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PERCEPTUAL RECOGNITION AS A FUNCTION OF MEANINGFULNESS OF STIMULUS MATERIAL[1]

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The present study evaluates a class of models of human information processing made popular by Broadbent. A brief tachistoscopic display of one or two single letters, four-letter common words, or four-letter nonwords was immediately followed by a masking field along with two single-letter response alternatives chosen so as to minimize informational differences among the tasks. Giving *S*s response alternatives before the stimulus display as well as after it caused an impairment of performance. Performance on single words was clearly better than performance on single letters. The data suggest that the first stages of information processing are done in parallel, but scanning of the resultant highly processed information is done serially.

Sperling (1960, 1963) and Averbach and Coriell (1961) used a "partial report" sampling technique for testing availability to show that after a very brief visual presentation of a matrix of letters *S*s initially have more information available than they can report. This suggests that *S*s have a limited capacity to handle input information so that when they are asked to report all of the items in a stimulus display, they lose information while they are responding. Sperling has called the storage system in which this information loss takes place visual information storage (VIS) and suggests that it is a fast-decaying system for storing sensory information (i.e., information which has not made contact with the central processor or with long-term memory). Presumably, VIS does not contain the information necessary to tell whether a particular figure is a letter or some other figure or whether four letters make a word or not. A scanning device (SCAN) selects information from the VIS and passes it on for further processing.

Sperling's model is based on an earlier model by Broadbent (1958). Both have a sensory storage system to hold information until the central processor is free to handle it, an attentional mechanism selecting information to be processed while holding the remainder in the sensory storage system, and a limited capacity processing system. In the early version of Sperling's (1963) model, the SCAN took place in a serial manner (the extreme case of a limited capacity processing system) at one letter every 10 msec. This was suggested by an experiment in which a visual masking field, assumed to erase VIS, followed the stimulus display after various intervals. The function relating time between the stimulus and the masking field to the number of letters correctly reported had a slope of 10 msec. per letter correctly reported.

Estes and Taylor (1966) have also reported data favoring a serial processing model. In Exp. I of their paper they reported a decrease in percentage of correct detections of the letters B or F in a display as the number of elements in the display increased from 8 to 16. They were able to fit to their data a serial model of the following form: During a given time interval, a single item is scanned and classified as sig-

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nal or noise. The limitation on behavior is imposed by a given probability that during that time interval the remaining traces will pass below threshold. Another possible interpretation of this result is that each item in the display has some probability of being mistaken for the incorrect alternative.

Sperling (1967) has more recently argued for a parallel, rather than a serial, mode of operation of the SCAN. Although his *S*s performed better on one particular position of a tachistoscopic display, all of the items in all positions had some probability of being reported correctly even after the shortest times were allowed for processing. This is unreasonable under the hypothesis that *S* completes the processing of one item before he can report any information about a second item and that he uses the same search pattern over trials. Sperling also notes that *S*s can report the approximate number of items, and the colors, as well as the particular letters which have been cued; he thinks that this fact also suggests parallel processing.

Further support for parallel processing is given by the data of Exp. II of Estes and Taylor (1966). For a fixed display size with redundant target items (i.e., two or four) in the display, one model, postulating the independence of target items, and another model, postulating that a fixed number of the items in the display were being sampled and interrogated at once, both fit the data better than their serial model. Eriksen and Lappin (1965, 1967) and Eriksen, Munsinger, and Greenspon (1966) have also obtained evidence for independent, as opposed to serial, processing of display items.

Thus the evidence on whether early analysis of visual information occurs in serial or parallel is equivocal. Certainly Sperling's (1960) data showing that forgetting has occurred while *S*s are emitting responses seem to demand that information is being lost while waiting for other information to be handled serially. His model stresses the initial stages of information processing (i.e., VIS) as the locus of information loss associated with the "waiting line" of serial processing. However, it is equally appropriate to assume that the serial processing occurs at some later stage in information processing, such as in identifying or attending previously processed (or analyzed) information. Notice that the term "processing" is being used here to refer to any operation performed on input information and not just to those operations that require attention. Thus far, single letters, the supposed serial elements of perception, have required complete, single-syllable responses and *S*s have not had the opportunity to say more than one of them at a time. Thus the inferences drawn about time for processing and about forgetting during processing could as well be made about identifying (categorizing) stimulus input or executing these responses. If *S*s were given an opportunity to respond to more than one letter at a time, perhaps they would have the same processing time for an *n*-letter unit as for a single letter. In that case it would be necessary to infer that the letters of the *n*-letter unit were processed in parallel. This would still allow the recognition or identification units, the "chunks" (Miller, 1956), to be handled in a serial fashion.

To test these alternatives the present study measured recognition performance on one or two letters, four-letter words, and four-letter nonwords. The informational differences among the tasks were minimized by: (*a*) requiring a forced choice between two alternative single letters for all conditions; (*b*) arranging the two response alternatives so that if a word was presented as a stimulus, both the correct and the incorrect alternatives would make a common word, given the other three of the four letters. For instance, if WORD was a stimulus, the alternatives could have been D and K. If a nonword was the stimulus, both of the alternatives made up a nonword.

Three display durations, with masking fields following immediately upon termination of the stimulus, were chosen for each *S* in an attempt to sample three stages of the development of the percept. The basis for inferring development of a percept was improvement at the forced-choice task as a function of increasing duration of stimulus presentation.

In an attempt to reduce the confounding of perceptual effects with memory effects, a condition was added in which the two alternatives were given in advance of the presentation of the stimulus display. With this information, *S*s would presumably have to remember only the target item so that memory loss would not confound the results.

METHOD

General experimental plan.—Nine *S*s were extensively tested so that each would contribute 48 observations to each level of all of the major variables: stimulus duration, cueing condition, and type of material. During any particular session, *S* was presented three blocks of trials corresponding to the three stimulus durations. Within these blocks, the order of presentation of the material and the position of the critical letter were random. The *S*s were not told and thus had no way of knowing what type of material would be presented on any trial. The stimulus durations for each *S* were determined separately. One of the six possible orderings of the three durations was chosen at random (without replacement) for each *S*. The durations were systematically changed after each second session so that each *S* received all possible orders of the stimulus durations under both the precue and the no-precue conditions. Five *S*s received the no-precue condition on the first session of the experiment proper and four received the precue condition. After the first session, these cueing conditions alternated.

Materials and apparatus.—The word stimuli were 216 four-letter words chosen such that each of the words could be changed by one letter to make up a new word. The letter which could be replaced (called the critical letter hereafter) to form a new word, as well as the letter substituted to form that new word, were the two response alternatives in the forced-choice procedure. For example, *D* and *K* were the alternatives for the word WORD, with *D* being the critical letter. The critical letter came from each of the four possible positions of the four-letter words equally often.

The single-letter sets were made up by using the same critical letters in the same position as were used in the word sets. For example, for the word WORD with alternatives D and K there was a letter "D" with alternatives D and K. The quadrigrams were anagrams of the words with the critical letter held in its same position. For example, OWRD was an anagram of WORD, again with D and K as alternatives.

Letters could appear in any one of eight possible positions in a stimulus display of two rows and four columns. A single letter would occur equally often in any of the eight positions. In the two-letter condition the critical letter occurred equally often in each of the eight positions, the other occurring randomly in any one of the four positions of the row not occupied by the critical letter. The same pattern was employed for one and two words and one and two quadrigrams.

A three-channel tachistoscope (Scientific Prototype Model GB) was used for the presentation of stimulus materials. A fixation point was displayed on a blank field, followed by the stimulus display initiated by *S* after a ready signal from *E*. This was followed by a visual noise masking field with the two response alternatives directly above or below the position of the critical letter in the prior stimulus display, depending on whether the critical letter had been in the top or bottom row of the display. Underscores were used on the alternative card to indicate the relative position of the critical letter in the stimulus display. For example, $---^{\mathrm{D}}_{\mathrm{K}}$ appearing above the masking field would indicate that the critical letter had been in the top row, fourth column. All channels were kept at 30-ftl. luminance. Stimulus materials were typed on white cards in Bulletin type style. Letters were in uppercase, $\frac{3}{16}$ in. high. The stimulus field was less than 2° of visual angle. Because of the necessity of making the alternative letters backwards for the nonstimulus channels of the tachistoscope, the type style was photographed and backwards letters were made on rubber stamps and appropriately placed on the alternative cards. The noise field was made with overlapping Xs and Os of the typewriter.

Procedure.—In Session 1 of the experiment, the duration at which each *S* performed at 90% accuracy (uncorrected for chance) in identifying single letters from two response alternatives was determined. The test materials were a set of 120 single-letter displays in which all of the letters of the alphabet were used approximately equally often. The incorrect alternatives were chosen randomly. The method for finding the 90% point was a modified up-and-down threshold procedure. Only the last 60 of the trials were used to determine the 90% performance durations. The second session was used to determine the duration yielding 60% performance for each *S*.

The actual durations used for each *S* were the duration at which *S* achieved 60% performance, the duration at which *S* achieved 90% performance plus 5 msec., and the duration lying midway between these two points. The range of durations over all *S*s was 35–85 msec. The mean difference between the longest and shortest durations was 25 msec.

The six types of material were sorted into blocks of 48 stimulus items with each block containing one instance of each type of material with the critical letter in each of the eight positions. The cards were randomized within each block so that type of material and position of the critical item were random. During an experimental session, three blocks—one at each duration—were shown. On alternate days *S*s were given the two alternative letters verbally before each stimulus exposure and repeated them. This verbal information before each trial was the only difference in treatment for the condition where

*S*s had information before the trial (precue) as opposed to the condition where they did not have such information (no precue).

On each trial, *S* waited until she got a signal from *E*. During this time the fixation point was visible in the tachistoscope. After receiving the signal, *S* could initiate the stimulus with a hand switch whenever she was ready. The card with the masking field and response alternatives followed immediately upon termination of the stimulus and remained on for 5 sec. After the appearance of the response alternatives, *S* responded with the letter which she thought had appeared in the stimulus display. The intertrial interval was dependent upon the time taken to initiate the stimulus and to respond. The *E* occasionally timed the period between successive initiations of the stimulus and found that this period was generally somewhere between 15 and 20 sec. Inasmuch as one of the possible hypotheses mentioned in the introduction calls for testing of a null hypothesis, confidence judgments were obtained to provide more data on which to base a decision. The confidence judgments ranged from "1" to "4" and corresponded to the following: (1) able to identify the critical letter without reference to the alternatives; (2) able to choose between the two alternatives with better than chance accuracy; (3) not able to choose between the two alternatives with better than chance accuracy; (4) did not see the stimulus display at all.

The instructions to *S*s emphasized (*a*) the way in which the position of the critical item in the stimulus display could be determined from the position of the response alternatives on the card appearing after the stimulus display; (*b*) that only one of the two responses could occur anywhere in the stimulus display; (*c*) that before each trial *S*s were to look at the fixation point, in a position corresponding to the center of the area where the critical letter might occur; and (*d*) that one of the two response alternatives was to be given on each trial even if guessing was required. Finally, *S*s were shown an example of the sequence of events in the tachistoscope with the stimulus duration increased to 5 sec.

Subjects.—Each of nine paid volunteer female students at the University of Michigan served for fourteen 1-hr. sessions. All *S*s were able to read the 20:20 line on an eye chart with each eye, with glasses if they needed them. In addition to the nine *S*s, there were three *S*s who could not complete the 14 sessions. Three experimental sessions were repeated, two because of illumination changes during a session and one because of *E* error.

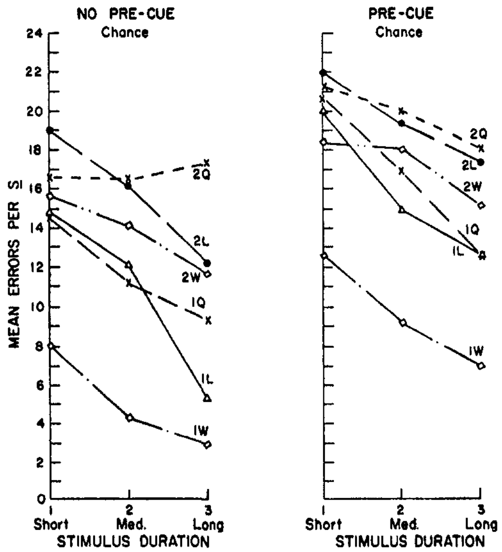

FIG. 1. Mean errors as a function of stimulus duration. (Data are for all *S*s combined, 432 observations per data point.)

RESULTS

A comparison of the left- and right-hand panels in Fig. 1 shows that *S*s did worse in the precue condition than in the no-precue condition. These conditions were exactly the same except for the advance information regarding the alternatives in the precue condition. The results (frequencies) for all comparisons to be cited were analyzed for significance by a contingency table analysis (Kincaid, 1962).[3] The differences between the precue and no-precue conditions for each type of material (collapsed over stimulus duration) were significant ($p < .01$ for each of the comparisons).

The experiment was successful in collecting data at three stimulus durations with different performance levels ($p < .001$ for all comparisons collapsed over type of material). This is also true when looking at data for individual *S*s. Collapsing over the other conditions, it was always the case that the long duration was easier than the short duration for every *S*.

The comparisons suggested earlier are as follows: Collapsing over stimulus duration in the no-precue condition, performance on

[3] Kincaid's procedure combines 2 (correct vs. incorrect) $\times$ *m* (conditions) contingency tables for each *S* to arrive at a single pooled 2 $\times$ *m* table; the test takes into account the consistent differences between *S*s in a manner analogous to the repeated measurements design in analysis of variance. The *S*s are treated as individuals rather than as a random sample from a large population, thus limiting statistical generality.

one word was better than performance on either one letter ($p < .001$) or one quadrigram ($p < .001$). Performance on two words was better than either two letters ($p < .05$) or two quadrigrams ($p < .01$). The same ordering was true for the results in the precue condition ($p < .01$ for all comparisons). Eight of the nine *S*s did better on the single words than on single letters. The one *S* who reversed this trend was the only *S* who said that she saw the words as four separate letters which she made into words. All other *S*s said that they experienced a word as a word and not as four letters making up a word.

Several other tests were made because they seemed of possible interest, although they are not independent of the tests made above or of each other. Performance on one of each type of material was better than on two of that same type of material ($p < .001$) for all comparisons in both cueing conditions. Performance on one quadrigram was better than performance on two letters ($p < .001$ for each cueing condition). Some *S*s reported that the two letters tended to divide their attention so that this type of material sometimes seemed more difficult for them than one quadrigram, which they could sometimes pronounce or make into a word.

The differences attributable to stimulus parameters held up over all serial positions except when the critical letter was in the bottom row in the two-item condition. The most important deviation from the general results was that performance on two words was not better than performance on two letters when the critical letter was in the bottom row. This was true for each stimulus duration.

The confidence scores support the frequency data in that *S*s were more confident on words than on the other types of material. However, the difference between one and two of each type of material was not as great as might be expected from the frequency data. Also, the finding that *S*s seemed slightly more confident on one quadrigram than on single letters does not support the frequency data.

Discussion

If we accept the assumption made in the past, i.e., that processing time is the critical variable in this task and is a monotonic function of the time between the onset of the stimulus and the onset of the masking field, we must conclude that single words are processed faster than single letters and reject a system for serial processing of sensory information. The Estes and Taylor (1966) fixed sample model suggests that there might be some limit to the number of letters which can be handled in parallel; this data can only suggest that for eight of nine *S*s the sample can be four or larger. The result that one *S* did better on single letters than on words (for all three durations) suggests that the type of scanning that *S* does may depend on set or strategy. If a person is looking for single letters, he may be able to scan letters rather than whole words. If he is expecting words, the reverse may be true. This would offer no particular problems to a parallel model of processing of sensory information but grave ones for a serial model. In that performance on two of each type of material was worse than performance on one of that same type, the interpretation that coded units or "chunks" might be handled serially remains tenable.

The fact that performance on words was actually better than performance on letters might suggest some difficulty with the assumptions made here. Thinking in terms of a hierarchical system of information processing makes it difficult to understand how a word might be processed faster than the elements of which it is comprised. If the assumption is wrong and some variable besides processing time is important in performance on this task, we would not know whether performance on words was as good as or better than performance on letters because of processing time or because of this other variable.

One possible explanation for the superiority of performance on words is that letters are forgotten more quickly than are words. The attempt to reduce the memory load by giving *S*s the response alternatives before presentation of the stimulus display was not successful. The data of the present experiment do not suggest any promising explanations of why prior information interfered with performance. Under somewhat different conditions, the opposite result has been found by Egeth and Smith (1967) and Long, Reid, and Henneman (1960).

A second possibility is suggested by the reports of some *S*s that a single letter was harder to find in the field of the tachistoscope than four letters. If the process of perception can be broken down into detection and recognition with the completion of the former necessary before proceeding to the latter, the superior performance on words could be explained in terms of their increased detectability due to the greater area taken up by words than by letters.

There are alternatives to hierarchical processing. Cattell (1886) thought that single words were read faster than single letters (in a reading reaction time experiment) because the association between a common word and the name of the word is more frequently made than the association between a letter and its name. Also, Gestalt field effects often suggest that whole figures are more easily seen than the elements of which they are comprised.

Neisser (1967) has recently postulated a theory of the sort considered here. He suggests that there are early passive analyzers which operate on information in parallel and that further "construction" of the percept takes place serially. The construction phase of perception could, presumably, take advantage of a considerable degree of lower level processing. Thus a word or even a "meaning response" could be constructed instead of the separate letters or words of which it is composed.

In conclusion, the present experiment cannot be considered conclusive with respect to the stage of information processing at which serial processing is imposed, but it appears quite clear that the total processing time for multiple-letter arrays need not exceed that for single letters.

REFERENCES

AVERBACH, E., & CORIELL, A. S. Short-term memory in vision. *Bell System Technical Journal*, 1961, **40**, 309–328.

BROADBENT, D. E. *Perception and communication.* Oxford: Pergamon Press, 1958.

CATTELL, J. M. The time taken up by cerebral operations. *Mind*, 1886, **11**, 277–292, 524–538.

EGETH, H., & SMITH, E. E. Perceptual selectivity in a visual recognition task. *Journal of Experimental Psychology*, 1967, **74**, 543–549.

ERIKSEN, C. W., & LAPPIN, J. S. Internal perceptual system noise and redundancy in simultaneous inputs in form identification. *Psychonomic Science*, 1965, **2**, 351–352.

ERIKSEN, C. W., & LAPPIN, J. S. Independence in the perception of simultaneously presented forms at brief durations. *Journal of Experimental Psychology*, 1967, **73**, 468–472.

ERIKSEN, C. W., MUNSINGER, H. L., & GREENSPON, T. S. Identification versus same-different judgment: An interpretation in terms of uncorrelated perceptual error. *Journal of Experimental Psychology*, 1966, **72**, 20–25.

ESTES, W. K., & TAYLOR, H. A. Visual detection in relation to display size and redundancy of critical elements. *Perception and Psychophysics*, 1966, **1**, 9–16.

KINCAID, W. M. The combination of $2 \times m$ contingency table. *Biometrics*, 1962, **18**, 224–228.

LONG, E. R., REID, L. S., & HENNEMAN, R. H. An experimental analysis of set: Variables influencing the identification of ambiguous, visual stimulus-objects. *American Journal of Psychology*, 1960, **73**, 553–562.

MILLER, G. A. The magical number seven, plus or minus two: Some limits on our capacity for processing information. *Psychological Review*, 1956, **63**, 81–97.

NEISSER, U. *Cognitive psychology.* New York: Appleton-Century-Crofts, 1967.

SPERLING, G. The information available in brief visual presentations. *Psychological Monographs*, 1960, **74** (11, Whole No. 498).

SPERLING, G. A model for visual memory. *Human Factors*, 1963, **5**, 19–31.

SPERLING, G. Successive approximations to a model for short-term memory. *Acta Psychologica*, 1967, **27**, 285–292.

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