REFERENCES

CHAPMAN, W. P., & JONES, C. M. Variations in cutaneous and visceral pain sensitivity in normal subjects. Journal of Clinical Investigation, 1944, 23, 81-91.

HALL, K. R. L., & STRIDE, E. The varying response to pain in psychiatric disorders: A study in abnormal psychology. British Journal of Medical Psychology, 1954, 27, 48-60.

HASLAM, D. R. Heat pain and pressure pain. Psychonomic Science, 1967, 9, 567-568.

HARDY, J. D., WOLFF, H. G., & GOODELL, H. *Pain sensations and reactions.* Baltimore: The Williams and Wilkins Company, 1952.

KEELE, K. D. The pressure algometer. Lancet, 1954, 1, 636-639.

MERSKEY, H., & SPEAR, F. G. The reliability of the pressure algometer. British Journal of Social & Clinical Psychology, 1964, 3, 130-136.

SCHLUDERMANN, E., & ZUBEK, J. P. Effect of age on pain sensitivity. Perceptual & Motor Skills, 1962, 14, 295-301.

SHERMAN, E. D. Sensitivity to pain. Canadian Medical Association Journal, 1943, 48, 437-441.

SHERMAN, E. D., & ROBILLARD, E. Sensitivity to pain in the aged. Canadian Medical Association Journal, 1960, 83, 944-947.

WOLFF, B. B., & JARVIK, M. E. Quantitative measures of deep somatic pain: Further studies with hypertonic saline. Clinical Science, 1965, 28, 53-56.

NOTE

1. In order to test the reliability of this method when used with children, a test-retest procedure was carried out on 12 hospitalized children. A rho value of +0.79 was found, which is significant at the 0.02 level of confidence.

Backward masking: Facilitation through increased target-field luminance and duration[1]

DEAN G. PURCELL, University of Toronto, Toronto, Canada, ALAN L. STEWART, Albion College, Albion, Mich. 49224, and WILLIAM N. DEMBER, University of Cincinnati, Cincinnati, Ohio 45221

Studies of visual backward masking demonstrate that increases in target-field luminance or duration will decrease the target's susceptibility to masking. A proposed theory predicts that, within certain limits, increases in target-field luminance or duration will increase the target's susceptability to masking. Two experiments support these predictions.

The present authors are developing a model of visual backward masking based on the concept of lateral inhibition. The model can handle the phenomenon of target recovery (Dember & Purcell, 1967; Stewart, Purcell, & Dember, 1968; Robinson, 1966); it has generated some verifiable predictions relating recovery to the phenomenon of brightness reversal (Purcell & Dember, 1968), as well as predictions about the effect on masking of spatial properties of the mask (Purcell, Stewart, & Dember, in press; Sherrick & Dember, 1968). The present research evaluates the model further by testing the prediction that the detectability of a masked target will *decrease*, at high levels of target-field luminance, as target-field luminance and target duration *increase.*

In brief, the pertinent elements of the lateral inhibition concept as applied to our black-disc target, black-ring mask configuration are as follows: A black, or phenomenally dim disc stimulus stimulates little or no firing in relation to the firing provided by its white or phenomenally bright surround. Ratliff (1965) points out that lateral inhibition on a given neuron is a positive function of the rate of firing of neurons adjacent to it, and a negative function of its distance from firing neurons. Thus neurons in the area of the visual system that the disc impinges upon are less inhibited than neurons in the area that the surround impinges upon.

Inhibition persists after the termination of stimulation, but decays over time. While inhibition is present in the visual system, it serves to reduce the rate of neural firing to further visual stimuli. Thus, a stimulus of a given intensity will generate more neural firing in an uninhibited area of the visual system than it will in an inhibited area. Because of the differential in inhibition established by the black-disc, white-surround target presentation, a white masking flash has the effect of setting up a pattern of neural firing which is the reverse of the firing to the target presentation. This reversal may be detected if the S is properly set (Purcell & Dember, 1968), but under many conditions, including those employed in the present experiments, reversal may also result in backward masking. Research on the compound eye of the *Limulus* (Ratliff, 1965) demonstrates that the build-up of lateral inhibition is positively related to both stimulus intensity and duration. If these relationships hold for the vertebrate eye, and our application of the lateral inhibition concept to visual backward masking is valid, then we can predict that increasing both the intensity or the duration of the target-field should increase the differential in inhibition between the target disc and its surround, thereby also increasing the amount of backward masking.

METHOD

Two experiments were run to test these predictions. In the first experiment, 20 naive Ss were run individually in a ½-h long, forced-choice detection experiment designed to test the effect of target-field luminance, with the contrast ratio between the target and its surround held constant. The target presentation consisted of a 3-deg 4-min square illuminated white field containing a black target disc 24 min in diam. The duration of the target presentation was 5 msec. Four target-field luminance levels were employed, measured as 30, 40, 50, and 60 ft-L by a Spectra brightness spot meter. The contrast ratio between the luminance of the target surround and the target disc was .12. The masking field contained two black rings (inner diam 24 min, outer diam 48 min) in the horizontal plane (57.6 min center-to-center), centered on a 3-deg 4-min square white field. Mask duration was 75 msec; its luminance was 40 ft-L, with a figure-to-ground contrast ratio of .12.

Presentation of stimuli was via a Scientific Prototype tachistoscope, Model GB. The target disc appeared in the center of one of the two rings on each trial in accordance with a random sequence. During both the interstimulus interval (ISI) and the intertrial interval, the viewing field was unilluminated except for four peripheral, pinpoint red lights that served to guide fixation. All viewing was monoptic (right eye). The ISI between the termination of the target and the onset of the mask was selected for each S so as to yield approximately 60-70% correct detections, corrected for guessing, with the 30-ft-L target presentation. The mean ISI averaged across the 20 Ss was 28.50 msec.

Subjects were instructed that they were participating in a visual-detection experiment involving the detection of one black dot that would appear in one of the two black rings. They were to indicate which ring the disc appeared in by saying "right" or "left," after each trial, even if they had to guess. The first 10 min of each session served three functions: (1) practice on the task; (2) determination of an ISI yielding the desired percentage of detections; (3) dark adaptation. At the end of this period Ss were exposed to each of the four conditions of target luminance 50 times, 10 trials in a block, with blocks randomized. Each trial was initiated by the S via a thumb switch after a ready signal from the E. The intertrial interval varied from 5 to 10 sec.

The second experiment was designed to test the effect of target duration on detectability. Fifteen new Ss were run under the same procedure as above, except that the luminance of the target was held constant at 30 ft-L, and the target duration was either 5 or 10 msec. The mean value of ISI was 26.60 msec. Each S was exposed to 50 trials at each target duration, 10 per block with blocks randomized.

RESULTS

The data in Table 1 express the mean per cent correct target detections, corrected for guessing and averaged across Ss, for the four luminance values used in the first experiment. The effect of target luminance is significant ($F = 6.95$, $df = 3/57$, $p < .001$) with target detectability *decreasing* as target-field luminance increases. The data in Table 2 express the mean per cent correct target detections, corrected for guessing and averaged across Ss, for the two values of target duration used in second experiment. The effect of duration is significant ($F = 26.93$, $df = 1/14$, $p < .001$) with target detectability *decreasing* as duration is increased.

DISCUSSION

The decrease in target detectability as target field luminance increased indicates that the differential in inhibition between target and surround areas increased. In the second experiment the decrease in target disc detectability as target duration was increased indicated that the differential in inhibition created by the target and surround increases over time. Both of these findings are consistent with findings concerning intensity and duration of stimulation and the build up of lateral inhibition in the visual system of *Limulus* (Ratliff, 1965). They lend support to the application of lateral inhibitory concepts to an explanation of backward masking of suprathreshold targets.

Decreases in target detectability with increases in both target-field luminance and duration are in all likelihood to be found at intermediate values of these parameters. Further increases in target duration will eventually lead to the target being read out before the mask is presented. The relationship of target detectability to further increases in target-field luminance is less clear. Dember & Purcell (1968) have demonstrated reliable brightness reversals with a target-field luminance of 80 ft-L.

An examination of the backward masking literature indicated that the findings of the two studies presented here are unique. Two studies investigating the effect of target illumination on backward masking (Cheatham, 1952; Schiller & Smith, 1965) found that masking was decreased as target intensity was increased. It is quite possible that the luminance values (.004 ft-L to 4.2 ft-L) investigated in those studies were too low to generate sufficient lateral inhibition to obtain a reversal to the masking flash.

Several studies have investigated the effect of target duration on backward masking (e.g., Heckenmueller & Dember, 1965; Kinsbourne & Warrington, 1962; Schiller, 1965a, b). These studies all found that masking was decreased as target duration was increased. In all of these studies stimuli were presented to the light-adapted eye. The light-adapted eye is more inhibited than the dark-adapted eye (Dowling, 1967) and as such would be less amenable to the establishment of a differential in inhibition sufficient to obtain a reversal to the masking flash.

Table 1
Mean Per Cent Correct Detection, Corrected for Guessing, Averaged Across Ss for Four Levels of Target-Field Luminance

Target luminance (ft-L)	30.00	40.00	50.00	60.00
Per cent correct	61.20	53.60	46.00	40.20

Table 2
Mean Per Cent Correct Detection, Corrected for Guessing, Averaged Across Ss for Two Levels of Target-Field Duration

Target duration (msec)	5	10
Per cent correct	71.26	57.33

REFERENCES

CHEATHAM, P. G. Visual perceptual latency as a function of stimulus brightness and contour shape. Journal of Experimental Psychology, 1952, 43, 369-380.

DEMBER, W. N., & PURCELL, D. G. Recovery of masked visual targets by inhibition of the masking stimulus. Science, 1967, 157, 1335-1336.

DOWLING, J. The site of visual adaptation. Science, 1967, 155, 273-279.

HECKENMUELLER, E. G., & DEMBER, W. N. A forced-choice indicator for use with Werner's disc-ring pattern in studies of backward masking. Psychonomic Science, 1965, 3, 167-168.

KINSBOURNE, M., & WARRINGTON, E. K. The effect of an after-coming random pattern on the perception of brief visual stimuli. Quarterly Journal of Experimental Psychology, 1962, 14, 223-234.

PURCELL, D. G., & DEMBER, W. N. The relation of phenominal brightness reversal and re-reversal to backward masking and recovery. Perception & Psychophysics, 1968, 3, 290-292.

PURCELL, D. G., STEWART, A. L., & DEMBER, W. N. Spatial effectiveness of the mask: Lateral inhibition in visual backward masking. Perception & Psychophysics, in press.

RATLIFF, F. *Mach bands: Quantitative studies on neural networks in the retina.* San Francisco: Holden Day, 1965.

ROBINSON, D. N. Disinhibition of visual masked stimuli. Science, 1966, 154, 157-158.

SCHILLER, P. H. Backward masking for letters. Perceptual & Motor Skills, 1965a, 20, 47-50.

SCHILLER, P. H. Metacontrast interference as determined by a method of comparisons. Perceptual & Motor Skills, 1965b, 20, 279-285.

SCHILLER, P. H., & SMITH, M. C. A comparison of forward and backward masking. Psychonomic Science, 1965, 3, 77-78.

SHERRICK, M. F., & DEMBER, W. N. Effect on visual backward masking of completeness and spatial distribution of mask contours. Paper presented at meetings of Midwestern Psychological Association, 1968.

STEWART, A. L., PURCELL, D. G., & DEMBER, W. N. Masking and recovery of target brightness. *Proceedings of the American Psychological Association,* 1968, 109-110.

NOTE

1. This research was supported by NIH Grant NB-07622-02.