Stimulus and response repetition effects for naming letters at two response-stimulus intervals¹

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Upper- and lower-case letters of the alphabet were presented sequentially to S using .2-sec and .7-sec RSIs. Reaction times for naming the letters were recorded for three classes of stimulus events: the letter was identical in form and name to the immediately preceding one (stimulus repetitions); the letter had the same name but a different form than the preceding one (response repetitions); and the letter was different in form and name from the preceding one (nonrepetitions). The results showed a significant advantage of SR over RR that decreased as the RSI increased and depended on the similarity of the upper and lower cases for the particular letters. These results are comparable to those obtained in letter-matching studies. A model to account for the results is proposed.

Posner and Mitchell (1967), Posner and Keele (1968), and Posner et al (1968), using the "same-different" reaction-time (RT) paradigm, have shown that the time required to call two visually presented letters the same depends upon whether the letters are physically identical (PI), e.g., AA, or whether the match must be made on the basis of their names (NI), e.g., Aa. Physical-identity matches generally are faster than name-identity matches; the magnitude of the difference depending upon the similarity of the upper and lower cases for the particular letters, and the interval between the offset of the first letter and the onset of the second (ISI) when the two letters to be matched are presented sequentially. The difference seems to be independent of the absolute latencies. Thus, the NI RTs for Cc, Ff, and Kk are found to average only about 20 msec longer than their controls, e.g., CC and cc, as compared to about 80 msec difference for other letters. And, at 0 sec ISI, NI - PI = 80 msec, while at 2 sec ISI, NI = PI.

There are similarities between this work with letter matching and recent studies concerned with the repetition effect in serial-RT tasks. In the serial tasks, Ss are required only to "identify" each stimulus presented, and are not required to match successive stimuli as in the S-D paradigm. However, Bertelson (1963) has suggested that Ss do make such comparisons, testing first whether or not the stimulus on Trial *n* is the same as the stimulus on Trial *n* - 1. This

strategy would result in a savings in RT on trials where the stimulus is the same as on the previous trial, assuming that either the stimulus-identification processes or the response-selection processes are serial. Bertelson (1965) and Rabbitt (1967) have also found that, if several stimuli are mapped into one response, there is an additional savings when both stimulus and response are repeated, as compared to trials when only the response is repeated. This stimulus-repetition (SR) effect corresponds to the advantage of PI matches over NI matches in the letter-matching studies. The latter difference has not been attributed to a serial stimulus-identification process but, rather, to the Ss' ability to match PI stimuli at an earlier stage of processing (where the letter has not yet been named, but where the physical characteristics of the letter are processed) than NI stimuli. This ability depends upon the state of the representation of physical information about the first letter presented and its similarity to the physical information representing the second letter.

The question arises as to whether or not the matching processes used in the S-D task are similar to the processes used in the serial task. The present study was run using stimuli, intervals, and sequential probabilities in the serial task that are comparable to those which have been used in the S-D task. If the processes are similar, we should expect: (a) a decrease in the advantage of SR over response repetitions (RR) as the response-stimulus interval (RSI) increases, and (b) a smaller advantage of SR for cases where there is greater similarity (visually) between the stimuli that are mapped into the same response.

METHOD

Subjects

Two male and six female undergraduates with normal or corrected normal vision served as paid volunteers.

Apparatus

The stimulus presentation, response-stimulus intervals, and recording of RTs was effected by means of a PDP-9 computer. The stimuli were presented in a rear-projection-type Industrial Electrical Engineering Series 10 read-out display situated in a room separated from the E and the computer. Communication was by

intercom and through a one-way window. A voice key, Grason-Stadler Model E73000A-1, in conjunction with a Wollensak Model B-162-20 microphone held to the S's throat were used to determine response latencies. Since the voice-key switch remained closed (the computer remained interrupted) while S was making his response, RSIs were timed from the end of his response. The stimulus remained on during S's response, but the display was blank (black) during the RSI. Thus, the RSI is also an ISI whose onset is determined by the S's response. Reaction times were recorded from the beginning of the stimulus presentation to the beginning of S's response. The RSIs were timed using a clock that pulsed every 1/60 sec. Reaction times were measured to the nearest millisecond.

Stimuli

Ten letters of the alphabet, A, B, F, H, K and a, b, f, h, k, in Alternate Gothic No. 3 type font, were used as stimuli. The computer was instructed to pick the order of presentation of the 10 letters randomly, with the restrictions that $p(\text{upper case/lower case}) = p(\text{lower case/lower case}) = p(\text{upper case/upper case}) = p(\text{lower case/upper case}) = .25$. Also, the probability of a letter with the same name appearing in Trials $n-1$ and n equals .50. Therefore, $p(\text{SR}) = p(\text{RR}) = .25$, while $p[\text{nonrepetitions}(\text{R})] = .50$. Note that the sequential probabilities are greater than they would be if the sequence were purely random. They were selected to correspond to S's expectations in the S-D matching paradigm.

Procedure

Each S participated in two sessions on consecutive days for ½ h each day. Day 1 was used to familiarize S with the equipment and task requirements and was not used in the analysis. Four blocks of 100 trials were run per day. Two RSIs, 200 and 700 msec, were counterbalanced in blocks within Ss in ABBA fashion. Half the Ss had the 200-msec RSIs on Trial 1.

Subjects were instructed to name the letter shown on the display as rapidly as possible and not to make errors. (No S made more than five errors in any block of 100 trials on the experimental day.) The sequential probabilities were explained, and

Table 1
Per Cent Errors Made by All Ss for SR, RR, and $\bar{R}$ in 200 and 700 Msec RSI Conditions

Repetition Class	Interval	
	200	700
SR	1.9	0.9
RR	2.1	1.1
$\bar{R}$	4.3	2.8
Mean	2.8	1.6

all Ss indicated that they understood these probabilities before the experiment was begun. The operation of the equipment and RSIs were also explained.

RESULTS

The Advantage of SRs over RRs

Error trials were included in the analysis, but all RTs less than .100 sec and greater than 1.500 sec were excluded. (Only 7 out of 3200 trials were thus eliminated.) The per cent error made in each condition is given in Table 1. An analysis of variance on square root transformed frequency scores showed a significant decrease in errors as the RSI increased [$F(2,14) = 6.54$, $p < .01$]. No other effect was significant. Since there was no restriction on the number of times any particular letter occurred within a block of trials, means were calculated for each letter within each class of repetition over both blocks of trials for each RSI and for each S. These means for individual letters were averaged to provide an estimate for each of the three classes of repetitions within each RSI for each S. A three-way repeated-measure ANOVA was performed upon the RT means of eight Ss, three repetition conditions, and two RSIs. Repetition class was a significant variable [$F(2,14) = 17.94$, $p < .001$], RSI was not [$F(1,7) = 2.31$, n.s.], but their interaction was significant [$F(2,14) = 4.57$, $p < .05$].

Fig. 1. Mean RT (in milliseconds) to nonrepetition ($\bar{R}$), response repetitions (RR), and stimulus repetitions (SR) as a function of RSI averaged over eight Ss.

The six means contributing to the interaction effect are plotted in Fig. 1. These means were further compared using Sheffé's procedure (Meyers, 1966).

A significant advantage of SRs over RRs was found at both RSIs. At .2 sec, SR trials averaged 48 msec faster than RR trials [$F(1,7) = 60.48$, $p < .001$], and at .7 sec, the advantage was 22 msec [$F(1,7) = 10.32$, $p < .05$]. Of primary interest is the decrease in this advantage as the RSI increases. The 26-msec decrease is significant [$F(1,7) = 18.58$, $p < .025$] and is comparable to the decrease in the advantage of PI over NI in the letter-matching studies. Extrapolating from Posner et al's Fig. 1, the difference goes from 74 msec, at .2 sec ISI, to about 45 msec, at .7 sec ISI, a decrease of 29 msec.

Effects of Similarity between Upper and Lower Cases on the Advantage of SR over RR Trials

Immediately following the final experimental session, Ss were asked which letters had the most similar upper and lower cases. All Ss reported that the capital "K" and the small "k" were most similar. When pressed further, only one S felt that "F" and "f" were "almost as similar" as "K" and "k." Therefore, a test was performed to determine if the advantage of SRs over RRs was less for the letter K than for all other letters combined. Difference scores (RR-SR) were calculated for each letter and S, averaged over both RSIs. An F test indicated that the difference for the letter K was significantly less than for all other letters combined [$F(1,7) = 7.21$, $p < .05$]. The RR-SR differences were: 40, 27, 67, 41, and 7 msec for the combinations Aa, Bb, Ff, Hh, Kk, respectively.

DISCUSSION

A Model

These results suggest that the processes used in the S-D letter-matching task and the serial letter-identification task are very similar; the S first tests whether or not two successive letters are the same, and this decision is faster when the letters are physically identical because they can make the decision at an earlier stage of processing than when the letters are identical in name only.

However, there are some difficulties with this explanation of the advantage of SR over RR trials in the serial task. Although the decreases in the SR and PI advantages are comparable as the ISI is increased, the overall advantage of SR over RR averages 24 msec less than the advantage of PI over NI. Furthermore, in all of Posner's matching studies, NI RTs remain fairly constant as the ISI is increased, while PI RTs increase. In the present study, the change in RR-SR tends to

be due to just the opposite, a decrease in RR of 39 msec and a slight decrease in SR of only 13 msec. The difference between these decreases failed to reach significance, however [$F(2,14) = 3.89$]. One might expect a decrease in all RTs as the RSI is increased within the limits of this experiment, as the longer intervals allow more time to prepare for the next response, regardless of its class (see Bertelson, 1967). Although six out of eight Ss show it, the decrease is not significant by the F test. However, we might argue that if the physical information were still as clear and as usable at 700-msec as it was at 200-msec intervals, then the SR RTs might decrease by another 39 msec. Since Posner et al (1968) found "rehearsal" of visual information when Ss were given the incentive (e.g., lists were constructed from letters using only one case, and no increase was found in PI RT as ISI increased), we would predict a greater decrease in SR in the serial task given such incentive. Bertelson and Renkin (1966) have investigated the two-response/two-stimulus case where only PI matches needed to be made (SR = RR), and where the RSI has varied from .050 to 1.000 sec. Their results suggest an increase in RT to repeated signals and a decrease in RT to new signals as the RSI increases.

This lack of evidence for a rehearsal effect in Bertelson and Renkin's data, as well as the smaller overall effect of NI - PI (RR-SR) in the serial tasks, suggests a major difference between it and the letter-matching task. In the latter, only the decision as to whether the letters are the same or different must be made. This decision can be made on the basis of the physical form of the letter alone, without regard to the name of the letter when the letters are identical. Thus, the advantage of PI matches over NI matches is a result of a terminal decision reached in the early stages of processing stimulus information. In the serial task, the name of the letter (or key press to some symbolic display) must always be processed. Therefore, the advantage of PI over NI repetitions may not be due to a terminal decision reached at a lower stage. Rather, we might think of the process as a savings in the time required to "read-in" the stimulus when it is physically identical to the immediately preceding one. It would be like regenerating a decaying trace or organization of neural elements that correspond to the "elements" making up the physical event. This might be easier than constructing a whole new organization of neural elements, which must be done when successive forms are not visually identical.⁴

Symbolic vs Spatial Displays

This analysis might help in resolving some conflicting results in the repetition-effect

literature. Schvaneveldt and Chase⁵ found no repetition effect at short ISIs (from .1 to 1.0 sec) for highly compatible two-choice and four-choice serial-RT tasks. A spatial display was used, where the correct key to be pressed was illuminated as a signal. Bertelson (1963) used a somewhat less compatible spatial arrangement (lights were separated from the keys) and found an effect at .050-sec RSIs. The effect increased as the stimulus/response mapping was made even less compatible. Therefore, each has argued that the repetition effect is a function of compatibility, and that the savings on RR trials is due to response-selection processes. However, in the present experiment, a highly compatible arrangement was used. Naming letters involves, on the average, about 15 years of practice for the college student. Yet, a large effect was obtained at short RSIs. The main difference seems to be that, in the present study, symbolic displays were used as stimuli. All previous studies involving the repetition effect at short RSIs, except for those mentioned above, have used symbolic displays (Hale, 1967; Bertelson & Renkin, 1966; Rabbitt, 1967; and Bertelson, 1965), and the repetition effect was found.

If the SR effect found in the present study is due to savings in the construction of some network of unit analyzers, the amount of savings could be a function of the complexity of the network to be constructed, so that a larger SR effect would be found using more complex displays. If spatial displays are less complex as stimuli than symbolic displays, then we might expect less of an SR effect. Thus, where spatial displays are used and where SR and RR effects are confounded, the direction and size of the effect will mostly be due to response-selection processes where compatibility and strategy are important. But for symbolic displays, the additional SR effect will give an advantage to repetitions over $\bar{R}$ at RSIs less than 1 sec.

The Advantage of RR over $\bar{R}$

A significant advantage of RR over $\bar{R}$ was found only at the 700-msec RSI. An advantage of 24 msec at 200-msec RSI [$F(1,7) = 2.30$, n.s.] increased to 43 msec at

700 [$F(1,7) = 10.32$, $p < .05$]. The increase in this advantage failed to reach significance [$F(1,7) = 3.10$], although six out of eight Ss showed this trend. If this trend is considered real, we might explain it by considering the following. Ss knew that the probability of a response repetition was .50. Since any one of four other letters could also occur with a probability of .50, a good strategy might be to prepare to say the name of the letter just given on the previous trial, thereby decreasing their RT to any response repetition. Preparing for any other letter would not help much, as they would have prepared for the correct letter only 12.5% of the time. Evidence for anticipation strategies has been shown by Keele (in press) and Schvaneveldt and Chase⁵ at long ISIs. If it takes time to utilize such a strategy (Hyman & Umlilt, 1968), then one would expect a larger advantage in RR over $\bar{R}$ as the RSI increases in the present experiment.

Conclusions

This experiment suggests that the repetition effect is a function of at least two components that may work in opposite ways in affecting the absolute RTs for the different classes of repetitions, thereby affecting the differences among them. The first is a stimulus-identification component that depends primarily upon the visual information available from the immediately preceding stimulus, and not on a strategy to test for the presence of the preceding stimulus first. The second is the ability of the S to make the correct response. This depends upon refractoriness of decision-making processes, as well as muscular and skeletal apparatus used in making the response, and upon whether or not the S has prepared to make the response. The second component tends to decrease SR and RR RTs as the RSI is increased, while the first tends to increase SR RTs as the RSI is increased.

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NOTES

1. This research was supported by the Advanced Research Projects Agency of the Department of Defense, and was monitored by the Air Force Office of Scientific Research under Contract No. F44620-67-C-0099.
2. I wish to thank Steven W. Keele for his many helpful suggestions on this paper, and Stephen J. Boies for programming the computer for the experiment.
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4. M. I. Posner (personal communication) has suggested an alternative model where the name of the stimulus presented on Trial $n - 1$ is stored along with the visual information. Ss always make PI and NI matches between the array on Trial n and the stored information. If the match is "same," then the name which is stored is repeated, and the S need not interrogate long-term memory to identify the stimulus. Thus, a savings will result where PI matches are made as opposed to NI matches.
5. Schvaneveldt, R. W., & Chase, W. G. Sequential effects in choice reaction time. In preparation.

(Accepted for publication April 30, 1969.)