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Lee S. Cohene
University of Iowa

Harold P. Bechtoldt
University of Iowa

Some Temporal Factors in Visual Pattern Recognition. II

LEE S. COHENE and HAROLD P. BECHTOLDT[1]

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Pairs of random dot patterns in which the patterns of each pair formed bigrams when superimposed were used to investigate the hypothesis that the temporal integration of visual patterns reported by Eriksen could be extended toward the longer time scale used in studies of eidetic imagery. An integration theory suggests that when the dot pattern stimuli are temporally separated, the neural trace arising from the first pattern must be combined with the second pattern for a verbal recognition to occur. However, the unexpected results of the present study indicated that a first dot pattern of 1, 3 or 5.4 sec. duration was not integrated with a complementary second dot pattern of 2 sec. unless the pair of patterns were overlapped in time. The duration of the overlapped exposure times required for recognition was five to eight times longer than the time required for recognition with simultaneous onset and offset of the same dot patterns. Suggestions as to the source of the serious interfering or masking effect in the integration process are discussed.
INDEX DESCRIPTORS: Eidetic Imagery, Iconic Memory, Visual Masking, Visual Recognition.

Backward and forward masking are terms used to denote an impairment in the perception of a target stimulus when that stimulus is closely preceded or followed by a second stimulus (the mask). Strong support for an integrative process associated with the phenomena of backward and forward masking in visual perceptual tasks has been provided by Eriksen and Collins (1967, 1968). This integrative process has been investigated with pairs of temporally separated dot pattern stimuli such that the neural trace, or icon (Neisser, 1967), arising from the first pattern must be combined with the neural activity of the second pattern for a verbal recognition response to occur. The two dot patterns when combined by superimposition form an easily recognized nonsense syllable (see Figure 1). As reported recently by Eriksen and Eriksen (1971), the neural trace decays at a sufficiently slow rate to allow measurable integration of the two neural representations over a range of 100 to 150 msec., and possibly to 350 msec.

According to Eriksen (e.g., Eriksen and Rohrbaugh, 1970) masking occurs because the combination of a second stimulus with the trace from a first stimulus usually forms a pattern too complex for recognition. However, when the stimuli complement each other, as in the above-mentioned dot pattern experiments, integration permits recognition of the display. Sperling (1963, 1967) has suggested erasure by the masking stimulus. However, an erasure interpretation is not consistent with the syllable-recognition results obtained in the Eriksen studies (Eriksen and Eriksen, 1971).

A visual retention demonstration also using dot pattern stimuli but with temporal separations which far exceeded the short times used by Eriksen and Collins was reported by Stromeyer and Psotka (1970) using Julesz-type stereograms (Julesz, 1964). A Julesz stereogram in simplest form consists of two dot patterns, each containing a 100 x 100 cell matrix with each cell randomly filled in or left blank. These patterns, one presented to each eye, are identical except for a chosen region, usually square, which is shifted laterally a few cells

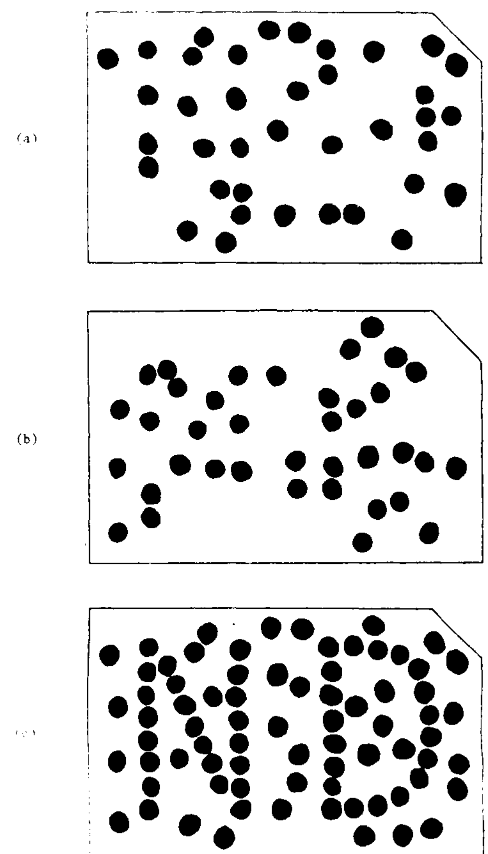

Figure 1. Two complementary dot pattern stimuli (a, b) which form a recognizable bigram composite (c) when one dot pattern is superimposed on the other.

[1] Department of Psychology, The University of Iowa, Iowa City, Iowa 52242.

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in one pattern relative to the other. Viewed by itself each pattern appears to have a random flat texture with no form or depth, but viewing the two displays together in a stereoscope results in a square easily seen in depth. Random dot patterns of this type were retained over a time interval of three days and then successfully integrated with their complementary halves to form the stereograms. This long visual retention performance was described by Stromeyer and Psotka as a demonstration of eidetic imagery.

The results of other studies of eidetic imagery, as reported by Leask, Haber and Haber (1969), suggest that a reasonable proportion of the population might retain visual nonverbalized impressions at least for as long as several minutes. The differences between the 100 to 350 msec. retention interval of Eriksen and Collins (1967) and the longer retention period of several minutes reported by investigators of eidetic imagery seem worthy of further study. The three studies reported here represent an investigation into the effects of certain temporal and experimental conditions that may be responsible for creating these differences.

The choice of stimuli for these studies was considered critical. The stimuli used by Eriksen and Collins (1967, 1968) included either black dots on a white background or white dots on a dark background; similar sets of the former type were used in eidetic imagery experiments by Stromeyer (1970). In order to reduce the effects of contour interaction and of possible verbal storage processes (i.e., to prevent verbal processing prior to visual integration), the stimuli chosen for the present studies were composed, like those of Eriksen and Collins and of Stromeyer, of nonoverlapping patterns of black dots on white grounds. The stimulus pairs formed letter bigrams of the type shown in Figure 1 when both dot patterns were presented simultaneously.

In a pilot study designed to set the stimulus time parameters for the main investigation, the results were entirely inconsistent with those reported by Eriksen and Collins (1967). No subject was able to recognize any of the bigrams when a dot pattern (S_1) of 1, 2, 3 or 4 sec. duration was followed after a delay of some milliseconds by a second, complementary dot pattern (S_2) of 2 sec. (Figure 2a). Recognition did not even result when the delay between S_1 offset and S_2 onset, or interstimulus interval (ISI), was reduced in successive stages to zero (Figure 2b). The stimulus presentation times were then overlapped (Figure 2c) so that concurrent presentation of S_1 and S_2 ensued. The criterion measure for recognition was then the time of overlap of the two patterns required for a correct response. This procedure utilizes a masking-type paradigm of concurrent presentation of the patterns but with asynchrony of onset and of offset of the two dot patterns. An additional paradigm utilized simultaneous presentation of the two patterns with coincidence of onset and offset (Figure 2d) as in a common tachistoscopic recognition task.

EXPERIMENT 1

The first *experiment* was concerned with estimating the time required for a recognition response using the concurrent paradigm but with asynchronous onset and offset of S_1 and S_2.

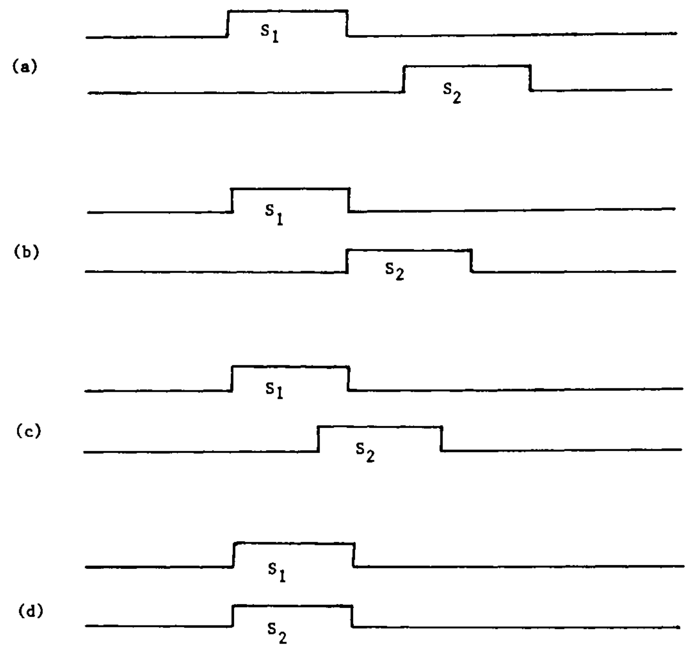

Figure 2. Presentation of two dot pattern stimuli (S_1, S_2) using four different paradigms to obtain bigram recognition: (a) S_1 and S_2 temporally separated, (b) zero ISI, (c) S_1 and S_2 overlapped for concurrent presentation and (d) S_1 and S_2 simultaneously presented.

Method

Stimuli and apparatus. An attempt was made to set the experimental conditions intermediate between those of Eriksen and Collins (1967) and of investigators of eidetic imagery. Eriksen and Collins tachistoscopically presented stimuli that subtended only 1° to 2° of visual angle, whereas the stimuli in the eidetic imagery investigations ranged from 7° arc (Stromeyer and Psotka, 1970) to 34° for some *Ss* in the Leask, Haber and Haber (1969) investigations. Also, Eriksen regularly used tachistoscopic exposures of his stimuli with no possible visual distractions, whereas room lighting and card or projector presentations are used in eidetic imagery studies.

For the present experiment the patterns subtended 26.2° of visual angle in width and 17.3° in height; the stimuli were made sufficiently large so they would require scanning by *Ss* using either actual eye movements or conceptual shifts of attention. Each dot pattern was drawn in India ink within a space of 125 x 200 mm and was photographically reduced to 12 x 20 mm dimensions on positive high contrast 35 mm transparencies. These transparencies were mounted in Stereo Realist slides for projection by a modified Compco Stereo 500 projector. The modification consisted of replacing the original bulbs with General Electric 30-watt BLC film viewer bulbs; control of the exposure durations was by solid state circuitry. The separate dot patterns contained from 36 to 42 dots of 1 mm diameter as photographed. Four practice slides formed the pairs of letters *ND, FC, OK* and *BN*. Six test slides contained the letters *MB, DV, KS, SM, CH* and *HO*.

The dot patterns were projected onto a rear projection

Polacoat screen 50 cm in front of S. The room lights provided 2.3 f.c. at the location of S, as measured by a Weston Model 756 light meter. At the point of S's eyes, the light transmitted by one projector alone was 1.1 f.c.; it was 1.2 f.c. with both projectors together. These light values were selected to reduce afterimages and apparent motion effects while maintaining adequate stimulus contrast.

Subjects and procedure. One conspicuous difference between the Eriksen and Collins (1967, 1968) studies and the eidetic imagery studies involves the duration of the initial presentation of the entire stimulus or of the first dot pattern. Whereas Eriksen and Collins used 6 or 25 msec. for each stimulus exposure, the initial presentations for eidetic imagery required from 30 sec. (Leask, Haber and Haber, 1969) to several periods of 3 min. each (Stromeyer and Psotka, 1970). In the present experiment an intermediate range of 1, 3 and 5.4 sec. was chosen for the duration of the first dot pattern, S_1, of a pair. The exposure time for the second dot pattern, S_2, of a pair was held constant at 2 sec.

In the fall semester 24 Ss from an elementary psychology class were randomly assigned to one of the three treatment groups with eight cases per group. A second sample of 24 Ss from a similar course was obtained in the spring semester and was assigned to the same treatment groups to establish the stability and generalizability of the fall semester results.

Each S was given a brief instructional period with the four practice slides wherein each bigram was presented with increasingly smaller ISI and increased overlap until recognition occurred. Then S was presented with the six test bigrams, these presentations involving the two dot patterns of each slide being presented for the specified times but with the ISI being determined by S's performance on the practice bigrams. The ISI for a given S on the first test trial was either 300 msec. (the approximate maximum observed by Eriksen and Collins, 1967), or a reduction of 300 msec. from the *minimum* overlap time found necessary for recognition on the practice slides, whichever was less. The overlap in exposure of the two dot patterns was then increased (or the delay was decreased) by 90 msec. steps from the starting value until Ss correctly recognized the two letters on two successive trials at the same exposure times. This procedure is similar to the ascending order of the psychophysical method of limits.

All test slides were presented at one ISI value before a change in ISI was introduced. On successive sets of slide presentations, the order of the two dot patterns, S_1 and S_2, forming a bigram was alternated so that S_1 and S_2 were each presented as the first pattern half of the time. When S reported correctly the two letters of a given bigram, the pair of dot patterns was then presented with S_1 and S_2 reversed at the end of the "trial" before a change was made in the exposure times.

When the letters of a given bigram were correctly recognized on the second successive presentation, the slide was removed from the set without informing S. No information or feedback was given to Ss regarding correct or error responses. A list of the 11 letters used in the stimuli was placed in front of Ss during the presentation of the practice and test stimuli. Subjects were told that two different letters were used for each bigram. The response system used was a verbal recognition report like that used by Eriksen and Collins (1967, 1968) and Stromeyer and Psotka (1970).

Results

The mean amount of overlap (concurrent exposure time) for each group in the fall and spring samples is shown in Table 1. The two mean concurrent times for the 24 cases in the fall and spring semesters were 260.3 and 281.9 msec., respectively. Every subject required some amount of overlap of every slide for a correct recognition response. An analysis

TABLE 1. MEAN AMOUNT OF CONCURRENT EXPOSURE TIME (IN MSEC.) FOR RECOGNITION OF SIX TEST BIGRAMS USING A SUCCESSIVE METHOD OF PRESENTATION WITH RANDOM SELECTION OF SLIDES AND THREE LEVELS OF DURATION OF S_1.

	S_1 Duration		
Semester	1 sec.	3 sec.	5.4 sec.
Fall	256.0	275.6	249.4
Spring	271.9	264.4	309.4

of variance of these data indicated that only the times for individual slides would be considered significant ($F = 12.50$, d.f. $= 5, 210$). Neither the variation in S_1 duration nor the semester replication, nor any of the interactions, showed any significant effects. The results indicate that with these exposure durations and stimuli, a concurrent (overlapping) presentation of about 270 msec. was required for recognition; these values can be clearly contrasted to the integration of dot patterns over a delay interval of at least 100 to 150 msec. reported by Eriksen and Collins (1967) and the retention of dot patterns over a period of 24 hours by the one S studied by Stromeyer and Psotka.

EXPERIMENT II

Informal observation in the pilot study indicated that when the two dot patterns were exposed simultaneously with coincident onset and offset (Figure 1d), the time required for recognition of the stimuli was only about 25 to 40 msec. This would suggest that the relatively long recognition times of Experiment I were obtained because of some serious interfering effect on the integration of the neural trace of the first dot pattern with the second dot pattern. Experiment II was designed to determine more precisely the recognition time of the dot stimuli under simultaneous presentation methods. Since data related to differences in the method of presentation were needed as a basis for further work, two different procedures for presenting the stimuli in a simultaneous manner were used.

Method

Stimuli and apparatus. The stimuli and apparatus were precisely the same as described for Experiment I.

Subjects and procedure. Two groups of 10 Ss each, obtained from the spring semester elementary psychology course, were assigned to the two procedures used. The data were collected first with a repeated presentation procedure (Haber, 1967) and then with a random presentation procedure. A criterion of only one correct response was used instead of the two successive correct responses as in Experiment I.

For the repeated presentation procedure each slide was first exposed for 18 msec., a value suggested by pilot data to be too short for a correct response; on the second and subsequent presentations the stimulus duration was increased successively by 1 msec. steps for the particular slide until S reported the two letters. The next slide was then introduced. The time interval between repeated presentations of the same slide was 5 to 6 sec. Haber (1967) has indicated that this procedure improves the perceptual recognition process by reducing the threshold below that reported for the random procedure.

In the random presentation procedure all slides were exposed for a given duration before the time was increased. The term "random procedure" indicates that the order of slides shown at any one time interval was random. This procedure is more time-consuming than the repeated procedure, and so fewer trials were employed, with a greater step size for increases in duration. The starting bigram duration was also lowered because of the larger step size. All slides were shown first for a 15 msec. duration; increases in the subsequent time intervals were in 5 msec. steps. The interval between slide presentations ranged from 20 to 30 sec.

Results

The mean recognition time for the first correct response on the six test slides using the repeated presentation procedure was 29.8 msec.; the mean recognition time for the random presentation procedure was 33.9 msec. for the same criterion. The difference in recognition times favoring the repeated presentation over the random procedure is significant ($F = 10.41$, d.f. = 1, 18). This difference may be due to the change in interpresentation intervals from 5 to 6 secs. for the repeated procedure to 20 to 30 secs. for the random procedure; however, the difference may also arise from the fact that the 1 msec. increments in the repeated group may have provided more precise results than the 5 msec. increments in the random group. As in Experiment I, the times for individual slides were significant ($F = 4.81$, d.f. = 5, 90). The slide by method-of-presentation interaction was not significant.

The main finding is clear: *simultaneous* presentations of these slides with identical onset and offset times, whether with the repeated or random presentation procedure, provide recognition times for dot patterns that are of the same order of magnitude as generally reported for tachistoscopic presentations using comparable stimulus parameters.

A comparison of the results of experiments I and II indicates that the recognition times with the overlapping (concurrent) but asynchronous paradigm were seven to eight times slower than those observed with simultaneous onset and offset when the random presentation procedure was used. In order to make the same comparison for the repeated presentation method, an additional group of eight Ss was tested following the main part of Experiment II. The purpose was an appraisal of the performance of these Ss at one of the exposure time conditions of Experiment I (overlapping paradigm) when the repeated presentation procedure was used. The $S_1 = 1$ sec. condition was selected; the stimuli and apparatus remained the same as in Experiment I.

The data obtained from this additional group also permitted a comparison between the repeated and random presentation procedures for the overlapping paradigm. The repeated presentation procedure with a mean recognition time of 171.5 msec. provided faster recognition ($F = 21.98$, d.f. = 1, 14) than did the random presentation procedure with a mean recognition time of 263.9 msec. However this procedural effect does not change the main result of interest. The asynchronous concurrent recognition times appeared to be five to six times slower than the simultaneous recognition times observed with the repeated presentation procedure. This is just slightly less than the magnitude of difference obtained with the random presentation procedure. While the repeated and random presentation procedures both appear to be acceptable for further work on visual pattern recognition, the repeated presentation procedure is easier to implement with the apparatus being used.

The general finding from the results of experiments I and II is that the concurrent presentation procedure, in which one dot pattern is initiated before the other and the second dot pattern is terminated after the other, creates a serious decrement in recognition performance relative to that demonstrated under conditions of simultaneous presentation.

EXPERIMENT III

Since differences in the ease of recognition of the letters in the 10 pairs of dot patterns (four practice and six test slides) had been demonstrated in the previous experiments, a study of one general hypothesis as to the source of the differences seemed indicated. The hypothesis was that the differences in recognition times of the separate dot patterns may have developed from cues in the first stimulus sufficient for Ss to make reasonable guesses about the two letters during the time only one dot pattern was exposed.

Method

Stimuli and apparatus. The stimuli and apparatus were the same as those described for Experiment I.

Subjects and procedure. Thirty Ss were randomly assigned to one of three groups with 10 cases per group. All Ss were given the alphabetic list of letters and were requested to guess which two letters were represented in each dot pattern. Twenty dot patterns consisting of the two parts of each of the 10 slides were presented at one of three exposure times, these being 1, 6 and 15 sec., with about 20 sec. between slide presentations of a dot pattern. Half of the Ss in each duration condition received a randomly ordered sequence of the 10 patterns from the left-hand halves of the stereo slides followed by a random ordering of the 10 patterns from the right-hand halves of the slides. The other half of the Ss were presented first with the right-hand patterns of the slides and then with the left-hand patterns. All Ss were informed that two different letters formed each bigram.

Results

The results are shown in Table 2. When the Ss were allowed 15 sec. to view the dot patterns, a reasonable number of correct guesses was made. Some slides did provide more letter cues than did others. However, when the times were limited to 1 and 6 sec., the range of times used in the recognition experiments with the concurrent paradigm, the performances were consistent with a hypothesis of random guessing, where the expected number of correct responses for each slide half at a particular exposure duration is 3.82. The difference in performance arising from variation in the time of exposure was quite significant ($F = 26.54$, d.f. = 2, 27). Although guessing of the bigrams was not superior for either

TABLE 2. MEAN NUMBER OF BIGRAM LETTERS GUESSED CORRECTLY FOR EACH SIDE OF TEN STEREO SLIDES AT THREE DIFFERENT EXPOSURE TIMES.

	Exposure Time		
Slide half	1 sec.	6 sec.	15 sec.
Right side	1.60	4.40	6.70
Left side	3.00	2.40	5.50

Note: Expected value of number of correct guesses = 1/11(20) + 1/10(20) = 3.82.

side of the stereo patterns, the side by time-of-exposure interaction was significant ($F = 5.08$, d.f. = 2, 27). This interaction probably arose because the supposedly random guesses at the 1 sec. level came more from the left stimulus half, while at the 6 sec. level they came more from the right. It is clear, however, that the results of experiments I and II cannot be explained as arising from cues concerning the letters in the dot patterns.

DISCUSSION

According to an integration theory analysis of dot stimuli with no contour interactions, recognition of the bigrams would be expected to occur at an ISI of at least a few msec. However the results of the three experiments clearly indicated strong masking effects defined by the unusually long times required for recognition associated with the asynchronous concurrent paradigm. This masking effect increases the recognition time to five to eight times that required in the simultaneous onset-offset presentation procedure for recognition of these bigrams. Every one of the 48 Ss used in Experiment I required an overlap time in excess of the range of 25 to 40 msec. characteristic of the performance of the Ss responding to the simultaneous presentations of the bigrams.

The results of the present studies are not necessarily incompatible with those of Eriksen and Collins (1967, 1968), since the experimental conditions for their group of investigations and the ones reported here differed quite considerably. The locus of the observed interference as well as the difference in results may lie in these experimental conditions. Some of these experimental differences involved experimental equipment, the amount of practice prior to the recording of data, the extent to which the same Ss are used for the different conditions, the between-laboratory variations in test stimuli, and, as the most likely source of the differences, the time parameters for the stimuli.

Nonetheless, the inability to obtain bigram recognition when a syllable's two complementary dot patterns, each of a few seconds' duration, are separated by only a few msec. points to a need for further investigation. One variable currently being considered by the present authors is the range of stimulus time parameters. Furthermore, a prediction derived from the integration theory which merits consideration is that forward and backward masking is symmetric. This implies that the portion of the total dot pattern shown before concurrent presentation and the portion of the total dot pattern shown following concurrent presentation should have equivalent masking effects on bigram recognition.

An important implication of the present studies should not be overlooked. It is possible that whatever is responsible for interfering with the integration process reported in this study may also partially account for the low frequency of eidetic imagery in the general population. A possible candidate for this interfering effect is verbal rehearsal (Leask, Haber and Haber, 1969) or some other higher cognitive mechanism such as attention.

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