

## A Functional Approach to Levels of Processing

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The present article argues for what is essentially a return to the functionalist approach to investigation of memory. Two experiments demonstrate that the effects of level of processing depend on scaled meaningfulness of the material and study time. Data from those experiments along with data currently in the literature are then reanalyzed to examine the effect of repetitions. Of particular interest is the form of the function relating number of repetitions to retention performance, and the manner in which that function is influenced by variations in level of processing and scaled meaningfulness. It is argued that task demands operate to change the form of the function relating repetitions to retention performance.

The functionalist approach that dominated memory research for years promoted a search for relationships between rather easily measured indices of the task and retention performance. Many experiments investigated the effects of study time, number of repetitions, meaningfulness of the material, and so on. The apparent goal of these experiments was to find a unique mathematical function relating each of the task indices to retention. In contrast to this emphasis on functional relationships, the early Gestalt approach and the more recent levels-of-processing approach (Craik & Lockhart, 1972) cast doubt on the existence of functional relationships that remain invariant across different tasks and contexts. These latter approaches emphasize the role of context and task demands as determinants of retention; an implication is that the effect of task parameters, such as number of repetitions,

should vary with changes in context and task demands.

The purpose of the present article is to argue for the importance of combining the concerns of the functionalist approach with investigations of the effects of context and task demands. Two experiments are reported that demonstrate interactions between task demands and the more traditional functionalist variables. In particular, it is demonstrated that effects of varying orienting tasks depend on characteristics of the study material and on study time. In the general discussion it is then argued that a concern with the form of the function that relates task variables to retention can yield substantially more information than is typically obtained from levels-of-processing experiments. This discussion includes both the data reported here and a reanalysis of experiments in the literature.

As proposed by Dewey (1910), functionalism was essentially a psychology of the adjustment of an organism to its environment. The nature of functionalism was changed considerably, however, when it was applied to investigations of verbal learning. Here the word *function* returned to its mathematical usage so that the apparent goal

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Although Wayne Bartz died of cancer prior to the writing of this article, prior discussions in which he was involved contributed greatly to the work reported here.

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was to find a unique mathematical function relating various parameters to retention. Other changes in functionalism involved the range of situations that were investigated and the definition given to meaning. Dewey considered a wide range of situations and in doing so argued that the meaning of an event must be defined with reference to the situation and the individual's *framework*. In contrast, investigations of verbal learning were largely concentrated on two learning situations: paired-associate learning and serial learning. With the restriction of situations and the standardization of procedures, meaning came to be defined as a characteristic of the material. As an example, meaningfulness of letter trigrams was scaled in terms of the number of associations elicited or the proportion of subjects giving an association (e.g., Archer, 1960). Using these definitions, it was commonly found that increasing meaningfulness enhanced retention.

The levels-of-processing approach has also claimed that meaning influences retention. Now, however, meaning is manipulated by varying the demands of a task rather than by varying the characteristic of the material. In the typical levels experiment (e.g., Craik & Tulving, 1975), the material is held constant while the task in which a subject is required to engage is manipulated. Performance on an unexpected test of retention is generally higher when the orienting task requires subjects to deal with the meaning of presented items rather than with their sound or physical appearance. This emphasis on manipulating orienting tasks has led to a relative neglect of characteristics of the material and study time, variables that were emphasized within the verbal-learning tradition.

We can combine the concerns of the verbal-learning tradition with those of the level-of-processing approach. In doing so, we return to the earlier functionalist approach of Dewey (1910) by arguing that both task demands and characteristics of the material must be considered when defining meaning. At the extreme, encouraging subjects to deal with meaning should have little

effect if the material is so impoverished as to be unable to support a meaningful analysis. More generally, it seems reasonable for encoded meaning to reflect both the conditions under which the learner is operating and the potential meaningfulness of the material. If so, manipulating task demands while holding the material constant should in some instances be equivalent to manipulating the material while holding task demands constant; both types of manipulations influence the derivation of encoded meaning. This common effect of the two manipulations should be revealed in the similarity of their interactions with other variables. In the present article, data are analyzed to show that the interaction of scaled meaningfulness with number of repetitions is sometimes quite similar to the interaction of level of processing with number of repetitions.

Processing time is a second factor that is expected to limit the effects of manipulating orienting tasks. The importance of processing time provides a potential explanation for a discrepancy among results in the literature. In contrast to earlier findings by Jacoby and Bartz (1972), Dark and Loftus (1976) reported that performance on a test of long-term memory was uninfluenced by whether a subject expected an immediate test of memory or a test after an interval filled with rehearsal-preventing activity. Jacoby and Bartz claimed that subjects prepare for a delayed test by processing presented items in a more meaningful fashion than they would if they expected an immediate test. The procedure employed by Dark and Loftus may not have allowed this more meaningful processing; Dark and Loftus presented items for study at a substantially faster rate than did Jacoby and Bartz. The faster rate of presentation might have made it impossible for subjects to alter their study strategy in a manner that would benefit long-term memory. That is, manipulating the orienting task is likely to have an effect on retention only if subjects are given time to do additional processing that is appropriate for the task.

A final concern is the influence of repetition on retention. Many verbal learning studies

have shown that repetition enhances retention. The early math models sought to formalize this relationship by finding a unique function relating repetitions to retention. However, recent work has shown that repetition does not always aid retention (e.g., Craik & Watkins, 1973; Jacoby & Bartz, 1972). It appears that the level of processing must be considered along with the number of repetitions. The present article seeks consistency in the effects of repetition across levels of processing. Such consistency is not always found. It is argued that task demands may sometimes operate to change the form of the function relating repetitions to retention. In agreement with the verbal-learning tradition, we are searching for functional relationships between task indices and retention performance. Our approach differs from the earlier one in that we expect the form of functional relationships to vary across situations. A goal of the approach that we advocate is a taxonomy of situations, with the situations being differentiated by the form of functional relationships that they produce.

### Experiment 1

In the present experiment, scaled meaningfulness of the material was varied across two orienting tasks. Subjects in one condition judged the pronounceability of items, while subjects in the other condition judged the meaningfulness of items. The depth-of-processing view predicts an interaction between scaled meaningfulness of the material and orienting tasks. The effect of meaningfulness should be larger when the orienting task requires subjects to deal with the meaning of presented items.

Some effect of meaningfulness, however, might also be expected in the condition that does not judge meaning. The scaled meaningfulness of a trigram is highly correlated with its scaled pronounceability (Underwood & Schulz, 1960); an increase in pronounceability, regardless of any effect of meaningfulness, might influence retention.

The number of repetitions of items was varied along with the scaled meaningfulness of the material and the orienting task. The

reason for the manipulation of number of repetitions concerns the form of the interactions of repetitions with meaningfulness and orienting tasks. The rationale underlying interest in those interactions is described in the general discussion, along with additional data that are relevant to the arguments.

### Method

*Design and subjects.* Two levels of meaningfulness of material were factorially combined with two orienting tasks to produce four between-subjects conditions. Further, items were presented either 1, 2, 3, or 4 times within a list, so that the total design was a  $2 \times 2 \times 4$  factorial. The subjects were 64 students who were enrolled in an introductory psychology course and participated in the experiment for course credit; 16 subjects were randomly assigned to each of the four between-subjects conditions with the restriction that there must be  $n$  subjects in each condition before there were  $n + 1$  subjects in any condition. Subjects were tested individually.

*Orienting tasks.* The study was introduced as being concerned with the scaling of verbal materials. Subjects were instructed to compare members of pairs of consonant-vowel-consonant trigrams (CVCs) on a designated dimension. In the meaning condition, subjects were to pick the member of each pair that brought the larger number of associations to mind; an example pair was given, and the meaning of the term *association* was clarified. In the pronounceability condition, subjects were to select the member of each pair that was easier to pronounce. As in the meaning condition, an example was presented to clarify instructions. Subjects in both conditions were cautioned that the discrimination between members of a pair would sometimes be a difficult one, but that they were still to select one member from each pair and to have some rationale for their choice, rather than choosing randomly.

*Materials and procedure.* The learning material consisted of 52 CVCs ranging in meaningfulness from 90% to 100% (mean = 95%) and an equal number of CVCs that ranged from 41% to 50% (mean = 45%) as scaled by Archer (1960). Overlap in letters among the CVCs was minimized and equated across the levels of meaningfulness. Twelve CVCs from each meaningfulness level were employed as buffer items. The remaining 40 CVCs at each level of meaningfulness were randomly broken into four groups of 10 for presentation either 1, 2, 3, or 4 times within a list. Items were rotated across lists to form four lists of each meaningfulness level; across lists, each level of repetition frequency was represented by the same CVCs.

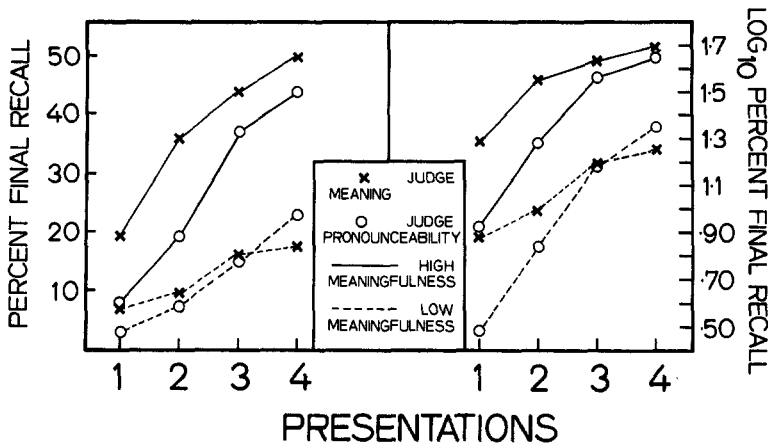


Figure 1. Absolute and proportional increases in recall as a function of number of presentations and judgment condition.

Including repetitions, a list contained 112 CVCs presented as 56 pairs. The first 3 and the last 3 pairs in each list served as primacy and recency buffers; CVCs in these pairs were presented only once. The assignment of the remaining CVCs to pairs and of pairs to list positions was random with the restriction that a pairing of CVCs could not be repeated and that at least 3 pairs must intervene between repetitions of a CVC.

Lists were presented as a stack of 3" × 5" (7.6 × 12.7 cm) note cards; one pair was typed on each card. Subjects were instructed to pick either the more meaningful or the more pronounceable member of each pair according to their orienting task condition. Pacing was controlled at 10 sec/pair by instructing subjects to turn over one card at each click produced by a timing device. Further instructions informed subjects that they could take the full time allotment to make their decision but that they were not to return to a pair once they had left it. Subjects indicated their decisions by checking on a mimeographed sheet whether they had selected the right or left member of the pair.

After completing the deck of cards, subjects were read four lists of nine digits, which they then attempted to recall in serial order. The purpose of this task was to destroy any short-term memory for list items. Next, subjects were instructed to write down all of the CVCs from the list. Free-recall instructions were given, and subjects were further assured that the pairing of syllables was not important. There was no time limit on the free-recall task.

### Results and Discussion

The percentage of items recalled is shown in the left-hand portion of Figure 1. The plot in the right-hand portion of that figure

is a log transformation of the percentage data. All analyses were conducted on the percentage of recall data. The significance level for statistical tests was set at  $p < .05$ . The  $MS_e$  for between-subjects tests (effects of meaningfulness, task, and their interaction) was equal to 378, while that for within-subjects tests (tests involving number of presentations) was 139.

The effect of meaningfulness and the effect of number of presentations were both highly significant,  $F(1, 60) = 69.84$ , and  $F(3, 180) = 53.17$ , respectively, as was the interaction between meaningfulness and number of repetitions,  $F(3, 180) = 7.63$ . The probability of recall increased regularly with repetition at both levels of meaningfulness; however, the increase in recall as a function of repetitions was greater with high-meaningfulness material.

Of greater interest is the significant effect of orienting task,  $F(1, 60) = 4.90$ , and the significant interaction of orienting task and level of meaningfulness,  $F(1, 60) = 4.06$ . The advantage in recall probability of high meaningfulness material over low-meaningfulness material was greater when subjects engaged in a semantic orienting task (.37 vs. .13) rather than a pronounceability task (.27 vs. .12). Further, the semantic orienting task resulted in a recall advantage over the pronounceability task only when the material was of high meaningfulness.

The plot in the right-hand portion of Figure 1 shows that the interaction between meaningfulness and number of presentations is removed when the data are subjected to a  $\log_{10}$  transformation. Within each orienting task, the effects of repetition are essentially constant across levels of meaningfulness; however, repetition has more marked effects in the pronounceability condition than in the meaning condition. The theoretical significance of these transformed data is described in the general discussion.

For present purposes, the main point of the first experiment is that the cognitive activity of the learner depends on both the material and task demands. The learner can be made to appear very inflexible in his processing if the material that is to be learned is so impoverished as to be unable to support a meaningful analysis; in the present experiment, the manipulation of orienting tasks had little effect when the material was of low meaningfulness. With regard to manipulations of the material, variations in meaningfulness had a larger effect when the orienting task directed the learner toward the processing of meaning. The effects of meaningfulness that were found in the condition that judged pronounceability may be due to some *automatic* encoding of meaning. However, an equally plausible interpretation is that the effects were due to an increase in pronounceability that is correlated with increasing meaningfulness.

## Experiment 2

Task demands were varied in the present experiment by manipulating the anticipated delay of testing. As indicated in the introduction, there is some evidence that long-term retention is enhanced if subjects anticipate being tested after a delay that is filled with rehearsal-preventing activity rather than anticipate being tested immediately after presentation of the list (e.g., Jacoby & Bartz, 1972). Subjects presumably prepare for a delayed test by further processing the meaning of study items and by establishing relationships among items in a study list.

This further processing is likely to require some minimal amount of time to accomplish. Consequently, effects of manipulating the anticipated delay of testing might be minimal when study items are presented at a fast rate (cf. Dark & Loftus, 1976) while being substantial when items are presented at a slower rate.

## Method

*Materials and procedure.* Thirty five-word lists were randomly constructed from a pool of 640 Thorndike-Lorge (1944) A and AA nouns. The rate of presentation was varied within subjects such that half of the lists were delivered at a rate of one word per second, and half at a rate of one word every 3 seconds. Two unsystematically ordered forms of the 30 lists were prepared by a haphazard shuffling of cards with the stimuli printed on them; within forms, the positions of the respective 1-sec and 3-sec lists were determined on the basis of a random number table. The lists were then recorded on magnetic tape for auditory presentation.

The between-subjects variable was type of delay: no delay, silent delay, or filled delay. Subjects in the filled-delay condition were given a subtraction task during a 14-sec interval between presentation of the last word in each list and initial free recall. The task involved subtracting 1 from each of seven 2-digit numbers presented at a 2-sec rate, and reporting the result aloud. In the silent-delay condition, subjects were free to rehearse each list during the 14-sec delay period. In the no-delay group, initial free recall occurred immediately after expiration of the allotted presentation time of the fifth word of each list.

Subjects attempted initial free recall of each list. The word *ready* preceded each list by 2 sec. After presentation of the list and any delay, the word *go* signalled the beginning of a 7.5-sec recall interval. In all groups, the ready signal for the next list was given immediately after the expiration of the initial recall interval.

At the end of the experimental session, each subject was given a test of final free recall; they were instructed to write down all words from all of the lists. Subjects were allowed as much time as they wanted to complete the final free recall.

Prior to presentation of the lists, subjects were informed of the number of lists and of the type and length of delay that would precede initial recall of each list. Subjects were not told of the final free recall tests until after all lists had been presented.

*Subjects and analyses.* The subjects were 36 introductory psychology students, who received extra course credit for participating in the experiment. Twelve subjects were assigned to each

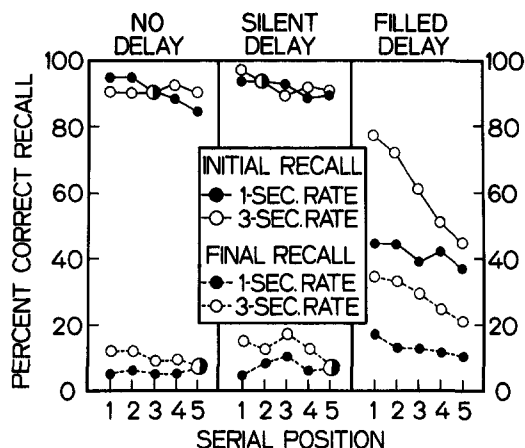


Figure 2. The probability of immediate free recall and of final free recall.

delay condition on a random basis, and half of the subjects in each condition were randomly assigned to each tape form.

Responses in initial recall were scored as correct if pronounced correctly; the experimenter categorized responses by serial position and by presentation rate. The final free recall responses were counted correct if they were words from the lists or were misspellings or homonyms of the list words. The final free recall responses were also scored with regard to serial position and presentation rate. Separate  $3 \times 2 \times 5$  (Delay Condition  $\times$  Rate  $\times$  Serial Position) analyses of variance, with repeated measures on the last two factors, were carried out on the initial and final free recall responses, respectively. Significance level was set at  $p < .05$ .

### Results and Discussion

Serial position curves from initial and final free recall are shown in Figure 2. Initial free recall was near perfect in both the no-delay and the silent-delay conditions and was substantially lower in the filled-delay condition,  $F(2, 33) = 95.95$ ,  $MS_e = 674$ . Initial recall was higher with the slower rate of presentation only in the filled-delay condition,  $F(2, 33) = 48.46$ ,  $MS_e = 77$ . Further, the interaction of presentation rate with serial position was limited to the filled-delay group,  $F(8, 132) = 4.48$ ,  $MS_e = 86$ . In the filled-delay group, the decline in recall across serial positions was greater with the slower presentation rate.

Aside from effects due to the presentation-rate manipulation, the final free recall data

replicate results reported by Jacoby and Bartz (1972). Final free recall probability was highest in the filled-delay condition (.21) and approximately equal in the no-delay (.08) and silent-delay (.10) conditions,  $F(2, 33) = 23.08$ ,  $MS_e = 242$ . Again, the additional rehearsal entailed by the silent delay as compared to immediate recall did little to increment long-term retention. Subjects in the filled-delay condition had less opportunity for rehearsal than did subjects in the silent-delay condition, but they showed higher final free recall.

The interaction of presentation rate and delay condition in the final recall test was of primary interest. Slowing presentation rate was expected to aid long-term retention in the filled-delay condition while having no effect in either the silent-delay or the no-delay conditions. This expectation was largely confirmed by the results. Although the slower rate yielded higher final free recall performance in all delay conditions, the effect was appreciably larger in the filled-delay condition,  $F(2, 33) = 7.47$ ,  $MS_e = 145$ . It is noteworthy, however, that rate of presentation was significant in the silent-delay group,  $t(33) = 2.23$ ,  $p < .05$ , and marginally significant in the no-delay group,  $t(33) = 1.85$ ,  $p < .08$ .

A final point is concerned with the dependence of serial position effects on presentation rate. The decline in final free recall across serial positions was more pronounced at the slower presentation rate,  $F(4, 132) = 4.05$ ,  $MS_e = 59$ .

The results of the present experiment allow two conclusions to be drawn. First, retention depends on the amount of study time provided. Decreasing rate of presentation substantially enhanced final free recall when subjects were preparing for an initial test that required long-term retention. The serial position effects observed in both the initial and the final free recall of the filled-delay condition can also be interpreted as being due to differential study time; with the slower presentation rate, items from early positions are likely to have been studied during the presentation of later items. The second conclusion serves to qualify the

first conclusion drawn. The final free recall data indicate that long-term retention depends on the way study time is employed as well as the amount of study time provided. Additional study time does more to enhance final recall when subjects are preparing for a test that requires long-term retention rather than merely maintaining items in short-term store.

Postman (1975) complains that in the Jacoby and Bartz (1972) experiment the final free recall difference between the filled-delay condition and the immediate recall condition is relatively small. More recently, Dark and Loftus (1976) have failed to find any effect of warning a subject that retention will be tested after a filled delay rather than immediately following presentation. The results of the present experiment demonstrate that the effects of warning a subject about an impending delayed test are greater when larger amounts of study time are provided; the effects could possibly be made still larger by further slowing presentation. In general, the effect of being warned about an impending test of delayed recall depends on the subject having sufficient time to modify his processing accordingly.

One problem in the interpretation of the present experiment is that floor effects may have forced the interaction between presentation rate and the form of delay. In general, the level of final free recall was so low in the silent-delay and in the no-delay conditions that a lack of difference between the two rates of presentation might be forced. In retrospect, it would have been better to use either longer presentation rates or fewer lists in order to increase the level of performance. However, data from another experiment provide some basis for confidence that the interaction of rate and type of delay is not due to a floor effect.

Bartz (Note 1) varied the form of delay along with the number of repetitions and obtained results similar to those reported here; the final recall advantage of a filled-delay condition over a no-delay condition increased across repetitions. Those results converge with the present results in that one would expect some parallel between

the effects of manipulating number of presentations and those of manipulating rate of presentation. Floor effects are not a problem in the interpretation of Bartz's experiment. The results of Bartz's experiment will later be described more completely in the context of a general discussion of the interaction between number of presentations and level of processing.

Results similar to those reported here have led others (e.g., Craik & Lockhart, 1972) to postulate the existence of two forms of rehearsal. One form is said to maintain items in short-term store, while a second form is considered necessary to enhance long-term retention. While the need to distinguish between forms of study seems clear, it is probably an oversimplification to use a dichotomy of rehearsal types. In the present experiment, decreasing presentation rate should have only increased maintenance rehearsal in the silent-delay and the no-delay conditions; consequently, the dichotomy of rehearsal types would predict that presentation rate would not enhance long-term retention in those conditions. Contrary to that prediction, effects of presentation rate were found. A similar effect of presentation rate when only maintenance of items in short-term store was required for an initial test has been reported by Craik and Watkins (1973). In the present experiment and earlier ones (e.g., Jacoby & Bartz, 1972), we have found that interpolating a silent delay between presentation and initial recall does essentially nothing to aid long-term retention. However, others (e.g., Dark & Loftus, 1976) have found that long-term retention is enhanced by a similar period of *maintenance* rehearsal. A simple division of study activities into those that aid long-term retention and those that do not appears insufficient. There is more likely to be a wide variety of study activities that can be placed on a continuum with regard to their effectiveness for long-term retention.

### General Discussion

At the simplest level, the present experiments establish some limits on the situations

in which effects of task demands are to be found. The encoded meaning of an event depends on the meaning-producing activity of the learner as well as the potential meaningfulness of the material. As demonstrated in Experiment 1, encouraging the subject to attend to meaning has essentially no effect if the material is so impoverished as to be unable to support a meaningful analysis. Conversely, increasing the potential meaningfulness of the material has a limited effect if the subject is not directed toward an analysis of meaning. Experiment 2 demonstrated that the effects of task demands are limited by the time available for processing. Being forewarned about a test of delayed recall has little effect on long-term retention performance if there is insufficient time for processing that would be appropriate for the delayed test.

In the introduction, it was suggested that the forms of functions relating indices of a task to retention vary across situations. As a special case of this general principle, interactions of meaningfulness and interactions of orienting tasks with number of repetitions will be considered in the remainder of this article. A continuing theme in research on memory has been an attempt to specify the means by which repetitions operate to enhance retention. The approach that we are promoting differs from earlier ones in that we are not searching for a unique functional relationship between number of repetitions and retention. Rather, we focus on the form of interactions between repetition and other variables. It is through an analysis of these interactions that we hope to learn about the processes underlying the effects of repetitions and the effects of meaning. We describe three possible forms of interaction between repetition and variables influencing meaning; experiments obtaining each of the three forms of interaction are also described. In describing these interactions, we suggest that task demands and other factors influence the form of the functional relationship between repetitions and retention. Consequently, it is argued that it is necessary to define classes of situations in which particular functional relationships are obtained.

The result of such an approach would be a taxonomy of situations, with the situations being differentiated on the form of the functional relationships they produce.

Before proceeding to the analysis of interactions, a comment on potential scaling problems is necessary. Some of the predictions that will be considered depend on retention performance being measured on a ratio scale. The likelihood of free recall actually providing a ratio scale might be considered to be so low as to lead to a dismissal of any confirmation of such predictions as being spurious. One defense against such a dismissal is to show that confirmation of predictions can be found quite frequently. Perhaps the best approach in this situation is the *functional measurement* strategy advocated by Anderson (1970). By this approach, characteristics of the scale and predictions from a theory are assessed simultaneously. An accurate prediction provides confirmatory evidence for both the theory and the assumed scale of measurement. When a prediction fails, either the scale of measurement or the theory may be at fault.

### *A Multiplicative Relationship*

One possible form of interaction between number of repetitions and variables influencing meaning can be described as a multiplicative relationship. In this section, we first describe the form of interactions that would be produced by a multiplicative relationship. We then consider theories that would predict a multiplicative relationship between number of repetitions and variables influencing meaning. Next, we provide evidence that interactions of the form produced by a multiplicative relationship are sometimes obtained. It should be noted that we are not claiming that a multiplicative relationship should be found in all situations. Other forms of interactions between number of repetitions and meaning are described in later sections.

Repetition and meaning may combine in a multiplicative fashion to determine the probability of recall ( $P$ ). As a simple equation, the postulated relationship is:  $P = F$



$(M) \times F(R)$ . Meaning (M) reflects the effects of level of processing and meaningfulness of the material, while the other factor (R) reflects only the effect of number of repetitions. The equation does not specify either the form of the functional relationship between meaning and retention performance or that between repetitions and performance. It does, however, state that the effects of repetition are independent of those of meaning. Interactions between meaning and repetitions can be analyzed to determine if the multiplicative relationship holds.

The effects predicted by a multiplicative relationship can be described for a level-of-processing experiment. Consider an experiment in which both level of processing and number of repetitions are varied. If the multiplicative relationship holds, level of processing will interact with number of repetitions; the effect of repetition will be greater for deeper levels of processing. Further, the form of this interaction will be such that it is removed by performing a log transformation on the retention data; the log transformation will result in parallel effects of repetition for the different levels of processing. The log transformation is equivalent to plotting the *proportional* increase in recall that results from repetition. For example, suppose that at all levels of processing presenting an item twice served to double the recall found after a single presentation. The proportional increase in recall would be the same across levels, and this identity would be reflected by parallel effects of repetition when the recall data are subjected to a log transformation.

*Models.* Models that claim that recall is a hierarchical process can be used to predict interactions that are of a multiplicative form. Although not involving the effect of repetitions, perhaps the best-known example of a model that postulates a hierarchical process is that proposed by Tulving and Pearlstone (1966) to describe recall of a categorized list. Those authors suggest that a categorized list is learned in a hierarchical manner so that recall of the category is a prerequisite for accessing presented items from that category. By this model, the total number

of words that are recalled can be described as being due to two factors that combine in a multiplicative fashion; a factor that reflects the recallability of categories is multiplied by a factor that reflects the recallability of items within categories to produce the total number of words that are recalled.

Mandler (Note 2) has recently proposed a model of repetition effects that portrays recall as being a hierarchical process. Mandler suggests that variables such as level of processing influence between-unit organization, while repetition influences integration (within-unit organization). Between-unit organization determines the probability of accessing any particular unit, while integration determines recall of the contents of the unit given that it is accessed. Thus, total recall can be described as being a function of the number of units accessed multiplied by recall from within each of the accessed units.

Models of the type used in perception can also be used to predict a multiplicative relationship. Of particular interest are models that were constructed to account for the influence of frequency in the language on tachistoscopic recognition (Broadbent, 1967; Morton, 1969). Broadbent and Broadbent (1975) have argued that information coming from the stimulus must combine in a multiplicative fashion with biases determined by frequency to produce effects of the magnitude observed in perception experiments. The effects of repetition in a memory experiment may be analogous to the effects of frequency in tachistoscopic recognition. Further, subjects may construct a *description* of presented items in a levels experiment (Jacoby & Craik, 1978; Norman & Bobrow, Note 3); the nature of this description would be influenced by both the material and the orienting task. To complete the analogy with perception, one need only assume that the description that is accessible at the time of test is not so complete as to uniquely specify any particular word as having been presented. It can then be claimed that the description combines with biases influenced by frequency of repetition to determine the particular word that is re-

called. That is, retention performance can then be described by the same models as have been previously used to describe perception. This application of those models predicts a multiplicative relationship between number of repetitions and variables influencing meaning.

*Effects of meaningfulness.* Some interactions involving scaled meaningfulness are of the form that would be produced by a multiplicative relationship. McCrary and Hunter (1953) investigated the effects of meaningfulness in serial learning. Prior to McCrary and Hunter's article, it had been found that the effect of serial position interacts with meaningfulness of the material, presentation rate, and several other variables. In contrast, McCrary and Hunter demonstrated that the effects of serial position are invariant across those variables when the proportion of total errors is plotted against serial position. This pattern of results provides evidence of a multiplicative relationship between some factor influenced by meaningfulness and another factor that is responsive to serial position. It has been suggested that the effects of serial position reflect differences in frequency of rehearsal (e.g., Rundus, 1971). If so, the interaction of meaningfulness with serial position reduces to an interaction of meaningfulness with frequency of repetition. Experiment 1 in the present article provides more direct evidence of the interaction between meaningfulness and repetition.

In Experiment 1, the interaction was such that repetition had a substantially larger effect with high-meaningfulness material than with low-meaningfulness material. As shown in the right-hand portion of Figure 1, this interaction of repetition with meaningfulness largely disappears when a log transformation is performed on the recall data. The relationship between repetition and recall in the transformed data is essentially constant across meaningfulness within each orienting task; however, parameters of the relationship vary with orienting tasks. That is, within orienting tasks, there is evidence of a multiplicative relationship between meaningfulness and number of repetitions.

In a later section, we discuss the effects of a level of processing that were obtained in Experiment 1.

*Levels of processing.* There have recently been several experiments that were designed to investigate the interaction between number of repetitions and level of processing. Next, we describe two experiments that provide evidence of a multiplicative relationship between level of processing and repetitions.

Craik and Tulving (1975, Experiment 3) varied the number of presentations of items along with the level of processing in a paradigm similar to that introduced by Craik (1973). Subjects were required to give a yes or no answer to questions about either the physical appearance (type font), the phonemic properties, or the semantic properties of words in a list, and were then required to engage in an unexpected test of free recall. The number of presentations of a word was crossed with the level of processing and with the answer appropriate to the levels question so that the total design was a  $3$  (levels of processing)  $\times 2$  (1 or 2 presentations)  $\times 2$  (yes or no answer to levels question) factorial. Items that were repeated appeared with a different question on each presentation. However, the questions that accompanied repetitions of an item were always from the same level (physical, phonemic, or semantic) and required the same answer (yes or no).

The results of the Craik and Tulving (1975) experiment revealed that recall increases with the depth of processing, and that recall is higher when study questions are compatible with the target item so that a yes response is given. Both of these effects replicate results reported by Craik (1973). Of greater interest, Craik and Tulving found that the effect of repeating an item depends on the level of processing; the effect of repetition increased when repeated items were processed to a deeper level.

The notions described in conjunction with the multiplicative relationship predict that the proportional increase in recall that results from repetition will remain constant across different levels of processing. First,

let us examine the effects of level of processing and the effects of repetition when the questions asked required a no answer. The probability of recall after one phonemic presentation was .06, while that after two phonemic presentations was .15. The proportional increase in recall that resulted from repeated phonemic processing, then, was  $.15/.06$  or 2.50. With semantic processing, the recall probabilities were .16 and .40. The ratio of these two probabilities is 2.50—identical to that found with phonemic processing. For questions requiring a yes answer, the proportional increases in recall were 2.73 for a phonemic repetition and 2.43 for a semantic repetition. Thus, the proportional increase in recall that resulted from repetition was near 2.50 across four comparisons. The prediction of constant proportionality seems to be well-supported in the phonemic and the semantic conditions. In the case condition, the effects of repetition were negligible and perhaps masked by floor effects; the proportional increase in recall in the case condition was not comparable to that in the other conditions.

An experiment by Bartz (Note 1) employed a procedure that is quite different from that used by Craik and Tulving (1975), but still provides data that are relevant to determining the interaction of level of processing and number of presentations. Bartz varied the level of processing of words in short lists by manipulating subjects' test expectations. As in the earlier study by Jacoby and Bartz (1972), the rationale is that immediate recall of a short list of words requires only superficial processing during study, whereas preparation for recall of the same words after a period of number subtraction requires deeper processing of the individual words.

Bartz presented five-word lists which subjects recalled either immediately after presentation or after a 20-sec period of number subtraction. The delay of initial recalls was varied between groups so that subjects were aware of how lists would be tested and could modify their processing of list items accordingly. A further manipulation was that one half of the lists that were presented

for study were not tested initially, while the other half were tested. This manipulation was intended to assess the effects of initial recall on final free recall. Finally, items were presented either 1, 2, 3, 4, or 5 times during study. Items were always regrouped prior to repetition so that each presentation of an item occurred in the company of different words. Summarizing, the total design was a  $2$  (prepare for an immediate or for a delayed test)  $\times 2$  (items tested or not tested initially)  $\times 5$  (1 to 5 presentations) factorial. The results of interest come from final free recall; these results can be considered as incidental learning data, since the final recall test was not expected.

The interaction of initial test conditions with number of presentations is of primary interest. As shown in Figure 3A, repetitions did more to enhance final free recall when subjects were preparing for a delayed test. That is, repetition had a larger effect when each presentation of an item was processed to a deeper level.

With the larger number of repetitions, the effect of anticipated delay of testing was quite substantial (cf. Dark & Loftus, 1976). Further, the effect of anticipated delay did not depend on the initial test actually being given. This finding replicates an earlier finding by Götz and Jacoby (1974) and is important because others have claimed that effects of delay are entirely due to a delayed recall doing more to aid later recall than does an immediate recall (e.g., Dark & Loftus, 1976; Modigliani, 1976). When an initial test was not given, the effect of anticipated delay in final recall must be attributed to differences in study processing.

A reanalysis of Bartz's (Note 1) data was done to determine whether or not the relationship between levels of processing and repetition was multiplicative in form. The curves shown in Figure 3B were obtained by plotting log percent recall against the number of presentations. As can be seen, the logarithmic transformation results in almost totally parallel curves. Again, the prediction of a multiplicative relationship is well supported.

Another result of interest that is displayed

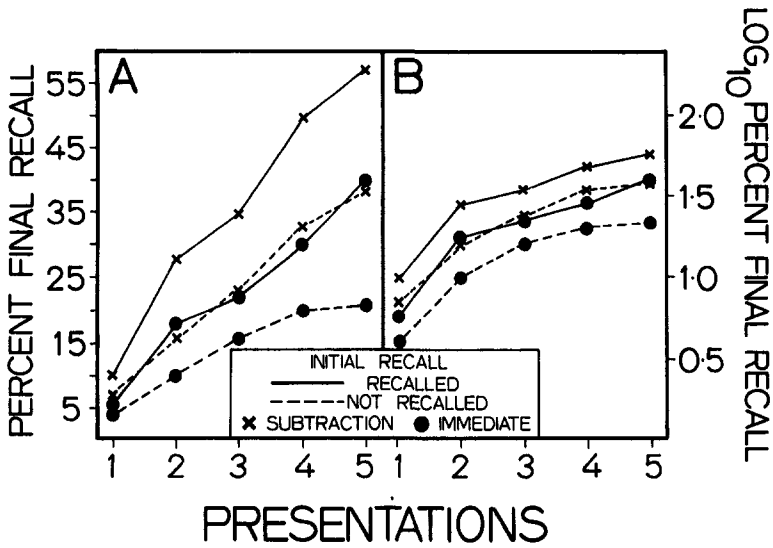


Figure 3. Absolute and proportional increases in recall as a function of task and number of presentations.

in Figure 3 concerns the effect on later recall of having provided an initial test. The effect of initial testing interacts with number of presentations when performance is plotted against percent final free recall. However, the interaction with number of presentations largely disappears when performance is plotted against log percent final recall. The variation in initial testing, then, seems to have the same function as does study under two different levels of processing.

The experiments described provide evidence that both meaningfulness and level of processing combine multiplicatively with the effects of repetitions to determine free recall. Such similarity of the effects of meaningfulness and levels is to be expected if both variables influence the derivation of meaning, as is implied by treating meaning as being dependent on both the meaning-producing activity of the learner and the potential meaningfulness of the material.

To this point, task demands have been treated as only influencing the level of processing of individual items. However, a situation can also be altered in a way that encourages subjects to search for relationships among items or to redistribute their study across a list of items. This type of manipula-

tion of task demands might alter the form of the interaction between meaning and repetition. Similarly, the form of interaction is likely to be altered by some manipulations of the material. The problem becomes one of delimiting the situations in which a particular form of interaction is to be expected. Next, we consider predictions from a multiple-trace theory and describe some evidence to support those predictions.

*Predictions from a Multiple-Trace Theory*

A multiple-trace theory of the type suggested by several investigators (e.g., Hintzman & Block, 1971; Madigan, 1969) offers a simple means of combining the effects of number of repetitions and depth of processing. By this view, each presentation of an item results in an independent trace being formed in memory. The assumption used to link the number of traces of an item in memory to recall performance uses the analogy of drawing marbles from an urn. The effect of repetition is to increase the number of marbles of a given color (traces of an item) in an urn (memory), thereby increasing the probability that a marble of the particular color will be drawn within some

set number of draws. Using the multiple-trace theory to describe the effects of repetition, it is a simple task to incorporate the effects of level of processing. Level of processing could influence the probability of a trace supporting recall given that the trace had been contacted. The prediction would be that overall recall will reflect the addition of independent traces across all levels of processing. Probability of recall could be predicted by the independence formula:  $P_n = 1 - (1 - P_1)^n$ . In this formula,  $n$  refers to number of presentations of an item, while  $P_1$  refers to the probability of recall after a single presentation. It is this latter term in the formula that would be influenced by depth of processing. This formula describes an exponential function. Note that constant proportionality in the exponent ( $n$ ) refers to the amount remaining to be learned rather than being of the form identified with the multiplicative relationship.

Goldman and Pellegrino (1977) assessed the independence of repetitions across different levels of processing; items were presented either one or three times, and level of processing was varied in much the same way as described for the Craik and Tulving (1975) experiment. Retention was assessed by means of both a test of free recall and a test of recognition. The recognition results were fit quite well by predictions derived from the assumption that repetitions produce independent traces. In contrast, the effects of repetition on free recall were not fit well by assuming independent traces. The effects of repetition in free recall were larger than could be predicted by a multiple-trace theory.

The magnitude of repetition effects can be used to choose between a multiple-trace theory and theories predicting a multiplicative relationship. In the experiments by Craik and Tulving (1975) and by Bartz (Note 1), the probability of recall after two presentations was over twice as high as that after a single presentation. The multiple-trace theory uses the independence formula to predict the effect of a repetition; consequently, it cannot predict that a repetition will even double the probability of recall.

The recall data in the Goldman and Pellegrino (1977) experiment also show repetition effects that are larger than those that could be predicted on the basis of independent traces. Floor effects make it impossible to determine if Goldman and Pellegrino's recall data can be fit by a multiplicative relationship.

Very little evidence to support predictions from a multiple-trace theory is provided by the level-of-processing experiments. However, it should be noted that the independence formula underlies substantial theorizing about all-or-none learning. The all-or-none approach has enjoyed some success in intentional learning situations (see Kintsch, 1970, pp. 61-85). The effects of repetition in incidental versus intentional learning deserve further investigation.

#### *Additive Effects of Repetition and Level of Processing*

An experiment by Nelson (1977) found main effects of level of processing and of number of repetitions but no significant interaction between the two. Unlike experiments described earlier, the manipulation of level of processing involved asking a single question about meaning (Is this a living thing?) or a single question about sound (Does the item contain an  $n$  sound?) for all items in the list. Thus, items were repeated with identical questions, whereas the question or list context was changed in the experiments by Craik and Tulving (1975) and by Bartz (Note 1). In Experiment 1 of the present article, the interaction of levels with repetition was negligible in the nontransformed data. As in Nelson's experiment, items were not associated with unique questions.

We are not aware of any theory that predicts that the effect of number of repetitions should add to the effects of level of processing in producing retention performance. However, other experiments show that a failure to use unique cues reduces the effect of level of processing (Moscovitch & Craik, 1976). It appears that the failure to use unique cues affects retrievability in a way

that also eliminates the interaction between level of processing and number of repetitions.

### *Summary and Conclusions*

One noteworthy finding in the experiments described here is that there is substantial evidence that the effects of level of processing and scaled meaningfulness are separable from the effects of number of presentations. That is, there are situations in which the effect of repetitions is separable from the effects of the meaning of that which is being repeated. Given such separable effects, not all differences in retention can be explained as being due to differences in level of processing or degree of organization. Similarly, a strength theory of the form designed to account for the effects of repetitions cannot account for all differences in retention performance. Some combination of organization and strength notions is clearly required.

An explanation of the effects of repetition has long been central to theories of memory. To learn more about the processes underlying the effects of repetition, analysis of interactions between repetition and other variables is important; the form of these interactions can be used as a constraint for theorizing. We have described evidence for three different forms of interaction between meaning and repetition. Other forms of interaction are also possible. For example, the form of interaction obtained when subjects are encouraged to organize members of a list may differ from any of the interactions described here. The massing of repetitions as in maintenance rehearsal is also likely to affect the interaction between level of processing and number of repetitions. The upshot of the analysis that we propose is that one should not expect a single set of processes to underlie the effect of repetitions. Rather, we suggest that it is important to find how the processing of repetitions varies across situations. In analyzing the effects of repetition, we also gain substantial information about the processes underlying the effects of meaning.

The experiments described provide some

evidence that the effects of level of processing can be mimicked by manipulations of the material. Some interchangeability of manipulations of the material and task demands is to be expected if encoded meaning reflects both the meaning-producing activity of the learner and the potential meaningfulness of the material. A frequent criticism of the level of processing approach has been that no objective definition of levels is given, so consequently, the whole approach is circular (e.g., Nelson, 1977). The relationship of level of processing to meaningfulness of the material is informative with regard to this problem of definition. The meaningfulness of CVCs has been defined by using subjects' responses to compile norms. Depth of processing could be defined in a similar fashion. One could simply prepare a long list of tasks such as that provided by Nelson and ask subjects to assign a number to each task with the number reflecting the amount of reasoning or the meaningfulness of the processing required by that task. As in scaled meaningfulness of material, we could use means across subjects to quantify the depth of processing required by each task. We could then go on to show that depth of processing defined in this noncircular fashion predicts retention performance.

What would be gained by scaling depth of processing? This procedure would probably contribute very little. First, we would only be doing in a group what we have previously done individually. More important, a main difficulty with the early definitions of meaningfulness of material is that the definition of meaning is limited to individual items and does not take into account effects of context or task demands. To scale depth of processing for individual tasks without considering the material or more global task demands and context adds little. What is required is a definition that at the very least involves both task demands and the material. Others have argued that one must define level of processing or meaning before we can understand it. We would argue that one needs a better understanding of levels of processing before it can be usefully defined.

The research strategy employed in the

present article is, in part, a return to the functionalist tradition. It differs from that earlier tradition mainly in that the focus is on interactions involving task variables, and a goal is to explain why mathematical functions involving those variables change across situations. We feel that the time is past when simple demonstrations of effects of levels of processing and effects of context are really helpful. What is now needed is some means of incorporating those effects into a larger theory. It seems to us that a reasonable first step toward developing such a theory is to search for regularity in the functions relating task variables to retention performance and to specify how those functions change across situations. If we can devise a classification of situations in terms of the form of functional relationships they produce, we will then be in a better position to speculate about the nature of the beast that can give rise to such diversity.

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