The relation of phenomenal brightness reversal and re-reversal to backward masking and recovery¹

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Three recent experiments have demonstrated that a visual target suppressed through backward masking can be recovered by the introduction of a second mask. Present theories of backward masking cannot account for this since they assume that a masked target has no representation in the visual system. A mechanism is suggested to account for both visual backward masking and recovery in terms of lateral inhibition. Experimental evidence is offered in support of the hypothesized mechanism.

Backward masking consists in the retroactive interference of one visual stimulus, the target, by another visual stimulus, the mask, closely following the target in time. Several models have been proposed to account for this phenomenon. Chief among them are models built on concepts of luminance summation (Thompson, 1966), size of array, (Erickson & Collins, 1965), and erasure (Averbach & Coriell, 1961). These models assert, in the first two cases, that a masked stimulus is never differentiated from its surround, and in the third case, that the masked stimulus is removed from the visual system.

Robinson (1966), Dember and Purcell (1967), and Mayzner (1967) have demonstrated that it is possible to "recover" a masked target when the masking stimulus is itself followed by a mask (the recovery stimulus). These findings cannot be accounted for by any of the previous backward masking models, since those models all insist that a target has no representation in the visual system once it has been masked.

The masking and subsequent recovery of a target demand that the target be represented in the visual system in such a way that it fails to mediate detection or recognition but remains retrievable. While these two requirements may seem incompatible, they are no different in principle from those that apply to analogous instances in the domain of "memory," such as extinction and spontaneous recovery, or extinction and disinhibition, failure to recall and reminiscence, and so on. The problem here is how best to conceptualize what is happening at both phenomenal and physiological levels.

At the phenomenal level, a lead is provided in the work of Heckenmueller and Dember (1965), who found that under certain masking conditions it was possible to transform, or reverse, a black target on a white surround into a bright target. They demonstrated

further that this phenomenal reversal of the target brightness was contributing to Ss' detection failures in a forced choice task because the reversed target no longer met the Ss' response criterion. In this case, then, a "masked" target is still represented in the visual system, though in such a way that it does not mediate detection.

Now, if one masking stimulus can reverse a target, a second mask might, in the same way as the first, act upon the reversed target to restore it, at least partially, to its original (i.e., unmasked) appearance. Thus, what is treated as masking may be the product of target reversal, while recovery may reflect the same process operating on the reversed target, or what might be called *re-reversal*.

As is sketched in the discussion section, a physiological mechanism in the form of lateral inhibition can be invoked that will handle both masking and recovery. The experiment described below was meant both to illuminate the preceding argument and to provide one test of its validity.

METHOD

The experiment followed the same general paradigm used in previous recovery studies, with certain instructional and parametric modifications. Two conditions, 100 trials each, were randomly presented via a tachistoscope (Scientific Prototype, model GB) to the Ss after a 5 min dark adaptation period. All stimuli were presented monocularly. Condition 1: A black dot ($24'$ of arc in diameter) on a square, white surround subtending $30^\circ 2'$ of arc, illuminated at 80 ft-L for 5 msec was followed by a 20 msec dark period and then by a 50 ft-L flash of white light (masking flash) with a duration of 40 msec. These parameters, which closely parallel those used by Sperling (1960) to reverse white dots to phenomenal black dots, were selected on the basis of extensive pilot testing so as to maximize reversals in Condition 1. Condition 2: The same sequence as Condition 1 was repeated and followed after 30 msec of darkness by a second 50 ft-L flash of white light (the recovery flash) with a duration of 750 msec. The intertrial interval varied from 5 to 10 sec and was not illuminated except for four dim, red, peripheral points; the intersection of the imaginary vertical and horizontal lines joining these points defined the center of the target area for S. Four

paid Ss were instructed to look for both black dots and white dots, and were permitted to make one of four possible responses on each trial: "black dot," "white dot," "black dot and white dot," "no dot." It was determined that Ss could easily see the black dot when it was presented without any masking flashes.

RESULTS AND DISCUSSION

If the double reversal hypothesis is correct, then the Ss should report more white dots in Condition 1 than in Condition 2, while more black dots should be reported in Condition 2 than in Condition 1. When tested by χ^2 analysis, the data presented in Table 1, confirm these predictions in each case ($p < .005$) with the exception of S4, who did not see significantly more white dots in Condition 1 than 2. The intersubject differences in number of Condition 1 reversals can be interpreted as reflecting differences in susceptibility to masking, which in our laboratory have been found to be reliable and extensive (Dember & Neiberg, 1966).

The general result, that a black dot is reversed to white by the first white flash and then reversed back to a black dot by the second white flash, cannot be handled by reference to simple luminance summation. In particular, such a model would predict that, as a consequence of subsequent flashes of homogeneous white light, a black dot on a white surround might approach the brightness of that surround, but could never exceed it, as the dot has in Condition 1.

The following mechanism is suggested as a way of accounting for masking and recovery where phenomenal brightness reversal and re-reversal are evident; it is also directed at those cases of masking and recovery (e.g., Dember & Purcell, 1967) where it is doubtful that the first masking flash reversed the target, though the second flash recovered it.

The mechanism is based on the lateral inhibitory effects found in the Limulus (Ratcliff, 1965) and as applied to the human visual system by Ganz (1966). Briefly, the lateral inhibition concept asserts that the firing of an aggregate of neural cells in the visual system has the effect of inhibiting or lowering the

firing rate of both those cells and adjacent cells to subsequent stimulation. This reduction in firing rate is due to a dynamic lateral interaction between adjacent neurons and not simply to fatigue of individual neurons. The amount of inhibition imposed on adjacent neurons, which are not firing, is a decreasing function of their distance from a firing aggregate and an increasing function of the firing rate of that aggregate. It is assumed that perceived brightness is a function of rate of firing. The phenomenal appearance of the target results from some integration of rates of firing evoked by both the target and masking flashes.

With the inhibition mechanism in mind, but without at this point considering unstimulated neurons which have been laterally inhibited due to their proximity to firing neurons, backward masking and recovery can be accounted for in the following manner. Assume a target consisting of a black dot presented in a white field, with both the masking and recovery stimuli being flashes of white light. For purposes of exposition, consider two distinct aggregates of neurons in the visual system: Group 1, those neurons upon which the black dot impinges; and Group 2, those neurons upon which the white areas surrounding the target dot impinge.

Upon presentation of the target field, Group 2 neurons fire and concomitantly inhibit themselves. Group 1 neurons do not fire, and, although they may receive some inhibition from the activity of Group 2 neurons, they remain relatively uninhibited. When the first masking flash is presented, Group 2 neurons, because of inhibition which has not yet decayed, fire at a lower rate than those of Group 1. Because of this differential firing rate, the target should now appear to be brighter than the surround.

It is assumed that what the S observes is some integration of the dark aspect of the target dot and the bright, reversed aspect of the target precipitated by the masking flash. In the present experiment, there were four such outcomes (see Fig. 1). These are interpreted as manifestations of intersubject differences as well as intrasubject fluctuations in visual sensitivity. Figure 1 is offered as a summary of our speculations about parameters which might maximize each of the four outcomes.

Even though the phenomenal appearance of a masked target is the resultant of the integration of discrepant (i.e., positive and reversed) inputs to the same visual area, the state of inhibition in the system is assumed to be dependent solely upon the pattern and rate of firing induced by the last flash of light. It is this assumption which makes it possible to deal with the recovery of targets which are masked, but not reversed.

At the time the recovery stimulus is presented, Group 1 neurons are inhibited more than Group 2

Table 1. Frequency of Responding "Black" or "White", "Black and White", and "No Dot Seen" to a Black Dot after the First (Condition 1) or Second (Condition 2) Mask. Data for 4 Ss are given.

Response	S ₁		S ₂		S ₃		S ₄	
	Condition 1	Condition 2	Condition 1	Condition 2	Condition 1	Condition 2	Condition 1	Condition 2
Black	11	60	17	43	9	27	45	83
White	84	34	73	41	85	68	10	6
Black & White	5	6	9	4	2	4	44	11
No Dot	0	0	1	12	4	1	1	0

Fig. 1. Schematization of the interaction of target field luminance (target lum) and interstimulus interval (isi) in yielding the four phenomenal outcomes of following a black target dot by a white masking flash. This schema is intended to apply only to targets which are readily detectable when presented alone.

because Group 1 neurons fired at a higher rate to the masking flash than did Group 2. This means that the recovery flash fires Group 2 neurons at a higher rate than Group 1 neurons and effectively re-establishes the "dark dot, bright surround," which is the criterion that the S is using.

Thus, when the target, masking, and recovery stimuli are presented, there are three inputs to the area of the visual system the target impinged upon. In terms of our example, the first is dark, the second bright, and the third dark again. Due to the preponderance of dark inputs, the integration process should favor the perception of a black dot, and recovery would be accomplished. The same relationships that hold between the target and masking stimulus should also hold between target, masking, and recovery stimuli such that the four outcomes obtained under masking conditions are also obtainable under recovery conditions. Masking and recovery of white targets in a dark field would be explained in much the same manner, with the inhibitory relationships simply reversed.

In discussing the results of his recovery experi-

ment, Robinson (1966) alludes to "disinhibition," but it may be more profitable to describe the events in a recovery experiment in the following manner. The target has not literally been inhibited by the masking flash, and thus cannot literally be disinhibited by a second flash. Rather, the masking flash has its effect because it acts upon areas of differential inhibition set up by the target itself. The recovery flash has its effect because it acts upon areas of differential inhibition which result from the presentation of the masking flash. Hence, both backward masking and recovery are interpretable as the phenomenal resultant of the integration of discrepant inputs to the same area of the visual system, the discrepancy being caused by the action of each stimulus flash upon the inhibitory relationships generated by the preceding stimulus flash.

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Note

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