experiment.

target stimuli are illustrated in Fig. 1. Three masking conditions included a pair of black rings, a pair of white rings, each pair horizontally arranged on a gray background, and a blank card of the same gray for the no-mask condition. Altogether, there were 18 stimulus conditions (6 disk conditions x 3 mask conditions).

The diameters of the disks, as well as the inner diameters of the rings, measured 8 mm, subtending 24 min of arc. The thickness of the walls of the rings subtended 12 min of arc, with the distance between centers of the rings subtending 58 min of arc.

APPARATUS AND PROCEDURE

Stimuli were presented tachistoscopically (Scientific Prototype Model GX). The target stimuli were attached to a plate that could be moved horizontally. The apparatus included adjustable stops so that the positions at which the disk was centered in each of the rings could be marked and the disk could easily be shifted between these two positions. Viewing was monocular.

The stimuli were presented in the following order: light fixation field, target, mask, light fixation field (target-mask interstimulus interval was 0 msec). The duration of the target varied, the duration of the mask was 105 msec, and the time elapsing between trials was about 10 sec. The luminance of all fields was 10 fL, with the fixation field present continuously except when the target or mask was presented.

Each S received 10 trials on each of the 18 stimulus conditions during the 2 days preceding the experiment. The target duration on Practice Day 1 was 20 msec, on Day 2, 10 msec. On each of the remaining 18 days of the experiment, S received only one of the 18 conditions. The order in which the stimuli were presented to the S was random on both practice days and during the actual experiment and was different for each S. On a single trial, the disk was randomly positioned in one of the two rings (or, in the no-mask condition, in one of the two positions in which the disk would be placed if rings were present). On signal from E, the S pushed a button initiating the stimulus sequence. The S then indicated, by saying "right" or "left," in which of the two rings the target appeared, guessing if necessary.

On the experimental days, the detection threshold of a disk of a particular target-mask combination was determined by varying target duration. The data were collected using staircase methodology combined with the forced-choice indicator. A staircase series was conducted by

presenting the S with a target of a given duration. If S responded correctly on two successive trials, target duration was decreased; if S responded incorrectly, duration was increased on the next stimulus presentation.

An ascending and a descending staircase series were conducted concurrently in order to preclude anticipation effects. Whether a given trial came from the ascending or descending series was determined randomly, with each group of 10 trials containing an equal number from each. On each experimental day, a preliminary series of 10 trials was used to determine the range of durations containing the threshold, and the end-points of this range were used as starting points of the two staircases. Nine levels of target duration were typically used in the double staircase, with the target durations of homogeneous disks varying in 1-msec steps and the nonhomogeneous disks varying in .5-msec steps.

Thirty-five data points of each staircase were collected, the first five of which allowed the two staircases to approach each other; these were not used in the calculation of the threshold value.

RESULTS

Thresholds for all stimulus conditions for each S were calculated according to procedures outlined in Dixon & Massey (1969), except for one condition for one S. In this case, the S correctly located the target on only one of the 60 presentations. For him, a threshold was generated based on his row, block, and column means according to a procedure given by Winer (1962) for supplying missing data. Means for each of the 18 basic conditions are given in Table 1.

Since thresholds in the masking condition reflect both target detectability

and maskability, we computed for each S ratios of thresholds in the mask condition to thresholds in the no-mask condition. The means of these ratios are presented in Table 2. A two-way analysis of variance, repeated-measures design, performed on the data presented in Table 2 reveals the main effects of target and mask to be significant at the .001 ($F = 10.03$, $df = 5/15$) and .05 ($F = 13.53$, $df = 1/3$) levels, respectively. The interaction between these variables failed to reach significance ($F = 1.12$, $df = 5/15$).

DISCUSSION

The results confirm the Sherrick & Dember (1969) finding that a homogeneous target is more easily masked than a nonhomogeneous target and show that this holds for white as well as for black target disks. Also consistent with previous research (Stewart, Purcell, & Dember, 1968) is the observation that the black disk is easier to mask than the white disk. The present data suggest, furthermore, that black rings are more effective masks of homogeneous targets than are white rings, but that black rings mask nonhomogeneous targets about equally as well as do white rings. Examination of the data in Table 1 clearly reveals that target detection is substantially impaired by the presence of rings in the masking field, in agreement with earlier findings on the importance of masking-stimulus contour (e.g., Eriksen & Collins, 1965; Purcell, Stewart, & Dember, 1968).

As to the main purpose of the present experiment, the data of Table 2 support the hypothesis that as the number of internal target contours increases, the target's susceptibility to masking decreases, such that for the 16-segmented target there is virtually no masking. Indeed, the data in

Table 1 suggest that the 16-segmented target is easier to detect when followed by the masking ring than when presented alone. This last unexpected finding, should it prove reliable, could be interpreted as evidence for a hitherto unreported (as far as we know) "backward facilitation" effect.

A second unanticipated result is the marked decrease in target detectability, in the no-mask condition, as the number of segments reaches 16. Again, should this result prove reliable, it may be indicative of some kind of self-inhibition induced by the interaction of internal target contours, perhaps mediated by the type of inhibitory receptive fields reported by Hubel & Wiesel (1962). The enhanced detectability of the 16-segmented target when followed by the masking stimulus may, then, reflect a disinhibiting effect of the sort suggested by Robinson (1966).

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NOTE

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Table 1
Mean Target Duration at Which Detection Occurred for All Stimulus Conditions

Mask	Target					
	Black	White	2	4	8	16
Black	22.42	12.65	5.65	5.65	5.28	6.00
White	18.52	10.00	5.00	5.78	4.55	7.52
None	3.25	2.25	2.20	2.42	3.75	7.05

Table 2
Mean of Ratios of Target Duration Thresholds with Black or White Mask to Target Duration Thresholds with No Mask

Mask	Target					
	Black	White	2	4	8	16
Black	7.75	5.65	2.58	2.45	1.42	.88
White	6.32	4.52	2.30	2.48	1.25	1.08