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MEMORY FOR THE SPACING OF REPETITIONS [1]

DOUGLAS L. HINTZMAN [2] AND RICHARD A. BLOCK

University of Oregon

Memory for the spacing of two events was investigated in an "incidental learning" situation. When the events were two instances of the same word, judged spacing increased monotonically with actual spacing; when the events were single occurrences of two different words, judged spacing was not significantly affected by actual spacing. It is suggested that the spacing of repetitions is encoded in memory as an implicit judgment of recency, stored at the time of the second occurrence of the word, and retrieved on the spacing-judgment test.

A number of recent studies have shown that when *S*s study word lists, information about temporal variables is stored in memory. Even under incidental learning conditions, for example, the recency or serial position of a single occurrence of a word can be recalled with some accuracy (Hintzman, Block, & Summers, 1973; Zimmerman & Underwood, 1968), the serial position of several repetitions of the same word can be simultaneously remembered (Hintzman & Block, 1971), and a word's exposure duration can be judged to some extent independently of its frequency (Hintzman, 1970). These findings raise a general question about the extent to which memory is "time encoding": What other temporal variables are *S*s able to recall?

Our present concern is with memory for the spacing of repetitions of an item. It is a well-documented fact that long-term retention of a word increases with the spacing of repetitions (e.g., Melton, 1970). The question of interest here, however, is whether spacing information is stored in memory as a retrievable quantity, and if so, how it is represented. The answer to this question may or may not be related to the effect of spacing on degree of retention.

One published study suggests that spacing information may in fact be stored. Hintzman and Block (1970) orthogonally varied the frequency and the spacing of repetitions of words and then had *S*s judge how many times in a row each word had occurred. Unlike frequency judgments, these judgments of successive repetitions were higher for massed than for distributed items. Apparently, information differentiating spacings of zero from spacings greater than zero had been stored. It is quite possible, however, that this conclusion does not hold generally over the spacing dimension. Successive or massed repetitions may be reacted to and therefore encoded in a distinctive way, while spacings greater than zero may all be encoded in a way that makes them indistinguishable.

The primary purpose of the present experiment, therefore, was to determine whether differences among spacings greater than zero can be judged reliably. Given that they can be, then a second question concerns the way in which spacing information is represented in memory. One logical possibility is that the time of occurrence of each presentation is represented by a distinctive time tag (Hintzman & Block, 1971) and that the spacing judgment is based on the difference between two such tags. Considering the degree of unreliability of judgments of serial position (e.g., Hintzman & Block, 1971, Experiment 1),

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[2] Requests for reprints should be sent to Douglas L. Hintzman, Department of Psychology, University of Oregon, Eugene, Oregon 97403.

it seems unlikely that a comparison of independent time tags would be a reliable means of judging relatively short spacings in a long list. Nevertheless, this hypothesis cannot be eliminated without a direct comparison. A second purpose of the experiment, therefore, was to compare judgments of the spacing of repetitions of the same word with judgments of the spacing of single presentations of two different words. If judgments in both situations are based on essentially the same kind of information, then they should be of comparable reliability.

Method

A word list was presented in which a number of words occurred two times, and the spacing of repetitions of these words was varied. Matched with each repeated word was a word pair. Each member of the pair occurred once, and the spacing between the first and second members was the same as that of the repeated word with which the pair was matched. On the retention test, *S*s were asked to judge the number of items that had intervened between two events. The two events were either instances of the *same* word or of two *different* words.

Materials and design. The experimental items were 96 three-letter nouns of high (20+ per million) Thorndike-Lorge count. Four words were randomly assigned to each of eight *same* word conditions and eight words were randomly assigned, in four pairs, to each of eight *different* word conditions. In the *same* word conditions, words were paired with themselves on the spacing-judgment test (e.g., ELK–ELK), while in the *different* word conditions, two different words were paired on the test (e.g., FAN–COT). The words in one of the *same* word conditions occurred on the test sheet, but not in the list (F = 0); those in another had a list frequency of one (F = 1); and those in the remaining six conditions occurred twice each (F = 2). The spacings of the F = 2 words were S = 0, 1, 2, 5, 10, and 20 intervening items. The eight *different* word conditions exactly paralleled the *same* word conditions. In one, neither member of the pair occurred in the list (F = 0); in another only one member occurred (F = 1); and in six both members occurred (F = 2) with spacing varied as in the *same* word conditions.

The appropriate number of slides of each word was constructed by typing the word on white paper and mounting it in a slide frame. Fifteen slides of filler words, also three-letter nouns, were similarly constructed. The 119 slides were arranged in a continuous sequence in two Kodak Carousel slide trays; the first 10 and last 5 slides were of filler words. The 104 slides of experimental words were divided into four blocks of 26 slides each, and all conditions except F = 0 were represented in each block. The order of conditions within blocks was varied.

A single test form was used for all *S*s. On it, 64 pairs of words were typed side by side, and a blank line for *S*'s spacing judgment appeared to the right of each pair. In the *different* word conditions, the member of the pair that had appeared earlier in the list was typed on the left and the one that appeared later on the right. In the *same* word conditions, as indicated above, both members of the pair were the same. The order of the pairs on the test form was random with the restrictions that each experimental condition was represented once and each block of the list was represented four times in every block of 16 test pairs.

Subjects and procedure. The *S*s were 56 paid volunteers obtained through the University of Oregon employment office. They were tested in groups of up to five *S*s each. Between sessions, the particular words assigned to each condition were rotated within the eight *same* word and within the eight *different* word conditions. Approximately equal numbers of *S*s received each of the eight rotations.

At the outset of the experiment *S*s were told that some of the words would be repeated in the series and that they were simply to study each word and try to remember it for a later test. The list was then presented by a Kodak Carousel projector set at a 5-sec. rate.

After the list had been presented, the test sheets were distributed. In order to bias *S*s toward indicating that both members of a pair had occurred, they were told to cross out all the words that they did not remember. It was further explained that when a word was paired with itself, they were to cross out one copy of the word if they thought it had occurred only one time, and both copies if they thought it had not occurred at all. The *S*s were told that when they remembered both members of a pair, whether a *same* word or *different* word pair, they were to estimate the number of other words which had occurred in between. They were told to restrict their estimates to the numbers 0–15, with 0 meaning that the members of the pair occurred in immediate succession. Finally, it was pointed out that when both members of a *different* word pair had occurred, the word on the left occurred earlier than the word on the right.

Results

Having *S*s cross out words that had not occurred raised both the hit and false alarm rates considerably over those obtained in experiments in which simple *old–new* judgments or numerical frequency judgments are given. Table 1 presents the proportions of test pairs for which *S*s indicated (by crossing out neither word) that both members of the pair had occurred. As would be expected, in both the *same* word

TABLE 1
PROPORTION OF TEST PAIRS BOTH JUDGED *Old*

Condition	*Same* word	*Different* words
F = 0	.40	.44
F = 1	.66	.58
F = 2 (all)	.84	.89
S = 0	.78	.92
S = 1	.86	.90
S = 2	.87	.88
S = 5	.83	.89
S = 10	.87	.85
S = 20	.84	.90

Note. Abbreviations: F = frequency; S = spacing.

and the *different* word conditions, this proportion was greater the more the members of the test pair had actually been presented. Performance on *different* words was slightly higher than that on *same* word pairs, F (1, 55) = 5.90, $p < .025$. It can also be seen that for F = 2 test pairs, a spacing effect occurred across the *same* word conditions, but not across the *different* word conditions. The contrast of S = 0 vs. S > 0 was significant in the former case, F (1, 55) = 7.10, $p < .01$, but not in the latter case, F (1, 55) = 3.09, $p > .05$. The interaction of this contrast with the *same* vs. *different* conditions was significant, F (1, 55) = 9.69, $p < .01$.

The *S*s gave spacing judgments only when they indicated that both members of the test pair had occurred (those cases contributing to the proportions in Table 1). In order to determine the effect of actual frequency of members of the test pair on spacing judgments, only data from 31 *S*s who contributed to all six proportions in the top three rows of Table 1 were included in an analysis of variance. The mean spacing judgments for F = 0, 1, and 2 for *same* word pairs were 7.67, 6.32, and 5.16, respectively, while the corresponding values for *different* word pairs were 7.47, 6.70, and 5.08. In the analysis of variance, the main effect of frequency was significant, F (1, 30) = 41.5, $p < .001$, while the *same* vs. *different* comparison and its interaction with frequency were not. Why this effect of frequency occurred is not clear, but it may simply mean that the less well the *S*s remembered the words of the pair being judged, the more they tended to distribute their judgments over the entire judgment scale (0–15). The lack of any effect of *same* vs. *different* pairs on these mean judgments suggests that there was no strong differential bias operating in the case of the two types of test pairs.

Data from all *S*s were pooled, and the median spacing judgment was determined for each spacing. These medians are presented in Figure 1. It is clear that judgments in the *same* word and *different* word conditions were not affected by spacing in the same way. Judgments of spacing increased monotonically with the spacing of repetitions of the *same* word, while the function for *different* word pairs was essentially flat. Further, the two curves cross. At S = 0, 1, and 2, spacings of *same* word pairs were judged to be shorter than those of *different* words, while at S = 10 and 20, they were judged to be longer.

For statistical analysis of the spacing-judgment data, within-*S* comparisons were desired. Therefore, those *S*s who failed to contribute at least one score to each of the 12 proportions in the bottom six rows of Table 1 were excluded from the analysis. Of the 56 original *S*s, 54 met the criterion for inclusion. For each of these *S*s, a mean judgment was computed for each spacing, and these scores were subjected to an analysis using planned comparisons (Grant, 1956). The analysis indicated a significant

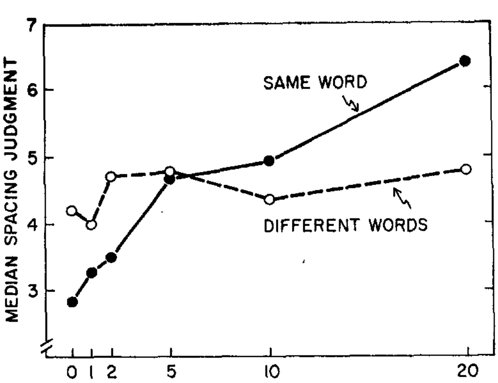

FIG. 1. Median judgments of spacing as a function of spacing for *same* word and *different* word test pairs.

linear increase of judged spacing as a function of spacing in the *same* word conditions, F (1, 53) = 36.0, $p < .001$, but not in the *different* word conditions, F (1, 53) = 1.10, $p > .10$. The Linear Trend Test × *Same* vs. *Different* Conditions interaction was significant, F (1, 53) = 14.0, $p < .001$. An additional test for linear trend, partially redundant with the first, indicated that the continued increase in *same* word judgments across S = 5, 10, and 20 was reliable, F (1, 53) = 17.6, $p < .001$. Thus, in the *same* word conditions, spacing information was encoded and retrieved at long, as well as at short, lags.

Discussion

The primary question this experiment was designed to answer was whether information about the spacing of repetitions is encoded in memory as a retrievable quantity. The answer to the question is clearly that it is. Further, there do not seem to be any discontinuities in the spacing-judgment function which would give immediate repetitions (S = 0) special status—the function is a smooth, monotonic curve over the spacings used here. Nor does it reach an asymptote at around three or four intervening items, as does the effect of spacing on judged frequency (e.g., Hintzman, 1969). This suggests that there may be no direct relationship between memory for spacing and the effect of spacing on degree of retention.

The question of secondary interest here concerned the way in which spacing information is represented. The experiment was designed to test the hypothesis that in making a spacing judgment *S* retrieves the time tags of the two presentations of the word and judges the difference between them. Traces of the two presentations of a word, in this explanation, are assumed to be stored and retrieved in a fairly independent way, just as traces of two different words would be. Contrary to this hypothesis, however, the results indicate that spacing judgments in the *same* word and *different* word conditions must have been based on different kinds of information. Performance in the *different* word conditions suggests that, under the present conditions, a spacing judgment based on a comparison of two independent time tags would have been very unreliable. Indeed, judgments of spacing of different words were not significantly affected by spacing. This was true even at S = 0, where one might expect word–word associations due to contiguity, if they were formed, to mediate the judgment.

Why was performance on *different* word pairs so poor? If, as hypothesized, spacing judgments in this condition are based on time tags, then there is reason to expect poor performance. In the first place, judgments of position are more accurate near the beginning or end of a word list than they are in the middle (Hintzman & Block, 1971; Hintzman et al., 1973; Zimmerman & Underwood, 1968), and in the present study experimental items never occurred in the first 10 or last 5 positions. In the second place, the accuracy of judgments based on time tags seems to depend on *relative* recencies (Yntema & Trask, 1963), and in the present case, in a fairly homogeneous list of 119 words, the maximum spacing was only 20. Presumably, under some circumstances—for example, if one word occurred near the beginning of the list and the other occurred near the end—temporal cues could provide information about spacing of different words. However, in the present experiment, relative differences in serial position were not great enough to produce reliably different judgments of position. And for a spacing judgment based on the difference between two such judgments of position, the degree of unreliability would be compounded.

In a previous paper (Hintzman & Block, 1970), it was suggested that temporal variables might be encoded in memory in a fairly direct way, much as in a tape recording. This was a basic idea underlying Koffka's notion of the "trace column" (Koffka, 1935). Such a model, without additional elaboration, suggests that spacing judgments for *same* word pairs should be no more reliable than those for *different* word pairs, and our present results indicate that this is not the case. While one might make the trace column model consistent with the present results by postulating different retrieval rules for *same* word and *different* word test pairs, we would like to propose another explanation instead.

Assume first that the memory trace for a given presentation of a word includes associations between the meaning of the word and elements of the cognitive context prevailing at the time it was attended to (Anderson & Bower, 1972; Hintzman et al., 1973). The cognitive context is assumed to include feelings, attitudes, associations, etc.—whatever *S* is aware of at the time he studies the word. Some elements of the context act as time tags in the sense that they provide information about when the word occurred. Second, assume that one typical effect of the second presentation of a word is to retrieve the trace of the first, including the corresponding contextual associations. Of course, this would occur only if both the trace and its contextual associations were still accessible in storage. At the time of the second presentation, then, *S* is usually aware of several circumstances surrounding the first presentation. He knows that the word occurred before, and because of the retrieved time tag he knows approximately how long ago it occurred. The second occurrence of the word during the study phase of the experiment thus produces what is essentially an implicit judgment of the recency of the word's first occurrence. When this implicit recency judgment is elicited by the second occurrence of the word, it is encoded in memory as part of the context of the second presentation. On a later retention test, when the word is presented as a memory probe, it retrieves the various contextual elements that were stored during the study phase. The *S* is able to judge the spacing of repetitions of the word by using the implicit judgment of recency which was stored when the word occurred the second time. The same information, of course, would not be available for *different* word pairs, since presentation of the second member of an unrelated pair during the study phase would not ordinarily retrieve the trace of the first member, and so the necessary implicit recency judgment would not have occurred.

According to this view, then, information about the spacing of repetitions is encoded in memory during the study phase, at the time of the word's second occurrence, and the spacing judgment is really a delayed judgment of recency. Considering the "incidental learning" nature of the present task and its several methodological peculiarities, the findings concerning judgment of recency (e.g., Hinrichs & Buschke, 1968; Peterson, 1967) do not seem inconsistent in any obvious way with this view.

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