Does backward masking by visual noise stop stimulus processing?

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The identification of one, two, and four random letters was studied under three procedures: (1) backward masking by a visual noise; (2) concurrent masking by a visual noise; and (3) no masking. With backward masking the number of letters correctly identified was independent of the number presented. Direct judgments of the duration, brightness, contrast, sharpness, and texture of the letters were also made. Under backward masking the letters appeared to be on for a very brief duration, but with high apparent contrast. The results indicate that backward masking impairs identification by interrupting the stimulus processing, not by degrading the stimulus input.

When a brief visual stimulus is followed by visual noise of similar luminance (one type of backward masking), identification of the stimulus may be considerably impaired (Averbach, 1963; Liss, 1967; Schiller & Wiener, 1963; Sperling, 1963, 1967). According to one interpretation, the mask of visual noise that follows the stimulus somehow degrades the stimulus input, perhaps by luminance summation (Eriksen & Steffy, 1964). According to another interpretation, the processing of the mask somehow stops the processing of the stimulus (Sperling, 1963).

In order to investigate the two hypotheses, it seemed advisable to compare the effects of backward masking with those of a procedure that reduces stimulus clarity without affecting processing time. If backward masking simply degrades the stimulus input, the two procedures should produce similar effects, but if backward masking stops stimulus processing, the two procedures should produce qualitatively different effects.

The simultaneous presentation of the visual noise and the stimulus (concurrent masking) provides an interesting comparison with backward masking. The luminance ratio between the stimulus and the mask would presumably affect the clarity of the stimulus, but would not seem to affect the amount of processing time available. Furthermore, any specific effects produced by the particular mask should be common to the two situations.

When no mask is used, the clarity of the stimulus can be altered by decreasing the stimulus duration below some critical value without changing its physical intensity. The question remains open, however, whether the time available to process the stimulus is also reduced by such a procedure. If it is found that backward masking stops stimulus processing, then the question arises whether the effects of stimulus duration resemble more closely those of backward masking or concurrent masking.

In the present experiment, backward masking, concurrent masking, and no masking were compared for their effects on the identification of one, two, and four random letters. How such procedures influence the apparent duration, brightness, contrast, sharpness, and texture of the letters was also examined.

METHOD

Four female undergraduates from the Harvard summer school served as Ss. Two Ss sat together in a dark room 5 ft from a dimly illuminated screen. They observed images projected by a three-field projector tachistoscope which was located on the other side of the screen in a well-lit room. One field was for a warning light, one for the stimulus, and one for the mask. Slides were made from high-contrast negatives of capital letters typed with a plastic ribbon. The letters appeared white on a dim grey background. The luminance of the letters of the stimulus was kept constant at 1.1 mL for all conditions, and the contrast ratio of the letters to the background was 1.0 to 0.13.

The stimuli were one, two, or four random letters presented in a horizontal row; vowels and the letter Y were never used. Each letter was .42 deg high in visual angle, and adjacent letters of the stimulus were separated by a space of .25 deg. The mask consisted of three long rows of Os superimposed on identically-sized Ns, as in ⊠. Adjacent letters of the mask were separated by only .05 deg. The middle row of the mask typically covered the area of the letters. The other two rows prevented slight variations in the positioning of the letters on the slides from having any perceptible effect. This mask of Os and Ns was selected because, compared to others which were tried, it produced the clearest impression of stopping the perception of letters presented prior to it.

All Ss had previously participated in an eight-day experiment on numerosity estimation, which familiarized them with the backward masking, concurrent masking, and no masking procedures. Two days of practice in identifying random letters under various testing procedures preceded the presented formal study. The exact tests used in the main experiment were determined by the results of these practice days.

A small warning light presented 1 deg above the stimulus areas always preceded the stimulus by 700 msec. In the four tests with backward masking, the stimulus was presented for either 30, 40, 50, or 70 msec and was followed without delay by the mask for 500 msec. (Further experiments indicated that, given sufficient stimulus energy, most perceptual effects are controlled by the onset-onset time between stimulus and mask rather than by the duration of the stimulus.) The luminance ratio of stimulus to mask was always 1.0 to 1.25. In the two tests with concurrent masking, the stimulus and the mask were presented simultaneously for 100 msec, and the luminance ratio between the stimulus and mask was either 1.0 to 0.53 or 1.0 to 0.37. In the two tests with no masking, the stimulus was presented alone for either 7 or 9 msec.

The eight tests were presented in a random order, each given once. Each test consisted of five trials with one letter, then five trials with two letters, then five trials with four letters. Different letters were used on each trial. The Ss knew in advance the number of letters to be identified, and they were told that vowels and Y were not to be reported. Responses were written. Letters were counted as correct only if correctly identified in their exact position.

The day after completion of the formal experiment, judgments of the duration, brightness, contrast, sharpness of line, and textural detail of the letters in the various experimental conditions were made by the method of successive comparison. The Ss were presented with one or more letters in one experimental condition, and then within a few seconds they were presented with the same stimulus in another condition. They had to judge which of the two images was of longer duration, brighter, of greater contrast, sharper in edge, and finer in texture.

RESULTS

Since the four Ss gave quite similar results, combined data are presented. Figure 1 shows that when one or two letters were presented under backward masking, the number of letters correctly identified was either at the maximum of one or two or almost equal to the number identified when four letters were presented. These results confirm Sperling's (1963) striking find that the number of letters correctly identified is essentially independent of the number presented.

In order to test whether the results with background masking are caused by degradation of the stimulus input or by an interruption of stimulus processing, it is necessary to compare them with the effects of concurrent masking. It is assumed that concurrent masking degrades the input without significantly influencing stimulus processing time. Figure 1 shows that with a

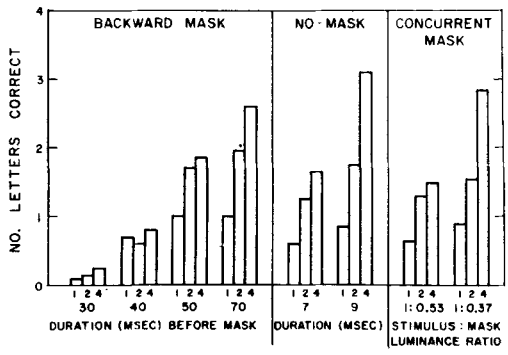

Fig. 1. Mean number of letters correctly identified as a function of the testing procedure and number of letters presented (1, 2, or 4). With concurrent masking, the duration of the stimulus and mask was 100 msec.

luminance ratio between the stimulus and mask of 1.0 to 0.53, stimulus clarity was quite poor. When only a single letter was presented, correct identification did not always occur. Yet, in contrast to the backward masking test in which the letters were presented for 40 msec, there was apparently enough processing time for correct identification of more than one letter when two or four were presented. When the luminance ratio was 1.0 to 0.37, stimulus clarity was still poor enough to prevent the perfect identification of two letters when two were presented. Yet, in contrast to the backward masking test in which the letters were presented for 50 msec, processing time was long enough so that almost three out of four letters were correctly identified.

The results with no masking (Fig. 1) are much more similar to those with concurrent masking than to those with backward masking.

The direct judgments of the duration, brightness, contrast, sharpness, and texture of the letters gave the following results. All Ss agreed that:

1. (a) With backward masking, the letters of the stimulus appeared for only an extremely brief duration when presented for 30 msec. (Pilot work indicated that letters could not be seen at all if presented for 20 msec and followed immediately by a mask.) (b) The letters increased in apparent duration as the duration of the stimulus before the onset of the mask increased. (c) The letters appeared for a briefer time when presented for 70 msec with backward masking than for even 7 msec with no masking. (A more exact measure of image duration with backward masking is provided by Sperling, 1967.)

2. The letters appeared much brighter when presented for 40 msec with backward masking than when presented for even 9 msec with no masking. There was little change in letter brightness as the stimulus duration before the onset of the mask increased from 40 to 70 msec. When presented for 30 msec, the letters appeared so briefly that brightness judgments were difficult to make.

3. With concurrent masking, although the letters appeared quite bright, they were hard to distinguish from the superimposed mask. (Pilot work showed that when the luminance ratio between stimulus and mask was made unity, the letters could rarely be detected.) With backward masking, the letters were seen on a dark background with the mask following. Thus, the contrast between stimulus and background appeared considerably greater with backward than with concurrent masking.

4. The letters appeared both sharper and more finely textured when presented for 40 msec with backward masking than when presented for 9 msec with no masking. Both the sharpness of the lines and the fineness of texture increased as the stimulus duration before the onset of masking increased from 30 to 70 msec. This increase in sharpness and texture seemed to be the result of parallel processing, since it was observed for all the perceived letters in a four-letter array, including both those that were and those that were not confidently identified.

DISCUSSION

The present results indicate that the effects of backward masking by visual noise are very different from the effects of procedures that simply degrade the stimulus input. With backward masking, the number of letters correctly identified was essentially independent of the number presented, while concurrent masking and no masking produced qualitatively different results.

The results with backward masking support Sperling's (1963) conclusion that, at some stage in the act of stimulus identification, random letters are identified serially at the rate of about one letter per 10 msec, at least for the first two letters. Three qualifications to this conclusion should be mentioned. First, there is some indication that, for some Ss, backward masking increases the normally negligible tendency for letters to be correctly identified but placed in the wrong position. Thus, a simple interpretation in terms of serial processing has to be somewhat modified, in that even with only two or four letters, some identity determination may occur prior to determination of the exact spatial position. Second, a further experiment indicated that the rate of letter identification may increase to about three letters per 10 msec for the first six letters if familiar words with which the Ss had previous tachistoscopic experience are used. In that case, the Ss were asked to write down a letter only if it was clearly seen as that letter. Third, Sperling (1967) has shown that, near the threshold for letter detection with backward masking, an increase in stimulus duration of 10 msec produces an increase in apparent duration of much more than 10 msec. If the apparent duration is a direct index of the amount of stimulus processing time, then all estimates of the rate of letter identification must be changed accordingly.

The results with no masking and concurrent masking were strikingly similar. Apparently, when no mask is used, varying the duration of the stimulus near threshold greatly influences stimulus clarity without having much effect on the available processing time.

The direct judgments of the brightness, contrast, sharpness, and duration of the letters further confirm the view that backward masking stops stimulus processing. For example, letters presented for 40 msec with backward masking (less than one out of four letters correctly identified) were judged to be brighter and sharper than those presented for 9 msec with no masking, and to have greater contrast than those under the luminance ratio 1.0 to 0.37 with concurrent masking. Approximately three out of four letters were correctly identified in the latter two conditions. Thus, reduced stimulus clarity does not appear to account for the poor letter identification observed with backward masking.

The Ss commented spontaneously that, despite the high contrast of the letters presented under backward masking, they seemed to appear for such brief duration that there was very little time to identify them before the mask appeared. Although letters presented for only 7 msec with no masking appeared weak and fuzzy, their duration seemed longer than letters presented for 70 msec followed by a mask.

Even if we accept the view that backward masking stops stimulus processing, it is still not clear at what stage the disruption occurs. In order to distinguish the possibilities, we may divide the act of stimulus identification into the following stages: stimulus input, pre-image processing, development of the image, conversion of the image into a form available to memory, memory, and response. Various explanations localize the point of disruption by the mask at different places in this temporal sequence. The view we have rejected states that backward masking degrades the stimulus input. It is still possible, however, that the mask stops the pre-image processing, the development of the image, or the conversion of the image into a form available to memory.

According to the last view, some attentional process is considered necessary to convert an image into a form that is available to memory. Since backward masking greatly shortens the image duration, perhaps this conversion of image to memory is stopped. Sperling (1967) has suggested that the visual image is converted by some scanning process into a nonvisual memory, such as an intention to speak. Another version of this theory,

based on the probable disruption of the identification of nonverbalizable forms by backward masking, would be that the mask stops the conversion of a short-term visual image into a visual memory.

The theory that the conversion of image to memory is stopped seems to predict that the mask should have no effect whatsoever on the clarity of the stimulus image. Such was not the case: (1) With stimulus durations of 20 msec or less, the stimulus was completely invisible. (2) As the time between stimulus and mask onset increased, stimulus clarity also increased in that the letters were judged to have sharper outlines and finer texture. Thus, although there may be some validity to the "stopped-conversion" interpretation, it does not provide a complete explanation of the effects of backward masking.

A possible alternative view is based on the microgenetic assumption that the image of a stimulus gradually increases in specificity before decaying. Perhaps, by shortening the image duration, the mask stops this development of the image. McDougall (1904) has shown that the microgenetic assumption is false if applied to brightness, since it is the most advanced part of a moving image of a constant-intensity moving slit that appears brightest. Also contrary to the assumption, the present Ss judged that the texture of the letters does not seem to increase while the image is being seen, but rather is at a maximum the first moment the image appears (see also Efron, 1967). The mask cannot stop the development of an image if the image does not gain in clarity after it first appears.

Owing to the inadequacies of the foregoing views, we may seriously consider the view that the mask stops the pre-image processing. In this case, the relevant events are assumed to be those that occur after retinal stimulation but prior to the appearance of the image. A detailed version of this theory would have to distinguish between: (1) the total time between retinal stimulation and image construction, which is probably not affected by the mask; and (2) the effective processing time which is controlled by the mask.

Since the Ss reported that the stimulus totally disappeared just as the mask appeared, it may be fair to assume that the mask stopped the effective processing of all aspects of the stimulus simultaneously. Under this assumption, the present data would indicate that (1) interrupting pre-image processing decreases the image duration; (2) random letter identification occurs during the pre-image processing period in a primarily serial fashion; and (3) the different aspects of the stimulus require different processing times to achieve maximum specificity. For example, determination of stimulus brightness appears to require less processing time than determination of fine textural detail. Differences in the critical duration for brightness and acuity (Kahneman & Norman, 1964) seem to support this conclusion. However, critical duration is not necessarily equal to pre-image processing time.

A possible reason why backward masking may interrupt the processing of the stimulus is suggested by the effects of different kinds of masks. Tests with a variety of masks indicate that backward masking disrupts stimulus identification to a greater degree the more the line thickness and the general form qualities of the mask resemble those of the stimulus. It appears that backward masking stops stimulus processing whenever the spatial analysis of both the stimulus and the mask requires the use of the same central mechanisms. An effective mask may stop stimulus processing by preempting a central system that has not yet finished analyzing the stimulus. With the less disruptive mask, the spatial analysis of the stimulus and the mask may be accomplished in parallel by different neural systems. Support for this interpretation may be found in the fact that, with the effective mask, the stimulus seems to disappear just as the mask appears, while with the less disruptive mask, the stimulus typically appears "through" the mask.[2]

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NOTES

1. Present address: City College of the City University of New York.

2. This research was supported by Grant No. PO1-MH-12623 from the National Institute of Mental Health to Harvard University, Center for Cognitive Studies.

(Accepted for publication March 20, 1968.)