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REPETITION AND MEMORY:
EVIDENCE FOR A MULTIPLE-TRACE HYPOTHESIS [1]†

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Two hypotheses concerning the effect of frequency on memory are (*a*) that repetition increments the cumulative strength of a single memory trace and (*b*) that repetition results in multiple traces, each identifiable by its "time tag." Results from two experimental paradigms supported the multiple-trace hypothesis. In one paradigm, words were presented twice in a single list, and subsequent judgments of serial position showed that the effects of the two repetitions could be discriminated in memory. In the other paradigm, a combined frequency-judgment and list-discrimination task demonstrated that *S*s could differentiate between recent and remote frequencies of the same word. It is concluded that the internal representation of frequency is one in which the identities of individual repetitions are preserved. Implications for the frequency theory of verbal discrimination learning are discussed.

The frequency or number of repetitions of a to-be-remembered event affects several measures of memory performance. The more times the event has been presented, the more accurate are its recall and recognition, the shorter is its retrieval latency, and the higher is its judged frequency. These effects may not all be due to the same underlying process, but it is most parsimonious to assume, lacking clearly contradictory evidence, that they are. This paper deals specifically with the question of how repetitions (i.e., frequency) are represented in memory, but it is assumed that the findings also have implications regarding the effects of repetition on recognition and recall.

Two hypotheses that have been offered to account for the effects of frequency could be called, respectively, the strength hypothesis and the multiple-trace hypothesis. The first states that the effect of repetition of an event is to increase the strength of a single memory trace representing the event. The second states that the effect is to increase the number of different memory traces of the event. Applied to the representation question, the strength hypothesis implies that event frequency is represented by trace strength (Hintzman, 1969, 1970), while the multiple-trace hypothesis implies that it is represented by trace frequency. The present experiments

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demonstrate certain effects of repetition that are expected by the multiple-trace hypothesis, but that the strength hypothesis, without additional assumptions, does not predict. As will be pointed out later, the two hypotheses are not necessarily mutually exclusive. Strictly speaking, therefore, the findings do not disprove the strength hypothesis, but might be interpreted as indirectly weakening it by lending support to its alternative.

The strength hypothesis assumes that a repeated event leaves only one, undifferentiated, trace, while the multiple-trace hypothesis assumes that it leaves more than one. If these assumptions are to lead to different predictions regarding behavior, the second hypothesis must further specify just how the multiple traces differ from each other. They might differ in several ways, but perhaps the most obvious way, since different repetitions necessarily occur at different points in time, has to do with stored temporal information. Let us assume, following Yntema and Trask (1963), that if two words, A and B, are presented at different times, they result in two traces, a and b, which can be differentiated in terms of stored temporal information, or "time tags." The evidence for this is that *S*s are able, with some accuracy, to discriminate and judge recencies of occurrence of serially presented items (Hinrichs & Buschke, 1968; Yntema & Trask, 1963). We wish to generalize this notion to repeated events by assuming that if Word C occurs twice, then two memory traces, c and c′, result, and they, like a and b, can be differentiated by their time tags.

Restated, then, the multiple-trace hypothesis assumes: (*a*) that each repetition of an event leaves its own trace, (*b*) that each trace coexists with traces of other repetitions of the event, and (*c*) that each individual trace can be identified by its time tag. This is to be contrasted with the strength hypothesis, which assumes only a unidimensional change in magnitude as a function of repetition. In a cumulative strength representation of frequency, the contributions of individual repetitions are not identifiable.

The experiments presented here use two paradigms which are somewhat different methodologically, but which have the same purpose of testing implications of the multiple-trace hypothesis. In the first paradigm, judgments of serial position are used to show that the effects of two repetitions of the same word can be discriminated in memory. In the second paradigm, a combined frequency-judgment and list-discrimination task is used to show that *S*s store information about local densities of repetitions that would not be reflected in strength.

In addition to providing evidence for the multiple-trace hypothesis, the findings suggest a way to account for a predictive failure of the frequency theory of verbal discrimination learning. This point will be elaborated in the Discussion section.

Position Judgments

Several experiments in which *S*s were asked about recencies of events have shown that memory involves some kind of temporal encoding. In one technique (e.g., Yntema & Trask, 1963), *S* is asked to tell which of two items occurred more recently. In another (e.g., Hinrichs & Buschke, 1968), he is presented with a test item and asked for a numerical judgment of the number of items that intervened since its last occurrence. Both experimental methods reveal that *S*s have some ability to judge the recencies of occurrence of events from memory.

The intent here was to demonstrate the coexistence in memory of time tags for two different repetitions of the same word by showing that the time tags can be manipulated independently. For this purpose, a slightly different task was used. A list of words was presented with *S*s instructed to study them for a alter memory test. Following this, *S*s were asked to record on a test sheet judgments of serial position for the words, one judgment if the word occurred once, two if it occurred twice.

For the present purpose, the method of position judgments has two primary advantages over that of recency judgments. First, the presentation and test phases of the experiment are separate; thus, acquisition can take place under "incidental learning" instructions, and more specific information about what it is that is to be retrieved from memory can be delayed until immediately preceding the test. This minimizes the likelihood that *S* will adopt a storage strategy that is peculiar to the task at hand. Second, the beginning and end of the list provide two distinct temporal reference points for the judgment scale, and intuitively it seems that it should be easier for *S* to make judgments about first and second repetitions of an item with reference to such a scale than to a recency judgment scale, which really has only one reference point.

Two experiments using position judgments will be reported. Experiment I was a preliminary study in which each word occurred only once in the list. Its purpose was to provide information regarding *S*s' abilities to remember serial position. The results were used in choosing conditions for Exp. II, in which words were repeated twice and *S*s were given the option of recording two position judgments.

Experiment I

Method

Materials.—A total of 55 three-letter nouns of high (20+ per million) Thorndike-Lorge count were selected as experimental items. Each word was typed in bulletin-style type and photographed, and the negatives were mounted in Easymount slide frames. Fifty of the words were randomly selected, and their slides were arranged in series in a Kodak Carousel tray. Three permutations of the 50-word list were used. The remaining 5 words served as distractor items and appeared only on the test form.

A single test form was used for all *S*s. On it, the 55 words were typed in random order in two columns, each word followed by a blank line for *S*'s position judgment. At the top of the test form, the position judgment scale was illustrated by a horizontal line divided into 10 equal segments. The segments were labeled from left to right with the numbers 1 through 10; in addition, the verbal labels "beginning of series" and "end" marked the left and right ends of the scale, respectively. To the left of the scale appeared the digit 0, with the label "did not occur."

Subjects.—The *S*s were 35 paid volunteers obtained through the University of Oregon employment office. They were run in groups of up to 5 *S*s each; approximately equal numbers of *S*s were shown each of the three versions of the list.

Procedure.—At the outset of the experiment, *S*s were simply told that they would be shown a series of 50 three-letter nouns and that they should study each word and try to memorize it for a later memory test. The slide series was then presented using a Kodak Carousel projector set at a 5-sec. rate. Following presentation of the list, test sheets were distributed and *S*s were told to write on the blank line after each word a number corresponding to their best guess regarding the tenth of the list in which the word had appeared. The instructions referred to the scale illustrated at the top of the page and carefully explained that "1" referred to the first five positions, "10" to the last five, etc. *S*s were told that if they thought a word had not occurred, they were to give a judgment of zero.

Results and Discussion

The false-alarm rate (nonzero judgments to the five distractor words) was 35%, and the hit rate was 85%, distributed about evenly over several positions. While position judgments were quite variable, the mean nonzero judgments described a fairly smooth increasing function of serial position, as can be seen in Fig. 1. The greatest increase in mean judgments occurred over the first 10 positions of the list, and the

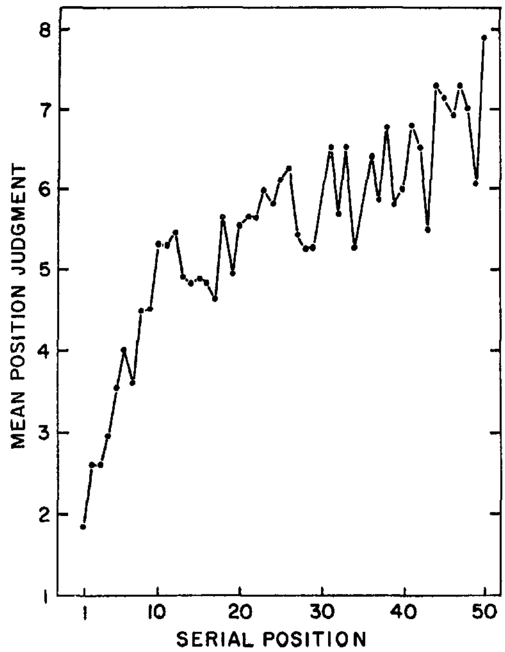

FIG. 1. Judgments of serial position, Exp. I.

slope of the curve over the remaining positions was more gradual. Thus, position discrimination was poorest in the middle and late portions of the list.

This experiment is of some interest in its own right, and although they deviate from the main purpose of the present paper, some brief comments are in order. First, the method is not entirely new; Schulz (1955) obtained judgments of serial position following multiple trials in a standard serial learning task, and more recently Underwood (1969) has described some unpublished experiments similar to the present one. Second, the finding that *S*s store serial position information is consistent with the hypothesis that position is a cue in multiple-trial serial learning (Young, 1968). Third, the shape of the curve of Fig. 1, with its strong primacy effect, bears a striking resemblance to the serial position curve of delayed free recall (e.g., Glanzer & Cunitz, 1966, Fig. 2). This suggests a common mechanism. One possiblility is that the primacy effect in free recall is due to a retrieval strategy that makes use of position information (cf., Shiffrin, 1970; Zimmerman & Underwood, 1968). Finally, the strong primacy effect in position judgments would be difficult to account for on the assumption that recency is represented in memory by the strength of an exponentially or logarithmically decaying trace (Hinrichs, 1970). Some other factor, possibly contextual information, may be responsible for the result. (Note that the question of whether recency is represented by strength is not the same as that of whether frequency is represented by strength, with which we are primarily concerned here.)

Experiment II

In this experiment, the first and second positions of repeated words were orthogonally varied, and *S*s were allowed to give two position judgments, in order to determine the extent to which the two judgments could be manipulated independently.

Method

Materials.—Four "zones" of the 50-item list were selected, each including six positions. Zones A, B, C, and D included Positions 3–8, 9–14, 15–20, and 43–48, respectively. On the basis of Fig. 1, these positions were expected to maximize *S*s' abilities to make A versus B and C versus D discriminations.

The word population and slide construction were as in Exp. I. Two words were assigned at random to each of nine different conditions. Words of one condition served as distractor items and appeared only on the test form. In four conditions—A, B, C, and D—words occurred once each, within the zones identified by the letters. In the other four conditions, each word occurred twice, in two different zones, identified by letter pairs as follows: AC, AD, BC, BD. Positions outside the four zones were occupied by filler words, most of which occurred just once.

The 18 experimental words were listed in random order on a single test sheet, each followed by a blank line. At the top of the page, the position judgment scale of Exp. I was illustrated.

Subjects and procedure.—There were 44 *S*s from the previously described population, run in groups of up to 5 *S*s each. Between sessions, the experimental words were rotated systematically through the nine conditions and conditions were rotated through positions within each zone so that effects of individual words, positions, and test order were all controlled.

The experiment was conducted in essentially the same manner as Exp. I. The one exception was that the test instructions gave *S*s the option of recording two different judgments for a word. It was emphasized that if *S* thought a word had occurred twice, he was to indicate this with two judgments corresponding to the two positions in which the word had occurred.

Results and Discussion

The false-alarm rate on distractor words was 16% (14% single and 2% double position judgments). The overall hit rate (nonzero judgments) was 86% on nonrepeated and 98% on repeated words. Each *S*'s nonzero judgments were categorized first by condition and then according to whether one or two judgments had been given to the word. An *S* could contribute zero, one, or two scores to each of these categories since each condition was represented by two words; however, only one mean score per category was recorded for each *S* who contributed to it, and the means of the *S* means are presented in Table 1. Also listed in the table are the percentages of responses (not of *S*s) falling in the one- and two-judgment categories for each

TABLE 1

MEAN POSITION JUDGMENTS TO NONREPEATED AND REPEATED WORDS, EXP. II

Cond.	Mean position judgment				
	One given	(%)	Two given		(%)
			First	Second	
A	*3.59*	(75)	2.86	6.85	(8)
B	*5.18*	(78)	2.60	7.60	(8)
C	*5.65*	(74)	3.69	6.54	(15)
D	*7.16*	(83)	2.00	7.00	(3)
AC	4.19	(39)	*2.18*	*7.16*	(61)
AD	4.60	(41)	*2.36*	*8.04*	(57)
BC	5.58	(43)	*3.55*	*7.49*	(55)
BD	4.91	(44)	*3.14*	*8.14*	(50)

condition. The italicized values are the mean judgments in cases where the correct number of judgments was given.

Notice first that if *S* gave two position judgments to a word, the judgments tended to be more extreme than if he gave only one. This was true regardless of how many repetitions the word actually received and is probably an artifact: when two judgments are made, the range of possible values for one or both of them is necessarily restricted. Next consider those cases in which *S* correctly gave one judgment to a word that occurred once (the first four means of Column 2). The values do not deviate substantially from what would be expected given the curve of Fig. 1 and the positions represented by the four zones, indicating that *S*s responded to nonrepeated words much as they had in Exp. I.

Of more interest are those cases in which *S* correctly gave two judgments to a repeated word (the bottom four means of Columns 4 and 5). It can be seen that the primary determinant of a position judgment was the actual target position of the word in the list. The nontarget position contributed little. That is, the first-position judgments of Cond. AC and AD were about the same and differed from those of BC and BD. Likewise, the second-position judgments of AC and BC were alike and differed from those of AD and BD.[3]

Separate analyses of variance were applied to first- and to second-position judgments of repeated words. Ideally, an analysis that takes into account the within-*S* design would be preferred. However, since *S*s could choose to respond with one or with two judgments, fewer than half of the *S*s (20) contributed to the two-judgment categories of all four repeated-word conditions. Rather than discard so many observations, it was decided to treat the four conditions as independent, and a 2×2 analysis of variance model for unequal *N*s which employs the method of expected cell frequencies was used (Myers, 1966, pp. 108–111). The two analyses supported the previous observations: judgments of first position were affected by first position, $F\ (1, 138) = 24.4$, $p < .001$, and not by second, $F < 1$, while judgments of second position were affected by second position, $F\ (1, 138) = 10.67$, $p < .005$, and not by first, $F < 1$.

These results show that the positions in a list of two repetitions of the same word can be remembered for the most part independently. The second repetition of a word does not simply increment the strength of the trace left by the first; its effect on memory (i.e., its trace) differs from that of the first repetition, at least as far as position information is concerned. Furthermore, position information regarding the second repetition does not destroy that regarding the first, as some theories of memory for recency would predict. The two time tags apparently coexist in memory and serve to separately identify the contributions of the two different repetitions, as the multiple-trace hypothesis predicts.

[3] According to the present hypothesis, the distribution of single judgments to a repeated word should be a composite of the two corresponding nonrepeated distributions since *S*s presumably are retrieving only one of the two time tags. While variability was too great for one to expect obvious bimodality in such composite distributions, one would expect their variances to be greater than those of the nonrepeated conditions. A combined test showed this to be the case, $F\ (143, 269) = 1.33$, $p < .05$, providing at least weak evidence for the hypothesis.

Frequency Judgments

An important difference between the strength hypothesis and the multiple-trace hypothesis (as amended to assume that each trace is time tagged) can be characterized as one of "path dependence." A strength construct represents frequency in a way that is path independent. That is, there are many different ways of producing a given strength, and if strength is all that is stored, they should all be indistinguishable in memory. Consider, for example, two different temporal distributions of repetitions, D_1 and D_2, both of which are mapped onto the same memory state, or strength. On a memory test, retrieval of that memory state should provide *S* with no information from which to decide whether D_1 or D_2 had been used in presentation. By contrast, the multiple-trace hypothesis postulates a representation of frequency that is path-dependent with respect to temporal variables; the information by which D_1 and D_2 might be discriminated is in memory and therefore potentially retrievable. Thus, while D_1 and D_2 might have identical effects on performance in some memory tasks (e.g., recognition), their effects should be different in tasks which require *S* to differentially respond to memories of different patterns (cf. Hintzman & Block, 1970). Experiment II is relevant to this question; Exp. III extends the conclusions to a situation in which more than two repetitions are involved and the task is one of judging frequencies.

Experiment III

This experiment was designed to demonstrate the extent to which *S*s retain information about local densities of repetition that would not be expected to be reflected in strength. Standard memory instructions were read, and two word lists were then presented, separated by about 5 min. to provide good temporal discrimination. A number of words occurred in both lists, and their frequencies in the two lists were varied orthogonally. Following the second list, *S*s were asked to make separate List 1 and List 2 frequency judgments for each word. The question was whether *S*s could apportion frequencies to the two lists with enough accuracy to rule out explanation by a path-independent strength notion.

Method

Materials.—A total of 36 nouns from the previously described population were selected as experimental items. Four words were randomly assigned to each of nine experimental conditions, representing all combinations of three List 1 and three List 2 frequencies (zero, two, and five repetitions for either list). The appropriate number of slides of each word was constructed by typing the word on white paper and mounting in Easymount slide frames. Forty slides of filler items, also three-letter nouns, were similarly constructed.

There were 104 slides in either list. Both lists were constructed in the same way: the first 10 and last 5 slides were of filler words, and 5 other slides of filler words were placed at intervals throughout the rest of the list. Within a given list, the design was such that six different conditions occurred. For words in each of these conditions, the mean position of first presentation was about 26, and that of last presentation was about 84. Thus, primacy and recency within a list were approximately the same for all conditions occurring in that list. The middle three presentations of five-repetition words were distributed evenly throughout the middle of the list. The spacings of these repetitions averaged 13 and were never less than 3 intervening items.

A single test form was used for all *S*s. On it, the 36 experimental words were typed in random order, arranged in two columns. After each word were two blank lines, one in a column headed "List 1" and one in a column headed "List 2."

Subjects and procedure.—The *S*s were 33 paid volunteers obtained through the University of Oregon employment office. They were run in eight groups of up to 5 *S*s each.

A partial rotation of words through the nine conditions was accomplished by presenting the two lists in one order for four groups of *S*s and in the reverse order for the other four groups. At the outset of the experiment, *S*s were told that they would be shown a series of about 100 words, that many of the words would be repeated in the series, and that they were simply to study each word for as long as it was presented and try to remember it for a later test. The nature of the test was not specified, and *S*s were not told there would be two lists. List 1 was then presented using a Kodak Carousel projector paced by a timer set at a 3-sec. rate. Following the presentation of List 1, a filler task was administered in which *S*s estimated the sizes of angles by indicating where extensions of the limbs of each angle would intersect a third line. Then they were told that another series of words would be shown, that some of the words would

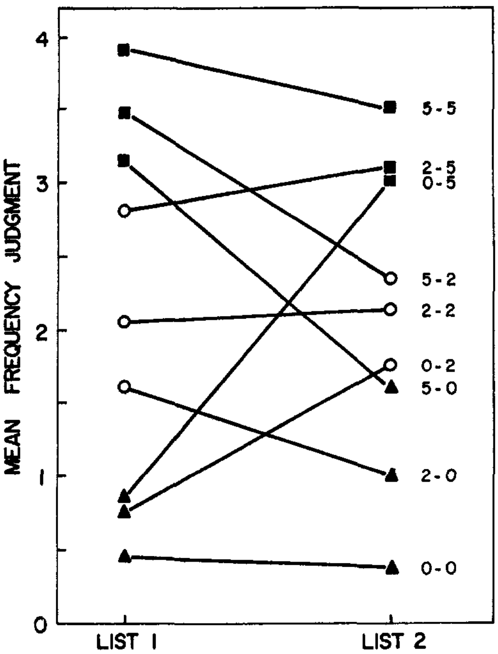

FIG. 2. Mean List 1 and List 2 frequency judgments as a function of List 1 and List 2 frequencies, Exp. III.

be repeated from the first slide series, and that, again, they were to study each word and try to remember it for a later test. About 5 min. separated the two lists. Following the presentation of List 2, the test sheets were distributed. The *S*s were told to indicate in the appropriate columns the number of times each word had appeared in the first slide series (identified at this point as "List 1") and the number of times in the second slide series ("List 2"). They were told that if they thought a word had not occurred in a particular list, it should be given a judgment of zero for that list.

Results and Discussion

Mean List 1 and List 2 frequency judgments for the nine experimental conditions are shown in Fig. 2. For both lists, mean judgments were ordered primarily by frequency in the target list. Further, the set of three conditions defined by each target-list frequency was internally ordered by frequency in the nontarget list. There were no exceptions to these two rules.

In terms of explained variance among means, linear regression on List 1 frequency accounted for 89.6% of the List 1 and 10.2% of the List 2 variance, while the corresponding figures for List 2 frequency were 7.2% and 86.4%. In terms of analysis of variance, all four effects of List 1 and List 2 frequency, on List 1 and List 2 judgments, were highly significant, $p < .001$.

These results indicate that not only do *S*s remember something of the overall experimental frequency of a word, but they can reconstruct the nature of the temporal distribution of the repetitions of the word that made up that frequency. Thus, the internal representation of frequency is not path independent, as a strength construct would predict. The ability of *S*s to discriminate recent from remote repetitions of the same word supports the hypothesis that each repetition produces its own memory trace and that the traces can be discriminated on the basis of their time tags.

It might be argued that the results of Exp. III can be explained using a strength notion if a minimum of two traces per word, one for List 1 and one for List 2, is assumed. There are several points to be made regarding this hypothesis. First, the list structure of the experiment was deemphasized by the instructions: the term "list" was not used until after both slide series had been presented, and *S*s did not know there would be a second series until just before its presentation, and so there was no special reason for *S*s to deliberately establish separate mnemonic organizations for the two lists. Second, to admit even two traces for the word's occurrence in the experimental context is a concession to the multiple-trace view: the step from one trace to two seems larger than that from two to many. Third, Exp. II provides evidence that within-list repetitions can be discriminated in memory. Those results cannot be explained by assuming a strength representation of within-list frequency. Taken together, Exp. II and III can most parsimoniously be explained in terms of the multiple-trace hypothesis. Finally, the difference between the two-trace and multiple-trace interpretations of performance in the frequency-judgment task could be tested experimentally. Since the multiple-trace hypothesis assumes that the primary basis for discrimination of list membership is the time tag of the individual trace (cf. Hintzman & Waters, 1969, 1970), it should be possible to alter the accuracy of the frequency judgments by moving positions occupied by a word in one list either toward or away from the other list. This manipulation should have predictable effects when positions are varied within a list, as well as when the interlist interval is altered.

General Discussion

Do the results of Exp. II and III really demonstrate that repetition results in multiple traces? In order to further clarify the single- versus multiple-trace issue, we wish to distinguish it from three other theoretical issues with which it is easily confused. These issues have to do with the nature of the trace, and not with the effect of repetition.

The first issue is whether the memory trace is associative or nonassociative in nature (Wickelgren, in press). The confusion here arises from the fact that if one thinks of the trace as nonassociative, say an engram or copy of the experience of the event, then multiple traces can be thought of as multiple representations; however, if one thinks of memory as associative, then a single generic representation can be imagined to be associated, as a result of repetition, with several different contexts or time tags. The question in the case of the latter, associative, explanation is whether it is the single generic representation or its contextual association that is to be called the trace. The term memory trace is usually used to refer to whatever it is that is stored when an event occurs and that mediates later retrieval of information about the occurrence of the event from memory. If this is the theoretical function served by a contextual association, then according to the preceding functional definition it is the association, not the preexisting and unchanged generic representation, that must be assumed to constitute the trace. The multiple-trace hypothesis is neutral with respect to the question of whether memory is basically associative or nonassociative; it simply asserts that different repetitions of an event have qualitatively different effects on memory.

A second issue is whether the memory trace is unitary or consists of several components that can be acquired or lost separately (cf. Bower, 1967). This question is orthogonal to the associative versus nonassociative one, and also, since it has to do with the nature of a single memory trace, with the question of whether repetition multiplies traces or strengthens a single trace. However, the existence of the unitary versus multiple-component issue means that the strength and multiple-trace hypotheses are not mutually exclusive—both may be true. In particular, this might be the case if the trace consisted of several components, rather than being unitary. If traces resulting from repetitions of an event had some components in common (e.g., the previously discussed generic representation), the shared components could be strengthened, while the unique ones would not be. Thus demonstrations like the present ones—that different repetitions have some effects on memory that are qualitatively different—do not necessarily rule out the possibility that frequency has other effects, as well. Nevertheless, it might be worthwhile to consider whether the concept of strength can be discarded altogether in accounts of the effects of frequency on performance in standard memory tasks. The question is whether there are any findings that can be explained by a strength, but not a multiple-trace conception of the effects of frequency. If such evidence cannot be found, then a strong interpretation of the multiple-trace hypothesis—that traces of repetitions are not only discriminable, but are separate and distinct—could be defended.

The third issue concerns the number of stages a memory trace passes through as a function of time. This too is a question that can be considered to be orthogonal to the one regarding the effect of repetition. However, confusion is possible here too, especially since there has been one attempt to explain memory for recency and frequency in terms of multiple stages of a single trace instead of multiple traces. There is evidence from studies of recency judgments (Peterson, 1967), frequency judgments (Hintzman, 1969), and list discrimination (Hintzman & Waters, 1970) that the effects of recency and frequency are not both mediated by a single underlying strength, but instead are based on two different dimensions of memory. Hintzman (1969) suggested that the two dimensions be identified with the strengths of the short-term stage (mediating apparent recency), and of the long-term stage (mediating apparent frequency). A difficulty with this two-stage hypothesis is that recency discrimination extends, and continues to decline, over longer time intervals than short-term memory ordinarily is assumed to span (e.g., see Exp. I; also Hintzman & Waters, 1969; Underwood & Freund, 1968; Yntema & Trask, 1963). Another difficulty is that the two-stage mechanism allows a word to have only one apparent recency and one apparent frequency at any given time, and any hypothesis with this limitation is inadequate to account for the present results. For example, Exp. II showed that temporal information regarding the second repetition of a word does not obliterate that of the first, as would be expected if the strength of a single short-term trace represented recency. The same inadequacy is illustrated by a comparison of the 0–5, 2–5, and 5–5 conditions of Exp. III. The two-stage hypothesis would expect the apparent recencies of the three conditions to be identical, and only the apparent frequencies to differ. The fact that *S*s quite accurately assigned the frequency differences among these conditions to List 1 rather than List 2 indicates that temporal information about List 1 repetitions was not destroyed by List 2 repetitions. Apparently, a word can simultaneously have several remembered recencies. This implies that it also has several frequencies, since frequency will be a function of the recency range over which the frequency estimate is made. (Underwood's (1969) position on this point is not clear, since he does not say whether an item can have more than one temporal attribute, or how the temporal and frequency attributes are related.)

The preceding argument does not deny that each trace passes through two or more stages, or even that traces of repetitions might, by succeeding each other through stages of the same system, have identical representations at different times. Presumably, in such a case, traces could merge in a later stage, so that the multiple-trace and strength hypotheses would both apply, but at different retention intervals. In order to be consistent with the present results, however, such a system would have to maintain the identifiability of individual traces for a minimum of several minutes.

The present findings help to explain an apparent failure of the frequency theory of verbal discrimination learning. The frequency theory assumes that in a verbal discrimination task, *S* rehearses the correct alternative (C) of a pair, and thus gradually increments its subjective frequency more than he does that of the incorrect alternative (I). An *S* can thus master a verbal discrimination list through frequency discrimination, by adopting the rule of choosing and responding with the more "frequent" alternative of each pair (Ekstrand, Wallace, & Underwood, 1966). If he is then transferred to a second list in which the I items of List 1 are retained as I items in List 2 while the C items are new, he can perform well initially by switching rules and responding with the less frequent alternative of each pair instead. As *S* continues responding with the new C items, however, the theory predicts that their frequencies will approach those of the I items, making the discrimination more difficult, and performance should therefore deteriorate to chance level. At this point, *S* can switch back to the original rule, and after he does so performance should again gradually improve. Attempts to confirm the prediction of deterioration to chance level on List 2 in such a paradigm have not been wholly successful (Underwood & Freund, 1970; Underwood, Jesse, & Ekstrand, 1964). The failure is understandable from the present point of view since, as Exp. III demonstrates, *S*s can discriminate recent from remote frequencies. Thus if it is assumed that early in the acquisition of List 2, *S* attempts to ignore recent frequencies and that after the rule switch he attempts to ignore older frequencies, than a deteriorization to chance level will not be expected. And presumably, the longer the interlist interval, the less deterioration there will be, since recencies or time tags for the two lists will be more discriminable. This prediction should hold for other methods of inducing frequencies prior to verbal discrimination learning, as well: the effectiveness of a manipulation, particularly one designed to inhibit verbal discrimination performance, should depend on the temporal separation of the initial and transfer tasks.

If this explanation is correct, then the only change needed in the frequency theory has to do with the nature of the underlying frequency representation. The troublesome prediction itself reveals that a path-independent, strength-like construct has been at least implicitly assumed. Such terms as "situational" or "experimental frequency" contrasted with "background frequency" imply that *S*s are able to discriminate recent from remote frequencies in a gross way. The present results indicate that *S*s are capable of finer, intraexperimental and intralist discriminations. We have not considered here the question of whether the time tags on which these discriminations are presumably based can be entirely explained in terms of contextual associations (cf. Underwood, 1969). However, if one adopts such an interpretation, he must assume that the experimental context is not static, but instead undergoes continuous change.

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