Backward masking, disinhibition, and hypothesized neural networks

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Backward masking, metacontrast, and disinhibition can be obtained under a variety of conditions. The mechanisms that underlie each depend, of course, upon the particular conditions responsible for the effects. Theoretical expositions seeking to explain phenomena produced by small brief concentric disks of light in the same terms as those necessary to explain effects produced by large displaced complex patterns of light are likely to be wrong.

In a recent article, Uttal (1970) reported a series of experiments which he considered to be germane to certain hypotheses regarding the mechanisms of backward masking and disinhibition. Specifically, he interpreted his results as evidence against the notion that lateral inhibition is responsible for a broad range of short-term interference phenomena in vision. The purpose of the present exposition derives from three considerations. First, the literature from which Uttal draws ostensible support is neither large enough nor as unequivocal as would be necessary for his argument to enjoy consensual validity. Second, there are aspects of his experimental procedures which tend to remove his findings from the theoretical domain in which he has located them.

In 1947, Crawford reported that absolute thresholds were elevated by immediately subsequent light flashes. A small disk of light had to be more intense to be visible when followed by a larger, brighter, and longer lasting concentric disk. Because this backward masking (not Crawford's term) occurred at interstimulus intervals as long as 150-200 msec, the phenomenon clearly was not photochemical in nature. Since Crawford's publication, the literature on backward masking has grown measurably and has revealed a steady diversification of methods. In fact, his increment-threshold technique has become almost a methodological rarity. Notwithstanding the commendable ingenuity of more recent investigators, however, it is important to recall that the basic and initial phenomenon of interest was altered sensitivity and not pattern recognition, letter identification, etc.

Crawford, of course, was not the first investigator to report retroactive influences in vision. I have cited a number of earlier papers (Robinson, 1968), many of which were written in the Gestalt tradition. Crawford's research was, however, the most rigorously controlled, the most quantitatively exacting, and certainly

one of the more theoretically specific. He advanced an "over-take" hypothesis according to which the second stimulus, by virtue of its greater intensity, gained representational priority over the weaker initial (test) flash. This concept of erasure or obliteration of the earlier signal remained intact in later and different investigations of backward masking (Averbach & Coriell, 1961; Sperling, 1960, 1963). The important addition to Crawford's early notions was that of a short-term (buffer) store in vision which allowed erasure only over a certain interval. According to this view, information in short-term visual memory is amenable to retroactive effects. Once the short-term store deposits the input into some longer term memory, such effects are not possible. It was principally in response to this hypothesis that I examined "disinhibition" (Robinson, 1966). The experimental paradigm involved three disk flashes, all concentric, and all of different angular subtense. It was found that a third flash, by masking the second flash, elevated the detectability of the first. In other words, since the masking of a mask served to "unmask" the first flash, it seemed unlikely that an erasure mechanism was involved. Again, because of the relatively long durations over which disinhibition was obtained, a central locus for the effect seemed probable. However, Mackavey et al (1962) had reported a disinhibition effect in a very different task and had related their results to the mechanism of lateral inhibition. Their study was of the metacontrast variety, i.e., multiple stimuli spatially displaced. In effect, it was a study of simultaneous contrast in which the phenomenal brightness of one target was reduced by the presence of a neighboring target. By introducing a third stimulus, Mackavey et al were able to "disinhibit" the test target from contrast suppression. Their metacontrast setting was analogous to conditions used to obtain neuroelectric inhibition and

disinhibition in *Limulus* (Ratcliff et al, 1963). Further research (Robinson, 1968) was then undertaken to determine the extent to which disinhibition under metacontrast conditions and disinhibition under backward masking conditions might be served by similar mechanisms. Specifically, it was necessary to determine whether interocular disinhibition could be obtained with a backward masking paradigm or whether the effect was intraretinal. The latter would provide inferential support for a lateral inhibition hypothesis. An experiment was conducted which employed both binocular and dichoptic viewing conditions. In the former case, both eyes received all three flashes. In the latter case, one eye received the test flash followed by the masking flash and the other eye received the third (disinhibiting?) flash. The results were as follows: (1) Weak interocular backward masking occurred (no surprise). (2) Test-flash detection was best when the interval between the second and third flashes was longest under the dichoptic condition. (3) Test-flash detection was best when the interval between the second and third flashes was shortest under the binocular condition.

In other words, interocular disinhibition did not occur, although backward masking did. In fact, given (2) above, it appears warranted to conclude that, under dichoptic viewing, there is interocular summation of masking effects. Thus, while central mechanisms contribute to backward masking, the effect of disinhibition was found to be exclusively intraretinal. Disinhibition in backward masking contexts has been confirmed by Dember and Purcell (1967) with letter stimuli, by Schiller and Greenfield (1969) with disk-ring stimuli, and by Mayzner (1970) with letters in a very imaginative experimental design.

The ultimate fate of explanations based upon lateral inhibition is, of course, not known. It does, however, enjoy tentative plausibility for several reasons. First, anatomically, there is ample provision for nearly any transretinal recurrent influence which may be warranted by psychophysical findings. Secondly, whether the experimental context is that of metacontrast or backward masking, the areal extent of the effect is highly circumscribed. This is true in *Limulus* as well as man. Neither metacontrast brightness suppression nor backward masking occurs when stimuli are presented to disparate retinal loci separated by more than 2-3 deg. Finally, the preponderance of information from studies comparing

Fig. 1. (a) Large circles form the letter N which is obscured by the insertion of smaller circles. The adjacent cluster (b) constitutes the disinhibition condition. Larger circles are delivered to the same place as the smaller occupy in (a). The question is whether the backward masking of the small circles by the larger ones leads to an enhanced recognition of N.

monocular or binocular with dichoptic viewing suggests that the major source of interference is intraretinal (1) when stimuli overlap or are very close, (2) when the task measures sensitivity, and (3) when the target geometries are simple. This is not to suggest that intraretinal effects dominate *only* under these conditions but that, under these conditions, *only* intraretinal (noncentral) influences are paramount.

Uttal's paper (1970) begins with the statement that, while lateral inhibition is a viable mechanism for spatial interactions of a limited sort, evidence argues against its use in explaining temporal interactions. To support this point, he goes on to say that, "... masking situations are not reflected by single cells (Schiller, 1968), and that dots do not exhibit lateral inhibiting properties (von Békésy, 1968) [p. 321]." The fact is that one of Schiller's principal findings is "... that the responses of ON center units in the LGN parallel the effects typically obtained behaviorally in masking [p. 863]." In fact, his single-unit recordings also show neural suppression under metacontrast conditions, although the frequently reported U-shaped function was not obtained; i.e., diminution of impulse rates from LGN units was found to be a monotonic rather than a U-shaped function of interstimulus interval. Moreover, although von Békésy reported a reduction in one type of inhibition when point stimuli are widely separated (1968, p. 1496), his paper provided no justification for Uttal's generalization that "... dots do not exhibit lateral inhibiting properties ..."

Uttal reported several experiments intended to elucidate the physiological mechanisms of masking. His method

involved the presentation of a random array of dots at varying intervals after the presentation of a letter of the alphabet formed by a dot pattern. The letter appears in a noise-free rectangular space, and the dots are arranged around it. In this setting, Uttal found that masking is essentially impossible when target and mask are separated by as great a spatial extent as he employed. Letters were correctly identified nearly all of the time at each interstimulus interval. He concluded, with many other investigators, that noise must overlap targets if it is to mask them. He did not cite Fehrer (1966), who not only used similar stimulus materials, obtained similar results, and concluded (as Uttal did) that masking increases with overlap and form similarity, but who, in addition, cited lateral inhibition as a possible mechanism for the effect. Indeed, given Uttal's Fig. 2 (p. 323) and the geometry of his stimulus display, the case for lateral inhibitory processes is enhanced.

In his second experiment, Uttal attempted to obtain disinhibition with the same displays. He is not clear in distinguishing between methods used in his first and second experiments. Thus, since he failed to obtain masking in Experiment 1 and since he is not clear in stating the methodological differences between 1 and 2, I cannot ascertain what could be disinhibited in 2. Nonetheless, something was different, because his Fig. 3 does show backward masking. And yet, while his 100-dot noise pattern does reduce letter identification, a subsequent 100-dot noise pattern fails to restore it. Of course, in order to "disinhibit" the letter, the second noise burst would have to mask the first and, using Uttal's complex displays, it is not apparent how this could be determined. That is, one does not know whether Uttal has failed to obtain disinhibition or whether dot patterns of noise fail to mask dot patterns of noise. A test of the alternatives could be based upon the arrangements given in Fig. 1. Here, the letter N is obscured by the insertion of dots into the target space, not around it. However, the noise consists of smaller dots than does the signal (Pattern a). Pattern b consists of dots larger than the noise elements and occupying the same retinal loci as the earlier occurring noise. Presumably, an interval exists at which b masks the noise in a and thereby restores detectability. However, given the very small spatial domain in which backward masking and disinhibition can be expected, even this arrangement is less than ideally suited to studies of lateral inhibitory processes.

In his third experiment, Uttal

compared monocular, binocular, and dichoptic viewing in relation to noise-reduced letter identification. Again, it is not obvious how this experiment differs from the first one in which masking was not obtained. He finds, however, that the monocular and binocular conditions result in similar effects, which are greater than those produced under dichoptic conditions. He considers the differences small but does not indicate whether he means by "... do not differ significantly [Fig. 4 caption, p. 324]" that the differences were not statistically significant or that they just didn't seem significant. In any case, they differ enough for Uttal to recognize "... that there may be some lesser peripheral masking effect ... [Fig. 4 caption, p. 324]." Since the data are described in terms of percents of the total detected, there is the added difficulty of not knowing whether or not the absolute detection rates were the same under the three viewing conditions. Setting this otherwise important point aside, one still wonders whether Uttal would accept a lateral inhibition model to account at least for the small (?) monocular-binocular contribution. Furthermore, given the typically enormous differences between monocular and dichoptic effects in traditional studies of backward masking, one is tempted to conclude that Uttal may not be studying backward masking at all. I find this possibility the most important product of his paper unless, of course, the effect turns out to be just a special example of binocular rivalry.

In his last experiment ("... a set of informal observations ... [p. 324]"), Uttal joins many other workers in reporting the dependence of backward masking upon the similarity of target and mask. According to Uttal, this not only "... precludes simple network models of masking [p. 325]" but suggests "... processes at the highest levels of cognitive function ... [pp. 325-326]." With respect to the first contention, I would agree enthusiastically that while backward masking phenomena lend themselves to relatively simple models, the kinds of effects studied by Uttal do not. Theoretical expositions that seek to explain effects produced by small brief concentric flashes of light in the same terms as those resulting from large, long-duration, laterally displaced complex forms will probably be wrong. The appeal of the lateral inhibition model resides in the fact that (1) it exists in nature, (2) it performs a job analogous to that observed in certain psychophysical settings, and (3) it does not violate the kinds of findings obtained under conditions in which one would expect

to find it operative. If, on the other hand, I understand at all what Uttal means by "cognitive," then settings which require cognitive functions are the very ones in which the role of a process such as lateral inhibition, at least retinal lateral inhibition, would be small. Of course, at every "level" of neural organization—including those which underlie "cognition"—neuroinhibitory and neurofacilitatory processes surely are involved. Notwithstanding the validity of such general impressions, it would seem premature for psychophysicists or cognitive psychologists to debate what Uttal called "the physiological basis of masking." Before specifying its basis, I think we should agree on its meaning.

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