On the "recovery" of masked targets*

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Robinson (1966) has claimed that a target which has been masked can be recovered by presentation of a second mask. Presumably, the second mask masks the first, an effect which disinhibits perception of the target. Two experiments were carried out to examine this phenomenon. Experiment 1 repeated Robinson's initial (1966) experiment, but failed to show a "recovery" effect. Experiment 2 showed that "recovery" is related to (1) brightness reversals which occur in the periphery but not in central vision, and (2) criteria which relate to the appearance of the stimuli and influence report of these reversals.

When a target consisting of a flash is immediately followed by a second flash, the target is often difficult to detect. Several investigators have reported that if a third flash is presented, the target becomes easier to detect (Robinson, 1966; Purcell & Dember, 1968). For example, Robinson masked a small homogeneous white disk (test flash) with a larger concentric white disk (Mask 1) of the same luminance. On some trials, a still larger disk (Mask 2) was presented after the test flash + Mask 1 sequence. Robinson (1966) reported that the test flash was detected (recovered) more often when the three stimuli were presented than when just two were presented. He called this effect "disinhibition." In his terms, the neural response to Mask 2 inhibits the response to Mask 1, which normally acts to inhibit the response to the test flash. Other investigators have expanded upon these studies, using very different methodologies, and in some cases have shown similar results (e.g., Long & Gribben, 1971; Dember & Purcell, 1967; Purcell & Dember, 1968; Purcell, Stewart, & Dember, 1968), but in other cases failed to obtain results consistent with those of Robinson (e.g., Schurman & Eriksen, 1969; Uttal, 1971).

The recovery effect is of importance because no existing theory of masking is capable of handling these data. Major theories of masking depend on foundations which can be broadly identified as either integration or interruption theories. A common assumption of integration theories is

that the test field is not perceptually distinguished from the mask which follows it. The neural representation of the stimulus is still in the visual system but represented below contrast threshold or otherwise combined with the mask. The integration approach cannot be used to explain how a third flash could combine with the combined test field and mask to restore a representation of the test field. On the other hand, interruption theories are based upon the view that the neural representation of the test field is erased by the mask or that processing is halted by the mask. It is not obvious in interruption models how the presentation of a second mask could restart processing on the test field if the result of the first mask were to halt processing on the test field.

Since recovery seems to represent a case most masking theories cannot predict and because of the implications of recovery for masking theory, it is important to examine this effect in greater detail. The present report describes two experiments on recovery and some of the parameters of the effect. These studies suggest that "recovery" is a function of retinal locus as well as being dependent upon criteria affecting reports of judgments on the relative brightness of the stimuli.

EXPERIMENT 1

Experiment 1 repeated Robinson's (1966) study. In addition, several stimulus combinations were added to the design so that forward masking effects, false-positive test flash detections, and response contingencies could be examined.

Method

Subjects. One paid undergraduate, one graduate student, and a faculty member served as Ss in this experiment. All had practice on tachistoscopic recognition but were naive with respect to the purpose of this experiment.

Apparatus. A Gerbrands

three-channel tachistoscope was used. Stimuli were produced by transilluminating circular holes punched in sheet brass. The brass plates were mounted inside the viewing box so that the test flash subtended 23 min of visual angle, Mask 1 was 46 min of visual angle, and Mask 2 subtended 98 min 58 sec of visual angle. All fields were set at a luminance of 5 fL.

Procedure. Ss were dark adapted for 10 min prior to beginning a session. Dim red pilot lights on equipment and a dim red work light were baffled from Ss' view. No fixation point or other such cues were available to S. Field durations were 20 msec in the test phase of the experiment. Ss viewed the stimuli monocularly (right eye); S initiated each trial.

Ten randomized repetitions of the seven stimulus combinations were presented. These were: test flash only, Mask 1 only, Mask 2 only, test flash + Mask 1, test flash + Mask 2, and test flash + Mask 1 + Mask 2. The interstimulus intervals used between test flash and Mask 1 were 25, 50, and 75 msec (interstimulus interval, *i*); the order in which each S received interstimulus interval conditions was randomized. The interstimulus interval between Mask 1 and Mask 2 was always 25 msec (interstimulus interval, *j*). Both interstimulus intervals were dark, as was the intertrial interval.

On those trials in which the test flash was not presented, the time slot allotted to test flash presentation was kept dark. Similarly, if Mask 1 was not presented, the entire timing sequence was executed but that field was not illuminated. Ss had two sessions at each interstimulus interval. The first session given to Ss was at 25-msec interstimulus interval. Although this session was identical with succeeding sessions, it was not included in the analysis and served primarily as practice for S. Thus, each S had seven stimulus sequences presented 10 times per session for a total of 70 trials. Two sessions were given for each of three interstimulus interval conditions, plus a practice session, yielding a total of 490 observations per S. At the beginning of each session, Ss received warm-up trials on the task of identifying the three fields by number (i.e., "1" for the smallest field, "3" for the largest field). During the warm-up, stimulus durations were 200 msec. When S reached a criterion level of 10 successive correct identifications, the test phase was begun.

Results

The dependent variable was percent correct test flash detections. Sign tests were calculated on this measure in the test flash + Mask 1 condition vs the

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Table 1
Averaged Percent of Correct Responses to the Indicated Stimulus Sequence*

Stimulus	Response	Robinson, 1966			Experiment 1			Experiment 2					
		ISI-1			ISI-1			Stimuli at Fixation			Stimuli in Periphery		
		25	50	75	25	50	75	25	50	75	25	50	75
TF + M1 + M2	TF												
	Light	75	80	90	42	53	67	72	62	75	63	62	85
	Dark	—	—	—	—	—	—	13	8	18	9	15	2
	Total	75	80	90	42	53	67	85	70	93	72	77	87
	Case A**				88	95	100	100	100	100	73	78	87
TF + M1 + M2	Case B†				25	32	33	31	24	28	62	58	80
	M1												
	Light	—	—	—	72	64	67	69	76	73	15	25	8
	Dark	—	—	—	—	—	—	14	13	17	66	62	80
	Total	—	—	—	72	64	67	83	89	90	81	87	88
TF + M1	TF												
	Light	7	55	75	30	28	74	85	69	100	5	19	31
	Dark	—	—	—	—	—	—	0	27	0	57	56	56
TF + M2	Total	7	55	75	30	28	74	85	96	100	62	75	87
	TF												
	Light	—	—	—	59	71	84	98	98	92	65	72	85
TF + M2	Dark	—	—	—	—	—	—	0	2	3	13	28	15
	Total	—	—	—	59	71	84	98	100	95	78	100	100
M1 + M2	M1												
	Light	—	—	—	42	67	57	92	90	100	33	32	27
	Dark	—	—	—	—	—	—	0	8	0	53	58	63
M1 + M2	Total	—	—	—	42	67	57	92	98	100	86	90	90

*TF = test flash, M1 = mask 1, M2 = mask 2, ISI = first interstimulus interval, light = "light" or "normal" brightness responses included, dark = responses "darker" than normal.

**Case A—Percent = $\frac{\text{Number of TF detected responses which also showed suppression}^1 \text{ of M1 responses}}{\text{Number of trials in which M1 responses were suppressed}} \times 100$

†Case B—Percent = $\frac{\text{Number of TF detected responses which also showed suppression of M1 responses}}{\text{Number of stimulus presentations (total)}} \times 100$

¹Suppression is defined as either a stimulus reported "dark" or not reported at all.

test flash + Mask 1 + Mask 2 condition for each interstimulus interval. For both 25- and 75-msec interstimulus intervals, there was no difference in test flash detection ($p = 0.188$ and $p = 0.500$, respectively), although a significant difference was observed at 50 msec ($p = 0.016$). In general, the present data are not consistent with the hypothesis that there is greater test flash detection in the three-flash "recovery" condition than in the test flash + Mask 1 masking condition. Table 1 shows these data in contrast to numbers taken from Robinson's curves (1966). Results of the present study differ considerably from those of Robinson's study. This outcome is especially surprising, since the present experiment used stimulus conditions¹ which were almost identical to those used by Robinson.

Size of the masking stimulus seems to be inversely related to the strength of the masking effect. When test flash + Mask 2 presentations are compared to test flash + Mask 1 presentations, greater test flash detection is found with the larger masking stimulus. Further, Mask 2 is not found to be an effective mask for Mask 1.

Discussion

The disinhibition theory of test

flash recovery (Robinson, 1966, 1968) rests on the assumption that masking is a lateral inhibitory effect and also on the condition that Mask 2 inhibits the effect of Mask 1. The resulting inhibition of the inhibitor would then allow a "test flash" response. Recovery is seen in only those cases where Mask 1 is suppressed (Case A, Table 1). In contrast, Mask 1 suppression occurs only 28%-36% of the time; thus, there is little overall evidence for recovery. The 28%-36% Mask 1 suppression seen in the present study is in marked contrast to the 100% suppression reported by Robinson (1966). Results from Experiment 2 show that this apparent inconsistency is due to variation in fixation and a criterion effect which influences report of the stimulus.

Conclusions

The present data indicate that if recovery is to occur, it will do so only when Mask 1 is itself masked in the three-flash sequence. Thus, the disinhibition theory explains only 30% of the data in this condition and does so by building a theoretical base on speculation about the specific physiology of interactive processes in human retina.

At least one point is made clear by

the present study: Simple counting of test flash detection in the test flash + Mask 1 vs test flash + Mask 1 + Mask 2 cases is not sufficient to evaluate the presence of a recovery effect or to assess its theoretical significance. A recovery-like effect was found in only 30% of the trials in the three-flash condition. It could be argued that the present experiment was sufficiently insensitive so as to obscure recovery. That argument receives some support from other experiments where recovery has been obtained. It is curious, however, that Experiment 1 is the only experiment which has repeated Robinson's conditions. Some insight into this problem was provided by the Ss who reported that brightness reversals had occurred (e.g., Purcell & Dember, 1968). In the test flash + Mask 1 cases, for example, the phenomenal appearance of the stimuli often was described as "a doughnut the size of Mask 1 with a dimmer center the size of the test flash." Further, since fixation was uncontrolled, Ss reported that the apparent location of the stimuli varied during the experiment. Finally, Ss complained that the response language allowed (field names: "one," "two," or "three") was not adequate to report everything they saw. The major

missing response dimension suggested by Ss was some indication of field brightness: Ss frequently saw areas that were about the size of one of the stimuli but which appeared gray or dark. Ss' criteria varied as to whether or not to report these. This suggested that if Ss had been instructed to report only those stimuli that seemed bright, the results might have provided stronger support for disinhibition theory than was found.

EXPERIMENT 2

The present study was done to clarify some parameters which could affect recovery of masked visual targets. Phenomenal reports of the Ss in Experiment 1 suggested that the retinal locus of stimulation and the response language might be important variables. Of particular interest is the assumption of the disinhibition theory that recovery is an effect of retinal interactions among adjacent stimulus-defined areas. If this is true, it is to be expected that for this set of stimuli, more recovery would be found in peripheral retina, where larger summation areas are found than in the fovea.

Method

Subjects. Two graduate students (one female) and a faculty member (peripheral presentations only) served as volunteer Ss.

Apparatus. Apparatus was the same as was used in Experiment 1, with the addition of a fixation point in a fourth channel of the tachistoscope. Stimuli were concentric on this dim red fixation in one condition, and they appeared 5 deg to the left of fixation in the other condition (5 deg in the temporal retina of the right eye).

Procedure. The procedure was similar to that used in Experiment 1. Ss were instructed to respond by telling the E which of the three fields were seen and were asked to give some indication of whether the fields appeared light, dark, or normal in brightness. Ss were repeatedly reminded to maintain fixation on the dim red fixation light. The light was a small red source at the same distance from the S as were the stimuli. Ss were unable to see the fixation point clearly unless it was accurately fixated (and thus accommodated). The S did not trigger a trial until fixation had been achieved. When a trial was triggered prior to achieving fixation, a rare occurrence, this was obvious to the S and the trial was rerun at random later in the session. Reliable differences between data taken with stimuli at fixation and 5 deg in the peripheral retina confirm that Ss were not maintaining a fixation bias at the locus of stimulation.

Results

Two separate analyses were done on correct detections, one for "light" and "normal" brightness responses and a second for total responses, including "dark" responses. These will be considered first for foveal and then for peripheral presentations.

Foveal presentation. When stimuli were presented at fixation, analysis of "light" and "normal" responses gave no indication of a test flash recovery effect at any interstimulus interval. Disinhibition theory predicts greater test flash detection in the three-flash condition when Mask 1 is itself suppressed. The small fraction of three-flash trials which show Mask 1 suppression also show perfect test flash detection, much as reported in Experiment 1. This "disinhibition" response contingency is seen to represent only 24%-31% of all responses in this condition. Since Case A explicitly tests a prediction of disinhibition theory, some support is derived from these data. However, what should be evident is that if only 30% of responses to the three-flash stimulus sequence are accounted for by this theory, not much predictive value is to be found in it.

Very little masking of any sort was observed under the stimulus conditions used. Mask 2 is almost completely incapable of masking the test flash at any interstimulus interval, used. As in Experiment 1, the total dark interval between the offset of test flash and the onset of Mask 2 is 45 msec longer than the tabulated ISI, value. This, however, cannot explain the small amount of masking of the test flash in test flash + Mask 1 presentations where both shorter interstimulus intervals and closer size similarity would tend to increase masking. With these stimuli, a U-shaped masking function is obtained with a minimum test flash detection of 69%. The U-shaped function is completely eliminated by inclusion of "dark" responses.

Two results are of particular importance. Under only one very restrictive analysis of the fixation data is a recovery effect found: the comparison of the Case A data with "light" test flash responses to test flash + Mask 1 trials. Even in this case, the magnitude of the differences in test flash detection are much smaller than was found in earlier studies. With inclusion of "dark" responses, these differences are even smaller. These results support the view that the foveal masking effects were in large part due to phenomenal reversal of brightness. Inclusion of "dark" responses showed that Ss were able to detect the stimuli presented. Under instruction sets which do not explicitly allow report of

"dark" stimulus perception, the S may choose not to make this response.

Peripheral presentation. With fixation maintained and the stimuli presented in peripheral retina, an apparent recovery effect was found when "light" and "normal" responses were scored. However, this "recovery" disappears when "dark" responses are included in the analysis. Wilcoxon matched-pairs signed-rank tests were calculated on test flash detection at each interstimulus interval, for the comparison between test flash + Mask 1 trials and test flash + Mask 1 + Mask 2 trials. Small differences seen in Table 1 are statistically not significant ($p > .05$ in all cases).

Examination of data for "light" responses to stimuli presented in peripheral retina reveals a very high proportion of false-positive test flash detections in the control condition Mask 1 + Mask 2 (Table 2). Data in Table 1 show that Mask 1 detection is low in the three-flash condition but moderately high in the Mask 1 + Mask 2 condition. These data indicate that differences in response content are clear between two-flash and three-flash presentations, but that within two flash trials, many confusions are made. The result may be due to reduced size-discriminability between test flash and Mask 1 in peripheral retina. This argument is supported by the false-positive Mask 1 detections seen in the test flash + Mask 2 control condition (Table 2).

Discussion

Disinhibition hypotheses require that Mask 1 be suppressed in a test flash + Mask 1 + Mask 2 stimulation sequence, i.e., Mask 2 must be a highly effective mask for Mask 1. The present data indicate that with centrally presented Mask 1 + Mask 2 stimuli, Mask 2 is almost completely incapable of masking Mask 1. This control condition is essential for independent assessment of this effect. Mask 1 is detected less often in three-flash presentations than in Mask 1 + Mask 2 presentations. This result might be attributed to forward masking of the test flash on Mask 1, but contrary to the present data, such an effect should decrease with increasing interstimulus interval. An alternative explanation might be based on phenomenal brightness reversal (e.g., Purcell & Dember, 1968). The data were examined to evaluate the possibility that the overall frequency of Mask 1 detections were the same in Mask 1 + Mask 2 and test flash + Mask 1 + Mask 2 presentations, but that the apparent brightness differed. Table 1 shows this to be the case; Ss report Mask 1 almost as often in the three-flash case as in Mask 1 + Mask 2,

Table 2
Averaged Percent of False-Positive Responses to the Indicated Stimulus Sequence*

Stimulus	Response	Experiment 1			Experiment 2					
		No Fixation			Stimuli at Fixation			Stimuli in Periphery		
		ISI-1			ISI-1			ISI-1		
		25	50	75	25	50	75	25	50	75
TF + M2	M1									
	Light	38	42	25	10	23	25	13	10	3
	Dark	—	—	—	23	17	10	17	27	40
	Total	38	42	25	33	40	35	30	37	43
M1 + M2	TF									
	Light	3	8	2	8	15	0	45	62	43
	Dark	—	—	—	2	0	0	0	0	4
	Total	3	8	2	10	15	0	45	62	47

but of different brightness; similar results are obtained for peripheral presentations.

In summary, the data show that Ss can report the test flash about equally often in test flash + Mask 1 presentations compared with test flash + Mask 1 + Mask 2 presentations in both the fovea and peripheral retinal presentations. These results suggest that recovery does not occur as a "disinhibition" phenomenon. Since increased test flash detection is found only for stimuli presented to the peripheral retina and then only with particular S criteria, Robinson's results can easily be explained. What seems to occur is that Mask 1 reverses the brightness of the test flash relative to Mask 1, with the result that the test flash is reported as dark. If the second mask is added to the stimulus sequence, the test flash is reported as appearing light, but Mask 1 is dark. Because Robinson (1966) did not employ a fixation point, there is no way of knowing where the stimuli fell on the retina, although the present data suggest that most of his presentations must have been peripheral.

GENERAL DISCUSSION AND CONCLUSIONS

The present data show that "recovery" presents no particular problem for either integration or interruption theories of masking. "Recovery" has been shown to be due to brightness reversal of stimuli which interacts with S criterion. Luminance summation of stimuli appears not to be a factor in this effect, and as such, the effect is not relevant to the integration theory of masking. Neither does "recovery" cause substantial difficulty for interruption theories,

since the effect does not conflict with any of the mechanisms or processes used in these theories to account for masking. The present study has shown that, for the most part, information about the stimulus sequence presented is available to the Ss but may not be reported. Failure to recognize "recovery" as a criterion-dependent effect may lead to unneeded concentration on pseudoproblems. The earlier work on recovery (e.g., Dember & Purcell, 1967) has been interpreted as indications of inadequacies of the major masking theories. Based on the evidence presented in this paper, "recovery" presents no theoretical problems for either interruption or integration theories. Although the Purcell and Dember model may have something to say about phenomenal reversal, it does not seem to apply to masking, except as reversal interacts with "true" masking effects.

Schurman and Eriksen (1969) presented stimulus sequences similar to those in the present study. Despite differences in stimulus parameters and procedure compared with the present study, these investigators were also unable to obtain "recovery" effects for central presentations of the stimuli. Among differences to be found in the present study and that of Schurman and Eriksen are stimulus sizes, heterogeneous luminance between stimulus fields, luminance levels and durations different from the present study, use of a low background luminance level, and temporal forced-choice response task. Together, their data and those of the present study cover a wide range of stimulus conditions and experimental demand characteristics with essentially the same results. Although the

results are similar, the conclusions drawn are quite different between studies: Schurman and Eriksen state that cues not related to "recovery," such as Mach bands and apparent motion, may have confounded recovery effects in their test. The present study has shown that recovery is not to be found in foveal presentations and that effects of stimulation described as "Mach bands" (p. 327) might be better interpreted as phenomenal reversals of brightness. Our Ss also noted an apparent movement effect, but the false-positive detection data (Table 2) show confusions between the test flash and Mask 1 which would not occur if the difference in apparent movement generated by these stimuli were reliable cues to the content of flash sequences. Differences in conclusions are, for the most part, in description rather than substance and should not obscure the agreement between these sets of data.

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NOTE

1. Robinson (1966) reported using field diameters of 0.28, 0.46, and 0.96 deg of visual angle, but in his 1968 paper, he reported diameters of 23, 46, and 93 min. The 1968 figures are correct (Robinson, personal communication, 1970). Other potential ambiguities in methods were also discussed and clarified with Robinson.

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