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SOME TEMPORAL CHARACTERISTICS OF VISUAL PATTERN PERCEPTION [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. Temporal organization in perception was studied in Experiment I by varying the interval between the presentation of the 2 corresponding patterns over 300 msec. Identification accuracy of syllables was a decreasing function of interstimulus interval over a range in excess of 100 msec. Experiment II used unequal energy levels for the 2 corresponding patterns and also varied the sequence of occurrence of the high and low energy members of corresponding sets. The relevance of such concepts as perceptual memory, afterimages, and psychological moments to the data was considered. It was suggested that mechanisms in the visual system such as the "off" response that detect the termination of a stimulus may be responsible for inhibition of integration over time.

The visual perceptual system under certain circumstances is unable to resolve short time differences. Bloch's law relates to the fact that the perceived brightness of the stimulus is dependent not only upon its luminance but its duration. Recent work indicates that this critical duration over which time intensity reciprocity holds is valid not only for perceived brightness but also for form identification. In the latter case the values of the critical duration are somewhat longer than those found for luminance summation (Kahneman & Norman, 1964). These findings would imply that the visual perceptual system sums or integrates energy over the critical duration prior to the occurrence of the perception of a form or of a brightness magnitude.

Experiments upon perception of simultaneity and of perceptual rate have indicated a perceptual time unit generally in the region of 50–100 msec. (see White, 1963, for an excellent review of these studies). These and the reciprocity studies have proven difficult to conceptualize. Attempts to deal with these temporal factors in perception have led to the conception of a psychological moment (Pièron, 1952; Stroud, 1956; White, 1963; White & Cheatham, 1959) that has many of the characteristics that have been ascribed to psychological time units by the philosophers Bergson (1913) and James (1890). Renewed interest in a psychological moment has come from research on backward and forward masking in visual perception. At least certain masking effects can be interpreted as a temporal summation of test and masking stimuli into a composite perception (Eriksen, 1966; Eriksen & Collins, 1965), and Boynton (1961) has suggested an explanation for tem-

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poral summation in vision and of masking phenomena in terms of a psychological moment.

Studies of temporal factors in visual perception, including the masking experiments, typically have dealt with brightness and acuity tasks and less frequently with form identification. However, Kahneman (in press) has suggested that the latter task as generally employed is essentially also an acuity task. In the present experiments we have employed a technique of stimulation that permits the study of the temporal development of organizational or integrational components in pattern perception. The first two lines in Fig. 1 show what appear to be two random dot patterns. When these dot patterns are superimposed they yield the perception of the nonsense syllable VOH. Each of the dot patterns, hereafter designated as a stimulus half, can be placed in the separate field of a tachistoscope and when the halves are properly aligned and exposed simultaneously at an appropriate luminance and duration, they yield the perception of the nonsense syllable. By introduction of systematic delays between presentation of the halves the temporal distribution of an organizational component in perception can be studied.

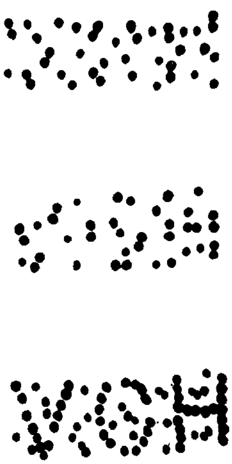

FIG. 1. The upper two dot patterns when superimposed result in the bottom stimulus pattern in which the nonsense syllable VOH can be read.

This task has several advantages. Not only does it permit the study of the temporal course of organizational components in perception similar to those that underlie perception of imbedded and street-gestalt figures, but it permits the study of a possible perceptual memory as suggested by Averbach and Coriell (1961) and Sperling (1963). As the reader can verify for himself, the two dot patterns are not such that they can be cognitized and/or remembered in such a manner as to yield the contained nonsense syllable. The nonsense syllable would seem to be capable of being perceived only if the two halves are perceived as psychologically simultaneous or the perceptual trace of the first half is still present when the second stimulus half occurs.

EXPERIMENT I

Subjects.—Five male graduate students with normal or corrected to normal vision served as paid *Os*.

Procedure.—A Scientific Prototype Model GA three-field tachistoscope was used for stimulus presentation. The "complete" stimuli consisted of 20 three-letter nonsense syllables. The first letter was always a T, V, or X, the second A, O, or U, and the third H, M, or W. As seen from the sample stimulus in Fig. 1, the letters were composed of dots. The dots making up the forms of the letters were divided over two cards so that the dots contained on either card alone yielded minimum information as to the nature of the nonsense syllable. To reduce cues further and to minimize the possibility that the nonsense syllable could be guessed from the dots on only one stimulus card, slightly smaller camouflaging dots were distributed over each card. This technique yielded stimulus halves from either of which alone it was impossible to perceive the imbedded nonsense syllable. These stimulus cards were originally made up of India ink dots on white cardboard. Before use they were photographed to yield high-contrast negatives. The photographic negatives of the stimulus halves were presented in separate fields of the tachistoscope which had been carefully aligned so as to superimpose properly the corresponding halves thus permitting the nonsense syllable to be perceived.

As presented in the tachistoscope the stimulus halves subtended 2° of visual angle in length and 1° in height. They were backlighted with a luminance of 5 mL. in each field. 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 syllable.

The *S*s were instructed to fixate the cross and to trigger a stimulus presentation when the cross appeared sharp and clear. An experimental trial consisted of the presentation of both stimulus halves either simultaneously or at an experimentally varied interstimulus interval (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. All *S*s obtained an accuracy level of at least 85% but less than 100% for identification of the nonsense syllables during the second practice session (average 93%). Following the practice sessions *S*s were run for five additional experimental sessions in which the stimulus halves were separated in time with ISI values of 0, 25, 50, 75, and 100 msec. between the offset of the first half and onset of the second stimulus half. In each session a block of 20 trials was run for each delay. The delays were counterbalanced over sessions and *S*s to cancel any order effects.

Following completion of the five experimental sessions, examination of the data failed to reveal a definitive asymptote in identification as the ISI was increased. To determine whether some temporal summation was still occurring at the 100-msec. ISI, *S*s returned for three additional experimental sessions during each of which they were run on ISIs of 100, 300, and 500 msec.

Results and Discussion

In Fig. 2 mean percentage of correct nonsense-syllable identification is plotted as a function of ISI between the offset and the onset of corresponding halves. The average function is

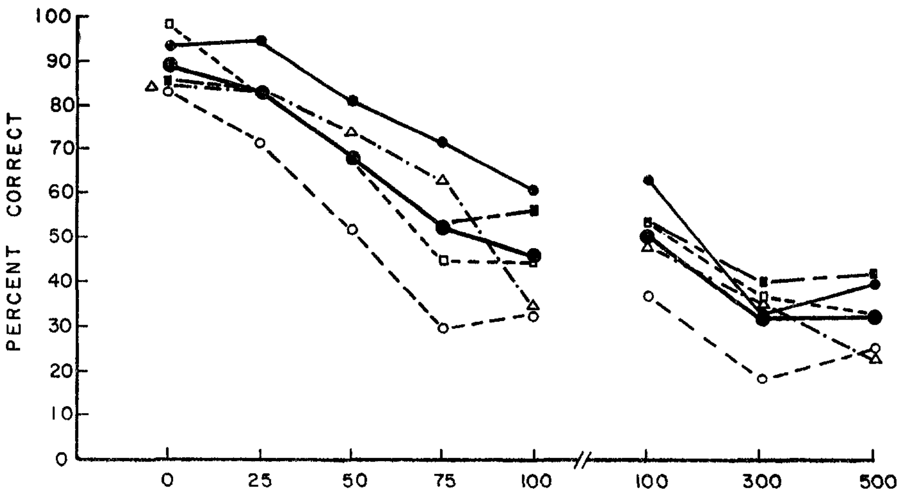

Fig. 2. Accuracy of nonsense-syllable perception as a function of ISI between the corresponding stimulus halves. (The heavy lined function represents the average and the lighter lined functions are for the individual *S*s.)

shown by a heavy line and the data for the five *S*s is shown in the lighter lined functions. The three additional sessions at ISIs of 100, 300, and 500 msec. that *S*s served following the counterbalanced experimental sessions are plotted separately in Fig. 2. For three of the five *S*s there is little if any drop in performance when the halves are presented over the range of simultaneity to an ISI of 25 msec. For all *S*s performance decreases at an accelerated rate between ISI values of 25 and 75 msec. It appears clear that an asymptote in identification is approached at somewhere between an ISI of 100 and 300 msec.[2]

Phenomenal reports obtained from *S*s indicated that nearly all were detecting the double stimulation or the separate halves by ISI values of 75 msec. At this separation *S*s reported a twinkling effect in the stimulation due to apparent movement of the dots toward adjacent dots. By 100-msec. ISI most *S*s could perceive the two halves as separate stimulations.

The decreasing identification performance as a function of increasing ISIs is similar to the masking effect produced by a second-field luminance upon identification of a form stimulus (Eriksen, 1966). However, the present function as well as many masking functions can be interpreted in either of two ways. Since these functions are obtained by averaging performance over a large number of trials, it is impossible to determine whether there is a constant effect on every trial, the magnitude of which varies inversely with ISI, or the effect is constant whenever it occurs but the proportion of trials upon which it occurs varies inversely with the ISI. For the present data the first alternative might be phrased in terms of a decaying trace of the first stimulus half. The longer the ISI the more the trace or "perceptual" memory of the first half has decayed. When the second half is presented *S* must put together or organize the decayed or less intense trace of the first half with the brighter second-half pattern in order to perceive the nonsense syllable. Thus at any ISI over the range where some integration occurs the difficulty of the organizational task is essentially constant for that given ISI on each trial. This would assume that the integration of the nonsense syllable from the two dot patterns is impaired if the halves are of unequal brightness.

In terms of the second alternative the obtained function is generated by an underlying process by which both halves are perceived simultaneously on some proportion of the trials. In this case performance is unimpaired. But on the remaining trials they are perceived as two separate dot patterns and integration is not possible. This second possibility would be commensurate with a concept of a psychological moment (Boynton, 1961; Murphree, 1954; Stroud, 1956; White, 1963).

If one postulates that experience and/or perception occurs in chunks or quanta of somewhere in the neighborhood of 50–100 msec. duration, the present data would be interpreted in the following manner. At short ISI values the probability that both stimulus halves would occur in the same psychological moment and therefore be perceived as though presented simultaneously is quite high. However, as the ISI value increases the probability decreases that both halves would enter the same psychological moment. By the time the separation of the two halves is greater than the duration of the psychological moment, identification performance would have reached an asymptote since under these circumstances the probability is zero that they could enter the same moment.

Other explanations are of course possible and the present data do not provide

[2] With 20 nonsense syllables the a priori probability of a correct identification by guessing is .05. However, the inability to completely eliminate the partial cues in the separate stimulus halves required the determination of an empirical guessing accuracy level.

even a choice between the decaying perceptual trace or memory explanation and the psychological moment concept. Experiment II was designed to test the appropriateness of a decay interpretation and also the possibility that the integration over time effects in the above study were due to subtle afterimages. This latter possibility is operationally difficult to distinguish or disentangle from a perceptual memory or a decay process and in the present paper no attempt is made to draw a distinction.

Experiment II

Design.—One of the stimulus halves is given a longer duration than its corresponding half. The energy of the longer duration half is thus greater and in keeping with Bloch's law would be expected to constitute a brighter or more intense stimulation. In the present experiment one of the stimulus halves was always presented at a 25-msec. duration at 5-mL. luminance while the corresponding stimulus half was presented at either 50-, 100-, or 150-msec. duration at 5-mL. luminance. A second variable was whether the longer duration stimulus half preceded or followed the corresponding 25-msec. duration half. Each combination of these two variables was presented at three ISIs: immediately successive (less than 1 msec. apart); 20 msec.; and concurrently. In the concurrent condition, due to the inequality of the duration of the stimulus halves, they were actually concurrent only for the 25-msec. duration of the shorter half. The order variable was manipulated by having the corresponding halves have a concurrent onset or a concurrent offset. Thus, under the concurrent condition when the long duration half occurred first its onset preceded the short duration half by the amount of the time difference in their duration but they shared concurrently the last 25 msec. of the duration of the longer half. For the reverse order both halves had a concurrent onset but after 25 msec. the short-duration half terminated and the long-duration half continued for the length of its remaining duration interval. In addition to these conditions control observations were systematically obtained for the conditions where both of the corresponding halves had a 25-msec. duration which was presented either concurrently, immediately successive, or at 20-msec. ISI.

This design should permit answers to the following questions raised by the preceding experiment. First of all, a decaying trace interpretation of the above data requires that integration of the nonsense syllable from the corresponding stimulus halves is more difficult if the halves are of unequal energy than if the halves are of comparable energy. In the present experiment this assumption would lead to the expectation that identification performance should decrease as the duration of one of the stimulus halves varies from 25 msec. to 150 msec. and the other half remains constant at 25-msec. duration. The decaying trace explanation is tested most directly by the order variable. It seems reasonable to expect that the absolute energy in a decaying perceptual memory (or the clarity of an afterimage) at some succeeding moment in time would be greater for a high-energy stimulation than for a low-energy stimulation. For example, at an ISI of 20 msec., identification of the nonsense syllable should be easier if the first stimulus half had a longer duration since there would be a more persistent trace to integrate with the following short-duration half. The reverse order should lead to much worse performance, not only due to less persistence from the low-energy half having occurred first, but also because under these circumstances there would be a greater absolute difference in energy of the corresponding halves. Further, the decaying perceptual memory explanation would expect an interaction between long-half duration and ISI since as ISI increases, high-identification performance could be maintained by increasing the energy in the first half presentation and therefore the amount of persistence of the memory trace.

Subjects.—Six undergraduate students (four males) served as paid volunteers. All had normal or corrected to normal visual acuity and none had served in Exp. I.

Apparatus and stimuli.—Apparatus and stimuli were essentially the same as those employed in Exp. I with these exceptions. Previously the dot patterns of the stimulus halves had been backlighted thus presenting a view of illuminated dots against a black ground. In this experiment the figure-ground relationship was reversed. The stimuli were made using India ink on white cards and were frontlighted in the tachistoscope at a luminance of 5 mL. To prevent luminance summation—contrast reduction effects that would vary as a function of ISI (Eriksen, 1966), the adapting field which contained a small black fixation cross also had 5-mL. luminance. To maintain contrast reduction due to luminance summation as a constant overall ISI and other experimental conditions, the adapting field was left on continuously except where the conditions required that both stimulus halves be on concurrently. Then the adapting field was off while the stimulus halves were concurrently presented but when either half terminated the adapting field came on instantaneously. As constructed on the white cardboards the black dots had a contrast of 95% but due to "veiling glare" arising from superimposition of adapting and stimulus fields or of the two stimulus fields at the eye the effective contrast was 47.5% (Kahneman, 1966).

Procedure.—The procedure was also essentially the same as in Exp. I. Each *S* served two practice sessions in which the 20 sets of corresponding stimulus halves were presented simultaneously for 25 msec. All *S*s who were subsequently used in experimental sessions attained an accuracy level of at least 85, but less than 100% during the last practice session. Several potential *S*s had to be dismissed because of their inability to achieve this criterion. Following the two practice sessions each *S* served for 12 experimental sessions. During these sessions each *S* had 40 trials under each combination of the 18 experimental conditions (three durations of the long stimulus half, 50, 100, and 150 msec.; two orders, long half first or second; and three ISIs, concurrent, 0- and 20-msec. delay between halves). In addition, 80 trials were run under the control conditions at each of the three ISI values where both stimulus halves were 25-msec. duration.

Results

The number of correct nonsense-syllable identifications was analyzed in a four-way classification analysis of variance (three durations of the long-stimulus half, order of occurrence of long- and short-duration stimulus halves, ISI, and *S*s). All main effects and interactions were significant beyond the .01 level except the main effect due to order of occurrence of long and short half, and the following interactions: Long-half duration with *S*s; ISI, long-half duration and *S*s; ISI, order and *S*s; and long-half duration, order and *S*s. The control condition for the equal duration halves at the three ISI values were analyzed separately and a significant effect ($p < .001$) was obtained for the effect of ISI.

In Fig. 3 average percentage of correct nonsense-syllable identification is shown as a function of the duration of the long-stimulus half. The parameters in Fig. 3 are the three ISI values: concurrent, 0, and 20 msec. For each of these ISI values the effect of order (whether the long duration-stimulus half preceded or followed the short-duration half) is also shown. The points at the extreme left of Fig. 3 are for the control condition where the corresponding stimulus halves each had a duration of 25 msec. and were ob-

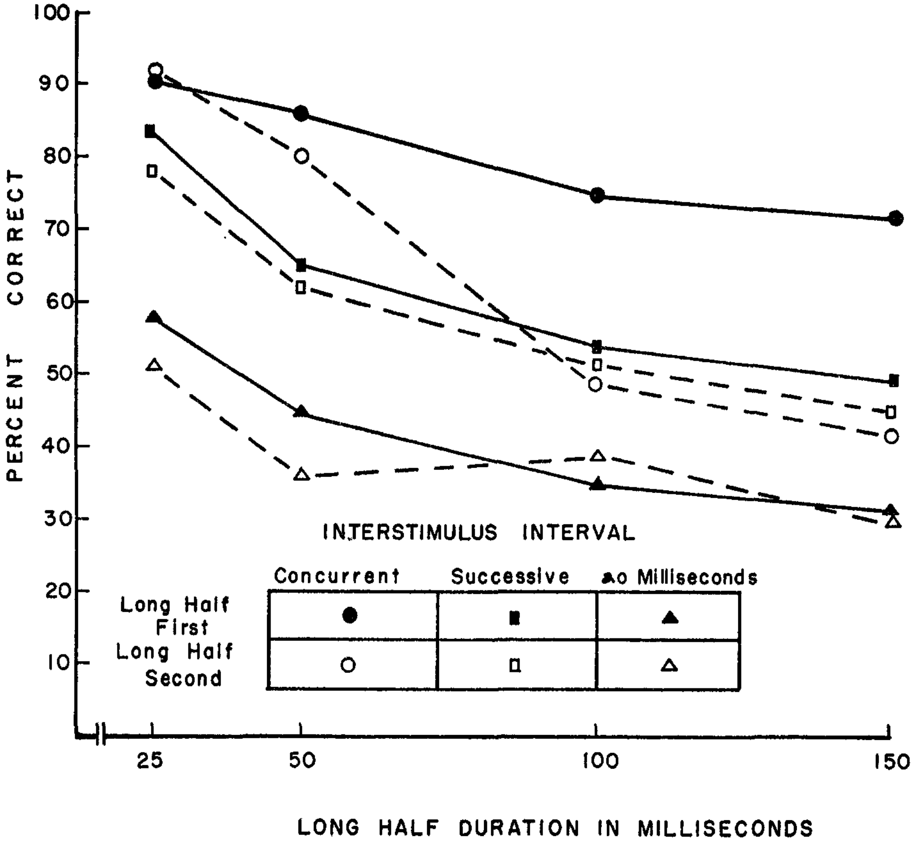

FIG. 3. Average percentage of correct nonsense-syllable perception as a function of the duration of long-stimulus half, ISI, and sequence of long- and short-stimulus halves.

tained under each of the three ISI values.

The data of Fig. 3 may be summarized as showing that the ability to organize the nonsense syllables from the separate stimulus halves is: (*a*) greatest when the stimulus halves are concurrent and decreases as the halves are separated in time; (*b*) highest when the stimulus halves are of equal energy (duration) and decreases in a negatively accelerated function as the mismatch in energy increases; and (*c*) indifferent to the order of occurrence of unequal energy-stimulus halves except when the occurrence of the stimulus halves overlap in time (concurrent). In this latter instance performance is best if the unequal duration stimulus halves share a common offset rather than a common onset, and the greater the inequality in durations the greater is this effect.

Discussion

The above data support the assumption that inequality in energy between stimulus halves reduces integration or organization of the imbedded nonsense syllable. This assumption is basic to a decay explanation. However, a simple decay explanation is countermanded by the fact that, (*a*) when the stimulus halves are not concurrent, there is no performance gain when the high-energy stimulus half occurs first rather than after the low-energy half, and (*b*) there is a progressive decrease in performance when the occurrences of the stimulus halves are varied from concurrent to successive to 20-msec. ISI for all duration or energy inequalities.

It seems reasonable that if a perceptual memory process exists, the greater the intensity or energy of the stimulation, the greater the intensity of the trace or memory at a succeeding point in time. Thus in the present study when a long duration half is presented first, there should be a more intense memory trace to integrate with the short-duration half when it occurs later in time. The reverse order should lead to inferior integration, not only because the short-duration trace is less intense but also because the energy inequality between the stimulus halves will also be greater. Since integration is best when the halves are of equal energy it also follows that an interaction of first-half duration with ISI should occur. This would represent the instances where the decay of the more intense first-half stimulus now matches more closely the intensity of the succeeding short-duration half.

As was seen, there were no indications in the above data to support these deductions. The only case where order of occurrence of long- and short-duration halves made a difference was when the halves were on concurrently for the duration of the short half. For example, if the long-stimulus half had a duration of 100 msec. and the short half 25 msec., perception of the nonsense syllable was more accurate if the 100-msec. stimulus half was turned on first and the short-duration half turned on 75 msec. after the onset of the long-stimulus half. If both stimulus halves were turned on simultaneously and 25 msec. later the short-duration half terminated but the long half continued for an additional 75 msec., perception of the nonsense syllable was much inferior.

This finding is in itself puzzling. It does not fit a memory decay process since both halves always share a common 25-msec. duration. Performance under either order is poorer than if both halves had been presented for only 25 msec. concurrently. The inequality of the energy in the stimulus halves would seem to account for the decreased performance except that this inequality should be the same for either order of the halves occurrence. When the halves share a common onset there is a 25-msec. period when they are of the same energy but it is apparent that perceptual integration does not occur that rapidly.

The interaction also is not readily interpretable in terms of a simple conception of a psychological moment. Since both halves always share a common 25-msec. duration, at least this much would be included in the same psychological moment, and perception of the imbedded nonsense syllable would be expected to be quite accurate. Some deterioration in performance could be attributed to the variability of the beginning of the psychological moment such that on some trials more than 25 msec. of the energy of the long stimulus-half duration might be included in the same moment with the 25-msec. duration half. This would lead to some energy mismatch between the two halves with a corresponding decrease in identification performance. However, the operation of such a process would be independent of the order of occurrence of the long- and short-duration halves and would not be commensurate with the obtained interaction.[8]

Those who have discussed the concept of the psychological moment (Boynton, 1961; Murphree, 1954; Stroud, 1956; White, 1963) have not been sufficiently

[8] Fred Attneave (personal communication) has suggested that the interaction of order of occurrence with the long and short-duration halves might be attributable to apparent movement. When the stimulus halves have a common onset but terminate 75–125 msec. apart, the short-duration half is assimilated into the long-duration half via apparent movement. This process would account for the unidirectional effect since if the halves have an asynchronous onset but common termination the conditions for apparent movement would not obtain.

specific in describing its characteristics. To determine whether the concept has theoretical value in handling phenomena such as produced in the present experiments we need greater explication. Does an arriving stimulation enter an ongoing psychological moment or is it stored and then represented in the succeeding moment? In the latter case when it's stored does any deterioration occur in its trace or intensity during the period of storage? Does the duration of the moment vary with intensity of stimulation? Specifications such as these are essential if the moment concept is to be applied to the interpretation of the present data. Failure of the theorists to deal with these details of the nature of the concept is undoubtedly attributable to the paucity of experimental data on temporal factors in perception.

The results of the present experiments are most likely a product of several different processes in the visual perceptual system. It seems apparent from the present data alone that perception lags at least 25 msec. or more behind the onset of stimulation in physical time. Differential latencies in transmission of stimulation from sense organ to higher brain centers may well be one factor in the present results. Perhaps most important is the consideration that a system which has the summative and persisting characteristics of visual perception would seem to require other mechanisms to detect discontinuity or interruptions in stimulation. The "off" response recorded at the level of the retina (Granit, 1947) would seem to be one such mechanism. It is possible that this mechanism or similar mechanisms that detect discontinuity in stimulation have an inhibiting effect on the summative or the integrative process underlying performance in the present experiments. This would be commensurate with the finding that any discontinuity or interruption of stimulation was found to have a deleterious effect on perceptual integration of the imbedded nonsense syllables.

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