Journal of Experimental Psychology
1968, Vol. 77, No. 3, 376–382

SENSORY TRACES VERSUS THE PSYCHOLOGICAL MOMENT IN THE TEMPORAL ORGANIZATION OF FORM [1]

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Visual stimuli were constructed so that any given stimulus by itself appeared to be a random collection of dots. However, when 2 corresponding stimuli were superimposed by means of a 2-field tachistoscope, a 3-letter nonsense syllable was perceived. When a temporal interval was introduced between the presentation of the corresponding stimulus halves, organization in perception was found to be a decreasing function of interstimulus interval over a range in excess of 100 msec. The applicability of a concept of a decaying sensory trace in accounting for the integration of form perception over time was investigated. Clear evidence of a decaying sensory trace was found; however, this concept was unable to account for all aspects of the data. The applicability of a psychological moment acting in conjunction with a decaying sensory trace was considered as was also the possibility of discontinuity detectors which inhibit or break up temporal organization.

Evidence for a persisting sensory trace has come from experiments such as those of Sperling (1960) and Averbach and Coriell (1961) in which an overload of information is presented in a brief visual display. Some milliseconds following termination of the display *S* is presented with a signal or indicator designating an element or a subset of elements of the display which he is to report. Accuracy of performance is a decreasing function of delay of the indicator out to delays of the order of 200 to 300 msec.

This result suggests the conclusion that the total information of the display is available for a brief period following termination of the display and if the indicator occurs before this information decays, *S* is able to encode the designated element or subset of the elements from the display.

[1] This investigation was supported by Public Health Service Research Grant MH-1206 and a Public Health Service Research Career Program Award K6-MH-22, 014.

However, an alternative interpretation of this result is possible for the visual system is considerably less than perfect in temporal resolution. Bloch's law is perhaps the best known example and recently many masking phenomena have seemed to be explainable in terms of the lack of temporal resolution in the visual system (Eriksen, 1966b; Eriksen & Collins, 1965; Thompson, 1966).

The applicability of a concept of a psychological moment (Stroud, 1956) to these temporal characteristics of vision has been noted by Boynton (1961) and by Eriksen and Collins (1965). The psychological moment has been variously conceived as having a duration of from 50 to approximately 200 msec. (Kristofferson, 1965; Stroud, 1956; White, 1963). Events separated by less than the duration of the moment have a probability of entering the same moment and thus being perceived as simultaneous. The closer the two events are in time the higher the probability that they will both enter the same ongoing moment, but as the time separation increases to the duration of a moment the probability becomes zero that the two events will be represented in the same moment.

The moment interpretation of the Sperling (1960) and the Averbach and Coriell (1961) data would explain the decreasing performance with delay of the indicator as the result of the decreasing probability that the indicator and the display are represented in the same psychological moment. The asymptote of the function is reached when the delay between termination of the display and the indicator is longer than the duration of the moment and therefore the probability that on any trial they would be represented as simultaneous is zero. Since the data are based upon average performance over a large number of trials it is impossible to choose between a decayed trace interpretation and a psychological moment.

In a previous paper (Eriksen & Collins, 1967) the authors reported a technique for studying form organization over time. In Fig. 1 the upper and middle patterns of dots appear to be essentially random, but when the two patterns are carefully aligned and superimposed in two fields of a tachistoscope and presented simultaneously, the embedded nonsense syllable shown in the bottom of Fig. 1 can be read. An *S*'s ability to read the nonsense syllable can then be determined by introducing a variable delay between the presentation of the two stimulus halves or dot patterns. The nature of the separate stimulus halves is such that it seems necessary that *S* has an image-like or sensory trace of the first half present in order to integrate it with the second half thus enabling *S* to read the nonsense syllable. The dot patterns do not seem to lend themselves to any type of cognitive encoding or memory that would permit the summing of the information of the two halves in any but an image-like fashion.

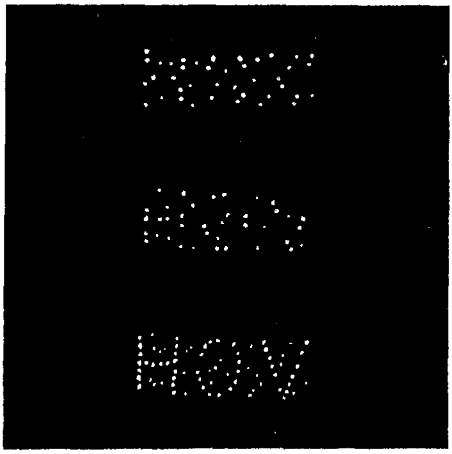

Fig. 1. The upper two dot patterns when superimposed result in the bottom stimulus pattern in which the nonsense syllable HOV can be read.

In the previous study (Eriksen & Collins, 1967) performance was found to decrease as a negatively accelerated function of the interstimulus interval (ISI) between the two stimulus halves. An asymptote was approached at ISI values between 100 and 200 msec. where performance reached a level to be expected from guessing for single stimulus half presentations. This result could be attributed to a decay of the first stimulus half in time. If the second half of the pattern is presented before the decay of the first half has progressed too far, it is possible to integrate the two patterns into the perception of the embedded nonsense syllable. This explanation assumes that integration becomes progressively more difficult if the two stimulus halves are of different brightness. Thus the longer the delay the less bright is the first stimulus half which has to be integrated with the now presented bright second half pattern.

In the present experiment luminances of 5, 2, and 1 mL. were used for the stimulus halves. The stimulus halves were presented either simultaneously or at ISIs between termination of the first half and onset of the second that varied from 0 to 100 msec. Control observations were made when both stimulus halves were presented simultaneously at 5, 2, and 1 mL. Also as a control both stimulus halves were presented at 5 mL. at each of the ISI values. Of greatest experimental interest were the conditions where the two stimulus halves were of unequal brightness. Here a 5 ml. half was presented with a 2 mL. half and with a 1 mL. half at each of the ISI values. At each of these ISI values the order of occurrence of the bright and dim half was systematically varied so that there were an equal number of experimental trials where the bright half had occurred first followed by the dim half as for the reverse order.

With this experimental design a concept of a decaying sensory trace would require certain expectations as to the results to be obtained. First the concept would require that recognition accurracy for the embedded nonsense syllable be decreased as the discrepancy in brightness of the two stimulus halves becomes greater even when both halves are simultaneously presented. Second, it would predict an interaction between order of occurrence of the bright and dim halves with ISI. If the bright half is presented first, then at any given ISI its trace, due to decay, will more nearly match the lower brightness of the second occurring stimulus half. On the other order, the dim half presented first will have a greater disparity in brightness with the brighter second half when it occurs at any given ISI due to some decay in the brightness of the first half trace. Further, the longer the ISI up to some maximum the greater the superiority of performance for the order in which the bright half occurs first. A third expectation that follows from the sensory trace concept is that at some ISI value a 2 mL. stimulus half following a 5 mL. half will exceed the performance that is obtained when both stimulus halves are 5 mL. Similarly a 1 mL. stimulus half following a 5 mL. half will exceed at a greater ISI value than that for the 2 mL. half, the performance obtained when both halves are 5 mL.

METHOD

Subjects.—Six graduate students (one female) with normal or corrected to normal vision served as paid *S*s.

Procedure.—A Scientific Prototype Model GA three-field tachistoscope in which Sylvania FT 45 CWX lamps had been substituted was used for stimulus presentation. The "complete" stimuli consisted of 20 three-letter nonsense syllables. These stimuli have been described in detail previously (Eriksen & Collins, 1967). In brief, they were similar to the one shown in Fig. 1. They were made up of two stimulus halves which when superimposed and properly aligned permitted the reading of the embedded nonsense syllable. Originally constructed with India ink dots on white cardboard, they were photographed with high contrast negatives and presented to *S* backlighted in the tachistoscope (contrast approximately 98%). The two stimulus halves for a nonsense syllable were presented in separate fields of the tachistoscope. As presented they subtended 2° of visual angle in length and 1° in height. The third tachistoscopic field was dark but contained a faintly luminous cross .3° of angle and positioned .5° below the center letter of the nonsense syllables. When an ISI occurred between the presentation of the two stimulus halves this interval was also dark.

The *S*s were instructed to fixate the cross and to trigger a stimulus presentation when this fixation point appeared sharp and clear. An experimental trial consisted of the presentation of both stimulus halves either simultaneously or at an experimentally varied ISI. The *S*s had available in their dimly illuminated booth a list of the 20 possible nonsense syllables from which they selected their response following each trial. On the average a 5-sec. interval occurred between trials.

Prior to beginning the experimental sessions each *S* served two practice sessions during which the corresponding stimulus halves were presented simultaneously for a duration of 6 msec. and at a luminance of 5 mL. All *S*s were required to obtain an accuracy level of at least 85% in order to participate in the experiment and several potential *S*s were eliminated for failure to do so. In each of the following 20 experimental sessions *S* was run for five blocks of 20 trials each under a particular luminance condition (dim stimulus half, 1 or 2 mL.) and order (bright half first or second). ISIs were varied within sessions over the values of simultaneous, 25, 50, 75, and 100 msec. Each stimulus half was presented for a duration of 6 msec. A total of 80 trials were run under each particular combination of variables. Two control conditions were also run but were not included in the main analysis. One control was the condition where both stimulus halves were 5 mL. and were separated by the five ISIs used. The second control involved the presentation of both stimulus halves simultaneously at a luminance of 1 and of 2 mL. The various control and experimental conditions were counterbalanced over *S*s throughout the 20 experimental sessions.

Results and Discussion

The percentage of correct nonsense syllable identifications were analyzed for the two experimental conditions (stimulus halves, 5 and 2 mL. or 5 and 1 mL.; order, dim half first or bright half first; ISIs; and *S*s). This four-way classification analysis of variance yielded significant ($p < .01$) main effects for all four variables. In addition, the interaction of order with ISI and order with *S*s was significant beyond the .05 level. The Conditions × ISI interaction was also significant ($p < .01$), but none of the third order interactions approached significance.

In Fig. 2 the percentage of correct nonsense syllable identifications is shown as a function of condition, order, and ISI. Also plotted are the data from the control condition where the two stimulus halves were of equal luminance at 5 mL.

The results in Fig. 2 are in agreement with our expectations from a sensory trace concept. The basic assumption that organization of the embedded nonsense syllable is more difficult if the test stimulus halves are of unequal energy is borne out by comparison of the data where the two stimulus halves are *simultaneously presented* at 5 mL., at 5 and 2 mL., and at 5 and 1 mL. Even though under these conditions both stimulus halves are simultaneously presented for the same duration, performance drops markedly as the disparity of luminance of the two halves becomes greater. That this performance drop is due to the relative brightness difference in the two halves rather than just the lower brightness of one half can be seen by comparison with the performance obtained when both halves are reduced in luminance. When both halves are presented si-

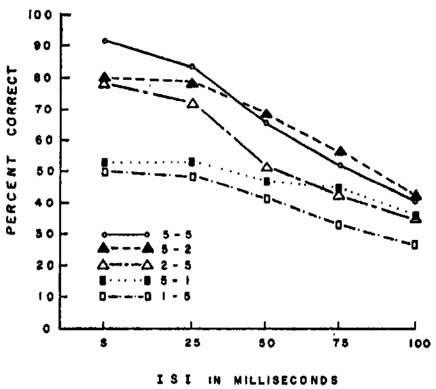

Fig. 2. Percentage of correct nonsense syllable identifications as a function of the luminance of the corresponding stimulus halves and the interstimulus interval.

multaneously at 2 mL., identification of the syllables is 88% and 80% when both halves are 1 mL.

The significant order effect and Order × ISI interaction are both seen to be in the direction expected from the sensory trace concept. Performance is superior if the bright stimulus half precedes the dim half and the discrepancy in performance for these two orders becomes greater as ISI increases.

The third expectation following from the sensory trace concept is only partly confirmed. In the case where the 5-mL. half is followed by the 2-mL. half, performance exceeds that obtained for the control condition where both halves are 5 mL. somewhere between an ISI of 20 and 50 msec. However when the first half is 5 mL. followed by a 1 mL. half, performance does not exceed that obtained when the two halves are 5 mL. within the range of 100-msec. ISI investigated. The data do suggest, however, that had longer ISIs been examined, these two curves would have met before the asymptote of performance was reached.

These results, taken as a whole, are certainly indicative that a decaying sensory trace does exist in the nervous system. Part of the shape of the function relating performance to ISI obtained for the control condition where both stimulus halves were 5 mL. and in the previous experiment (Eriksen & Collins, 1967) can be accounted for in terms of a decaying trace and the increased difficulty in organizing a form from stimulus halves that are disparate in brightness.

There are however indications in the present data that more is involved than the decaying trace. This can be seen if one considers the control observations where both halves were simultaneously presented either at 2 mL. or at 1 mL. As long as both halves are of equal luminance, reducing the luminance level of both halves has only a small effect upon identification performance. Thus the syllables are identified with 92% accuracy when both halves are at 5 mL., with 88% accuracy at 2 mL., and 80% accuracy at 1 mL. If performance decrement as a function of ISI was solely attributable to the decayed trace and therefore the greater disparity in brightness of the two halves, presenting a 5 mL. half followed by a 2 mL. half should at some ISI value equal the performance obtained when both halves are simultaneously presented at 2 mL. Similarly, 5 mL. presented first followed by 1 mL. should at some longer ISI value equal the performance obtained when both halves are simultaneously presented at 1 mL. Inspection of Fig. 2 shows that this performance level is not achieved by either of these two experimental conditions. For both, performance is consistently below that obtained for the respective control observations. The most that seems to be achieved by presenting a bright half first followed by a dimmer half is an attenuation in the rate of decay of the performance measure with increases in ISI.[2]

[2] In the previous study (Eriksen & Collins, 1967) a similar attempt was made to test a sensory trace concept with equivocal results. In that study the importance of a mismatch in brightness of the two stimulus halves was found, but there was no interaction of order with ISI nor a significant order effect. Hindsight suggests that this prior failure was attributable to the manipulation of intensity or luminance disparity via increased exposure time of one stimulus half in terms of the $I \times t = c$ relation. Perhaps more important was the use of black on white stimuli. Subsequent research in our laboratory has shown that the temporal interval over which black on white stimuli can be integrated or organized is appreciably shorter than that for the backlighted stimuli used in the present experiment.

It is possible that something like a psychological moment may also be involved in the form organization over time that occurs in the present task. The concept of a psychological moment (Stroud, 1956; White, 1963) is too unspecific with respect to such characteristics as whether incoming stimulation can enter an ongoing moment or whether it has to be stored for the following moment. And if stored, is there decay in the stored trace? A decaying sensory trace concept and the concept of a psychological moment are not necessarily incompatible. If one posits that an incoming stimulation cannot enter an ongoing psychological moment, then two stimulations separated by less than the psychological moment but by a finite time period would both be stored until they could enter the next moment. But because of their differential time of arrival one would have decayed more than the other leading to, in the present experimental task, a mismatch in the brightness level of the two stimultations. Such a concept would account quite well for the present data in describing the organization of form over short temporal intervals. It would attribute the decrease in performance as a function of ISI as due to two processes; first, to the differential decay of the two stimulus halves with the resulting mismatch in brightness, and second, to the decreasing probability that they would both enter the same psychological moment as ISI increased.

A third possibility can also be entertained. For convenience this possibility may be termed discontinuity detection. A system that has the pronounced temporal integration that vision does would also seem to require mechanisms capable of detecting or responding to discontinuity in stimulation. Such discontinuity detectors might be responsible for the breaking up of integration of incoming stimulation over time so as to permit discrete perceptions. Granit (1947) has suggested such a role for off receptors and more recently Barlow (1961) has speculated along these lines.

If discontinuity detectors are responsible for interruption of temporal integration the data of the present experiment for the 5-5 mL. control condition would reflect the increasing probability of discontinuity detection with lengthening ISI as well as the decay of the stimulus trace. Also the monotonic negatively accelerated forward and backward masking functions (Eriksen, 1966; Eriksen & Collins, 1965) might be viewed in part as threshold functions for discontinuity detection.

Thus in the Eriksen and Collins (1967) experiment it is possible that the time period over which temporal organization could occur was too short to demonstrate the order effect.

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(Received June 23, 1967)