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Acquisition of information from rapidly presented verbal and nonverbal stimuli*

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Two experiments tested recognition memory for rapidly presented stimuli. In Experiment I 16 words were presented at exposure times ranging from 25 to 500 msec followed by a yes-no recognition test. The results showed a strong dependence of memory performance on both exposure time and serial position. In Experiment II 16 random forms were presented at exposure times ranging from 125 to 2000 msec followed by a yes-no recognition test. Results for random forms showed that memory performance was strongly dependent on exposure time but not on serial position. Taken together, the results of Experiments I and II suggest qualitative encoding differences between verbal vs nonverbal stimuli.

Consider the encoding processes carried out by a person when confronted with a stimulus that he will later be asked to recognize. Such processes may be quite different, depending on whether the to-be-remembered stimulus has a verbal label (e.g., a word) or whether it does not (e.g., a randomly generated form). For *verbal* material, there are several ways of characterizing encoding. For example, one class of models emphasizes *rehearsal* of an auditory code for a stimulus (Sperling, 1967; Atkinson & Shiffrin, 1968; Rundus, 1971). Alternatively, encoding may be viewed in terms of "levels of processing" (Craik & Lockhart, 1972). Here, a S is seen as extracting successively "deeper" types of information from the stimulus: Visual processing is followed by acoustic processing, which in turn is followed by semantic processing, associative processing, and so on. Common to most theoretical frameworks, however, is the notion that after some fairly early processing stage the continued physical presence of the stimulus is unnecessary. That is, a pattern recognition process is assumed to operate on the physical stimulus, resulting in the activation of some preformed representation of the stimulus in long-term memory. Subsequent processing is done on this internal representation and may continue indefinitely after the physical stimulus has disappeared.

For *nonverbal* stimuli such as random forms, however, the situation is quite different. Unlike a word, a random form is a genuinely "new" stimulus, inasmuch as the S has presumably never seen it before and, therefore, does not have a preformed internal representation of it. In the absence of such a representation, processing would have to be done on the physical stimulus itself and would not be expected to continue after the stimulus has been removed. The results of two recent studies indeed suggest that encoding of a visual stimulus takes place only during the time that the stimulus is physically present (Potter & Levy, 1969; Shaffer & Shiffrin, 1972).

The experiments to be described in this paper have two purposes. The first purpose is to compare recognition memory for words and random forms in the same experimental paradigm. Qualitative differences between various memory functions for the two types of stimuli provide direct support for the notion that qualitative encoding differences exist between verbal and nonverbal material. The second purpose is to obtain functions relating recognition memory for random forms to the amount of time that the forms were originally exposed. Such functions may be viewed as relating acquisition of visual information to time, and they provide a useful basis for inferring possible mechanisms of visual encoding.

Two experiments will be discussed. Experiment I deals with words and Experiment II deals with random forms.

GENERAL METHOD

The method common to both experiments was as follows:

Subjects

A total of 10 Ss was used, one of whom (G.L.) served in both experiments. All the Ss except one (R.U., an artist) were workers or graduate students at New York University. Ages of the Ss ranged from 20 to 30 years.

Apparatus

The experiments were controlled by a Digital Equipment Corporation (DEC) PDP-15 computer. A DEC VT05 graphic scope was used to present the stimuli. The size of the scope face was 1000 x 1000 raster units.

Procedure

Ss served in experimental *sessions*, each of which was divided into 20 study-test *blocks*. A study-test block consisted of the

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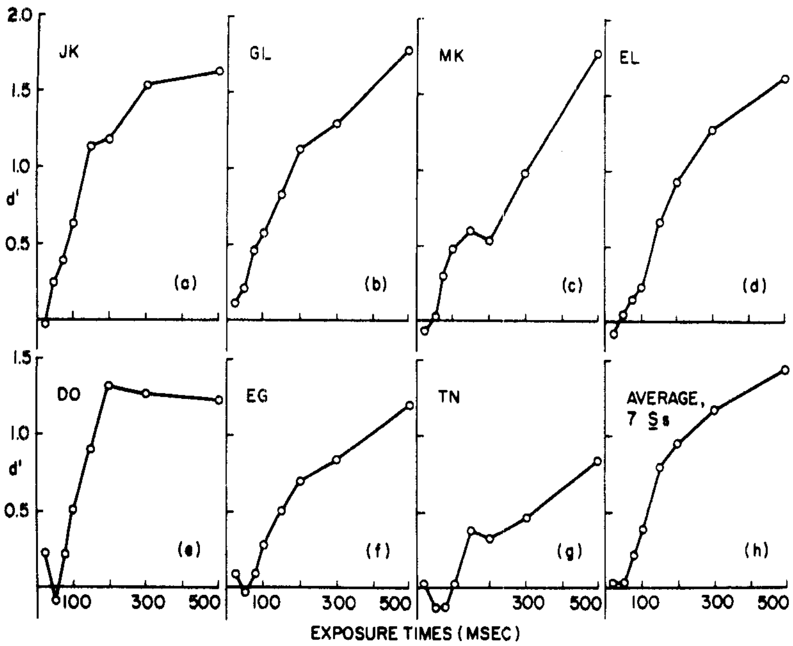

Fig. 1. Recognition memory for words as a function of exposure times. Panels a-g represent individual S functions and Panel h represents the average function.

following: The study phase began with a fixation point in the center of the screen for 2 sec. Immediately thereafter 16 target stimuli were presented to S at rates varying from 25 to 500 msec (words) and 125 to 2000 msec (forms). The interstimulus interval was always zero. Following the study phase, the word TEST appeared on the screen for 2 sec. In the test phase, the 16 target stimuli were randomly permuted and randomly intermingled with 16 distractor stimuli drawn from the same stimulus pool. The resultant 32 stimuli were then presented to S one by one in a self-paced yes-no recognition test. A response was made by pressing one of two specially marked keys on a Teletype. No feedback was given.

Memory performance was measured in terms of (1) the probability of a hit, p(H), which was the probability of correctly saying "yes" to a target item, and (2) the probability of a false alarm, p(FA), which was the probability of incorrectly saying "yes" to a distractor item. The hit and false alarm probabilities were then combined into a single measure of memory strength, d' from the theory of signal detection using the tables from Elliott (1964).

EXPERIMENT I

Method

The stimuli in Experiment I were the 3200 most frequent nouns from the Kucera and Francis (1967) norms. The 3200-word pool was randomly divided into five sets of 640 words per set. Each of seven Ss served in five sessions, with a different word set for each session. Each S had one practice session in which Word Set 1 was used. Word Sets 2-5 were then given in a random order over Sessions 2-5.

For a given session, the 640-word set for that session was broken into 20 groups of 32 words per group. Each of the 20 groups thus corresponded to one study-test block. At the beginning of a study-test block, the corresponding 32-word group was randomly divided into 16 target words and 16 distractor words.

Eight exposure times were used: 25, 50, 75, 100, 150, 200, 350, and 500 msec. In the study phase of a block, each exposure time was used twice. The ordering of exposure times within a block was random, with the restriction that each exposure time occur once in the first eight serial positions and once in the second eight serial positions.

Results and Discussion

Figure 1 (a-g) shows d' as a function of exposure time for the seven individual Ss and Fig. 1h shows the average function. In these functions, the data from Serial Input Position 16 are not included, since words in this position were not masked and were, thus, qualitatively different from the first 15 words. In general, all Ss show increasing performance at exposure times greater than 50 msec. However, only four of the seven Ss showed greater than zero memory strength for words exposed for 25 or 50 msec, and Fig. 1h seems to indicate that, on the average, memory performance is virtually zero for words presented at these exposure times. It will be argued below, however, that to accept this conclusion would probably be to make a Type II error.

Figure 2 shows memory performance as a function of serial position. For purposes of clarity, the only curves shown are the unconditional curve (collapsed over eight exposure times) and those conditionalized on exposure times of 25, 50, and 500 msec. Both the unconditional and the conditional curves exhibit the classical U shapes (Murdock, 1962). A two-way analysis of variance (ANOVA) was performed with exposure time and serial position as the independent variables. (For this analysis, serial position was collapsed into Positions 1-4, 5-11, and 12-15. Note that the qualitatively different Position 16 is omitted.) This analysis yielded significant effects of exposure time [$F(7,42) = 69.1$, $p < .01$] and of serial position [$F(2,12) = 9.90$, $p < .01$], but no significant interaction [$F(14,84) = 1.23$, $p > .05$]. The hypothesis of a U-shaped serial position curve is significant [$F(1,12) = 18.54$, $p < .01$] and accounts for 93% of the variance due to serial position. The residual variance due to serial position is not significant [$F(1,12) = 1.27$, $p > .05$]. Mention should be made of words exposed for 25 and 50 msec. As noted above, memory for such words barely exceeds zero when collapsed over serial position. However, the fact that these exposure times yielded typical U-shaped serial position curves and the fact that exposure time does not interact with serial position suggest that there is some memory at these exposure times for words in the first and last few serial positions.

In the present experimental paradigm, it may be assumed that incoming words are first pattern recognized and entered into a limited-capacity rehearsal buffer (Atkinson & Shiffrin, 1968). Processing (which corresponds to transfer of information to long-term memory) is carried out on words in the buffer. Thus, the longer a word resides in the buffer, the more processing is done on the word and the higher will be its eventual recognition rate. In addition, processing is assumed to be dispersed over all the words in the buffer, i.e., the smaller the number of words in the buffer, the more processing is accorded an individual word.

Within this framework, the total amount of processing received by a particular word depends on both its physical exposure time and its serial position. Denote a word in Serial Position i by W_i. The longer the exposure time of W_i, the more processing can be done on it before presentation of W_{i+1}, which could potentially displace W_i from the buffer. Words close to the beginning of the list receive more processing for two reasons. Consider an early position, i, where i is less than the buffer capacity.

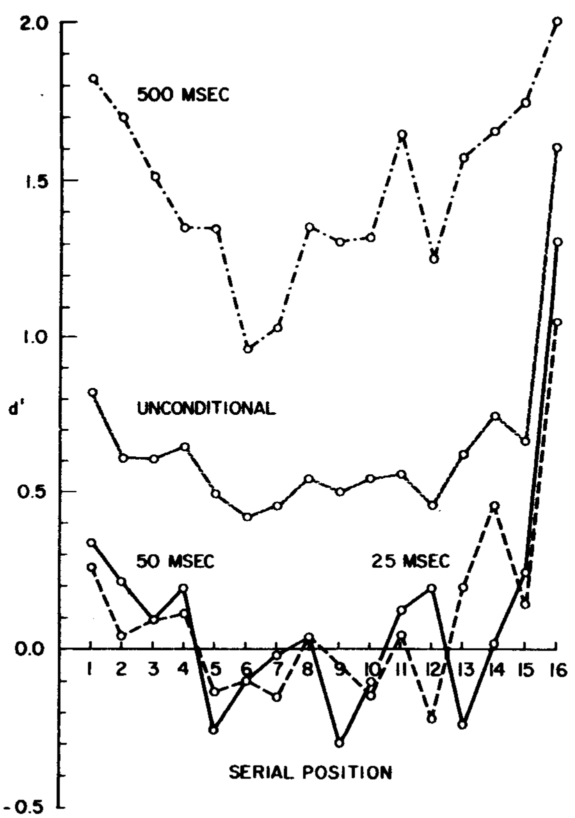

Fig. 2. Recognition memory for words as a function of serial position. Curves are shown for exposure times of 25, 50, and 500 msec and for performance collapsed over all eight exposure times.

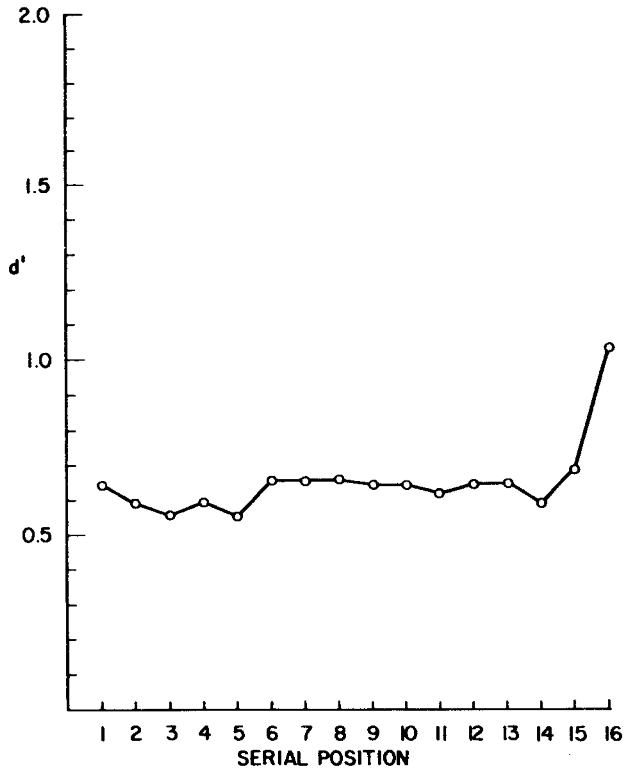

Fig. 3. Recognition memory for random forms as a function of serial position.

In such a case, the smaller is i (i.e., the closer W_i is to the beginning of the list), the greater will be the number of empty slots in the buffer. This means (1) that the probability of W_i being displaced by a subsequent word is lower, yielding a higher expected number of trials in the buffer and (2) the greater is the expected amount of processing per unit time on W_i. On the other hand, the closer W_i is to the *end* of the list, the smaller is the number of upcoming words which could potentially displace it. Therefore, a word close to the end of the list has a high probability of being in the buffer at the end of the study phase, in which case it can be processed for a relatively long time during the study-test interval.

EXPERIMENT II

Method

The stimuli were open-ended forms generated via the following algorithm: The first line of the form was of a random length between 40 and 70 raster units and was in a random orientation chosen from one of the eight compass directions. A second line was chosen in a similar way to the first, with the restriction that the orientation of the second line could not be 0 or 180 deg relative to the orientation of the first line, and then added to the end of the first. This procedure continued until a 10-line figure had been generated. The coordinates of the figure were then shifted appropriate distances along the Xand Y axes such that the figure, when presented, would be centered on the screen.

Four Ss participated in Experiment II. Each S participated in two practice sessions and eight experimental sessions. The exposure times used in four of the eight experimental sessions were 125, 250, 500, and 1000 msec. In the remaining four sessions, the exposure times were 500, 1000, 1500, and

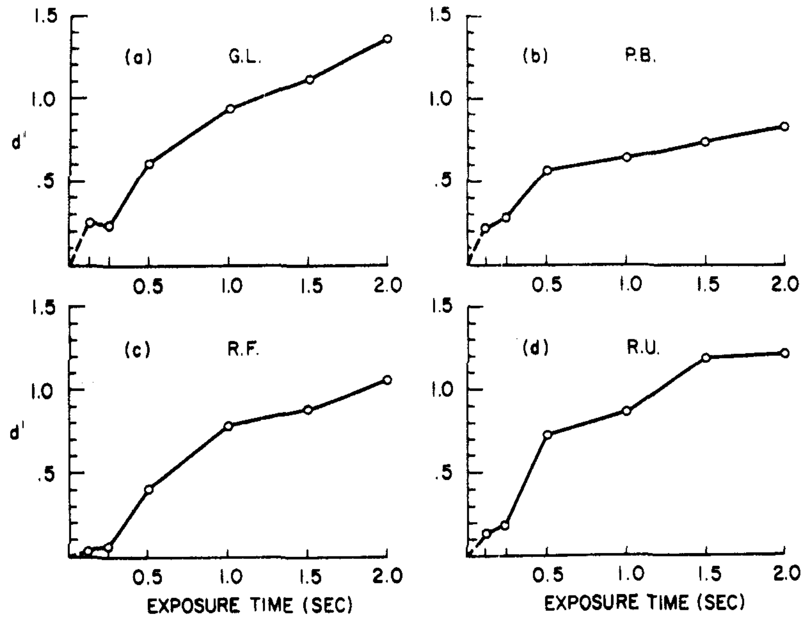

Fig. 4. Recognition memory for random forms as a function of exposure time. The four panels represent performance for the four individual Ss.

2000 msec. The order of presentation of these two types of sessions was counterbalanced over Ss. Within the study phase of a block, each of the exposure times was used exactly four times. Order of exposure times was random, with the restriction that each exposure time be used once in the first four serial positions, once in the second four, once in the third four, and once in the last four. A new set of random forms was generated for each S session.

Results and Discussion

Figure 3 shows d' as a function of serial position, collapsed over exposure times. In contrast to the corresponding curve for words (Fig. 2), this curve is essentially flat except for the qualitatively different Serial Position 16.

Figure 4 (a-d) shows d' as a function of exposure time for each of the four Ss. (Again, Serial Position 16 is omitted from these data.) All four curves display the following characteristics: Performance differs very little for exposure times of 125 and 250 msec; at times greater than 250 msec, the curves rise smoothly and monotonically. The effects of serial position and exposure time were tested in a two-way ANOVA, just as in Experiment I. This ANOVA yielded a highly significant effect of exposure time [$F(5,15) = 44.12$, $p < .01$], no effect of serial position [$F(2,6) = 1.08$, $p > .05$], and no interaction ($F < 1$).

When random forms are used as stimuli in the present experimental paradigm, the only variable affecting performance is exposure time, in keeping with the notion that a nonverbal stimulus such as a random form is processed *only* during the time it is physically present. The shapes of the curves in Fig. 4 allow some speculation as to the nature of the processing. Previous research on recognition memory for pictures has indicated that an eye fixation may be regarded as a special "unit of encoding" for visual material (Loftus, 1972). The conclusion of the Loftus (1972) study was that, within an eye fixation, most or all of the processing relevant to subsequent recognition memory is carried out very early in the fixation--perhaps within the first 100 msec. The present data are in accord with this notion: Forms exposed for 125 or 250 msec probably receive only one fixation. If all the acquisition of information takes place within the first 100 msec, then one would expect that recognition of a form exposed for 250 msec would be based on the same information as a form exposed for 125 msec and, therefore, performance would not differ for these exposure times. At exposure times greater than 250 msec, performance would be based on information acquired from two or more fixations and would increase over exposure time. These expectations are borne out by the data shown in Fig. 4.

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