Associative Processing During Rote Rehearsal

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Four experiments investigated whether associations are formed between items rehearsed together under incidental learning conditions. This research responded to the suggestion that subjects may fail to engage the necessary "control processes" that lead to the formation of interitem associations when items are rehearsed together simply for maintenance. Subjects overtly repeated pairs of words for various intervals either prior to immediate recall or as distractor activity intervening between presentation and recall of a digit string. Following rehearsal trials, an unexpected pair recognition test was given in which rehearsed pairs had to be discriminated from mismatched pairs containing words that had been rehearsed but never together. In all four experiments, subjects demonstrated substantial memory for the rehearsal pairings, but the strength of pair memory did not change as a function of the length of the rehearsal interval. Two exceptions to the null effect are reported: First, when pair rehearsal was distributed across two discrete trials, pair memory improved. Second, subjects showed increasing pair memory as a function of rehearsal interval when they were expecting their rehearsal to be interrupted but, in fact, it was not. It is concluded that incidental rehearsal may sometimes lead to improvements in associative learning. It is suggested that attention given to rehearsal material may play an important role in producing continued growth in interitem associations.

When stimulus information is kept continuously available in consciousness through repetition, that information is maintained through the process of rehearsal. For many years it has been common to assume that rehearsal activity, in addition to maintaining the immediate availability of an item, increases the long-term durability of a memory trace (e.g., Atkinson & Shiffrin, 1968; Waugh & Norman, 1965). Rundus and Atkinson (1970) showed that when subjects study information for a subsequent memory test, recall correlates highly with the number of overt rehearsals that an item receives. However, in recent years, the belief that a single rehearsal process could account both for short-term maintenance and for improvement of long-term memory has been questioned. Instead, it has become popular to distinguish between at least two types of rehearsal activity: a maintenance (or Type 1) rehearsal process that is engaged exclusively for short-term operations and an elaborative (or Type 2) rehearsal activity that supports long-term retention.

The important feature of this separation of the rehearsal process is the postulation of a rehearsal activity that does not lead to the transformation of information to a more permanent long-term format. The Type 1 rehearsal process, as first characterized by Craik and Lockhart (1972), was perceived instead as an operation for maintaining the availability of information for which a perceptual-cognitive analysis had already been completed. It was described as a mechanism for sustaining information in a kind of short-term holding pattern, as when an individual might want to remember a telephone number as he or she walks across a room. Although considered to be highly effective for the short-term usage of information, Type 1 rehearsal

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was presented as ineffective for long-term learning because it did not support the kind of elaborative processing that is needed for successful long-term retention. In short, the Type 1-Type 2 distinction suggested that the effectiveness of repetition as a learning procedure may depend importantly on the specific task demands of an experiment.

Evidence in support of a qualitative distinction between Type 1 and Type 2 rehearsals has come from studies showing that the amount of rehearsal that an item receives does not necessarily affect its subsequent long-term recall. These experimental situations typically have been arranged to induce subjects simply to maintain the availability of stimulus items for varying intervals of time without anticipation of long-term recall. Glenberg, Smith, and Green (1977) and Rundus (1977) had subjects repeat a word aloud for varying periods of time as a distractor activity intervening between the presentation and the recall of a digit string. A subject might be presented with four digits, followed by a 10-sec interval that was to be filled with continuous overt repetition of a word until immediate recall of the digits was required.

The key feature of these experiments was the likelihood that the subjects would engage only in passive maintenance of the word throughout the distractor interval; that is, they would devote only a minimal amount of attention to maintaining the word. After a number of trials, an unexpected final free-recall test for the distractor words was administered. Subjects failed to show a significant relation between the time spent repeating the items and a later ability to recall them. Because these results were interpreted as an apparent violation of the established dictum that repetition improves learning, rehearsal for maintenance was accorded independent processing status (e.g., Craik & Watkins, 1973; Woodward, Bjork, & Jongeward, 1973).

The experiments described in this article sought to analyze a particular suggestion that has been made by a number of memory theorists (e.g., Glenberg et al., 1977; Woodward et al., 1973) that during Type 1 rehearsal subjects may fail to form interitem associations among the stimuli that are rehearsed in an experiment, even if those stimuli are rehearsed concurrently. This hypothesis is relevant to the question of why memory for items rehearsed for maintenance does not improve with increased rehearsal time. Specifically, if Type 1 rehearsal is “nonassociative” (i.e., associations are not formed between rehearsed items), then one might not expect the presentation, or the recall, of one stimulus in the experiment to increase the probability of recalling other stimuli that might also have occurred. Consequently, if the beneficial effect of a repetition is due to an increased opportunity to interassociate items on the memory list (see Tulving, 1968), then one might not expect performance to improve as a function of rehearsal interval on long-term retention tests. Perhaps more important, the possibility of a nonassociative rehearsal process suggests that simple word–word contiguity may not be a sufficient condition for the formation of associations. In other words, the establishment of an association may require some kind of associative “control process” or strategy, in addition to contiguity, that is directly under the control of the learner. Such an assertion is, of course, inconsistent with many historically prominent positions on the role of contiguity in the formation and growth of associations (see Hilgard & Bower, 1975).

The present experiments were designed to examine the formation of associations among pairs of items rehearsed together for maintenance. If Type 1 rehearsal is nonassociative, then of course little evidence for associations should be found between items rehearsed together under maintenance rehearsal conditions. Moreover, the length of time that the items are maintained should not be a determinant of the likelihood that associations will be formed. A recent study by Glenberg and Bradley (1979) provided some preliminary evidence on these points. Their experimental procedure was identical in most respects to the one used by Glenberg et al. (1977); however, subjects engaged in rote repetition of pairs of common words as distractor activity in a series of Brown-Peterson short-term memory trials. Because each subject was under the impression that digit strings were the to-be-remembered items, Glenberg and Bradley reasoned that any associations would likely be formed as an exclusive by-product of word–word contiguity. The empirical questions of interest were two-fold: First,
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would there be any memory for the particular word–word pairings? Second, would that memory change as a function of the time the items were maintained together (i.e., the length of the distractor interval)?

Subsequent tests of associative learning revealed some memory for the specific rehearsal pairings but no change in that pair memory as a function of the duration of pair rehearsal. During testing in Experiment 1, for example, subjects were required to discriminate intact rehearsal pairs from pairs containing words that had been rehearsed but on separate trials. Subjects were able to discriminate the intact from the mismatched pairs, but that discrimination failed to improve despite a 10-fold increase in the number of word–word pairings. These results led Glenberg and Bradley (1979) to conclude that whereas Type 1 rehearsal may be sufficient to form an initial weak association between co-rehearsed words, continued Type 1 rehearsal is not sufficient to increase the strength of an association.

Experiment 1

The purpose of Experiment 1 was to replicate the results of Glenberg and Bradley (1979). A Brown-Peterson short-term memory paradigm was used, with overt repetition of word pairs as distractor activity intervening between the presentation and the recall of digit strings. Two unexpected tests of associative learning were administered after the short-term memory trials: a pair recognition test similar to the one used by Glenberg and Bradley and a paired-associate transfer test. For the recognition test, each subject was required to decide whether two presented words had been rehearsed together (i.e., on the same trial). Half of the test pairs contained words that had been rehearsed together during the same Brown-Peterson trial (paired) and half contained words that had been rehearsed for the same length of time but on different trials (unpaired). Therefore, the ability to discriminate between paired and unpaired test pairs was taken to be an index of associative learning unconfounded by memory for the individual words. In addition, these subjects were given a final test of recall to ascertain whether memory for the individual words would increase as a function of rehearsal interval. For the transfer test, a second group of subjects was required to learn a list of paired and unpaired pairs. Any prior associative learning between the co-rehearsed words was expected to lead to positive transfer, as revealed through an increased learning rate for the paired test pairs.

Method

Subjects. The subjects were 36 Yale undergraduates who participated for course credit. One additional subject was removed from the experiment for failing to meet an incidental learning requirement; he suspected that word recall might be required at the end of the experiment.

Materials and apparatus. All stimulus events were presented on a Digital Equipment Corporation VT50 terminal and were controlled by a PDP-11/40 computer. Individual letter and digit characters were .4 × .2 cm and were presented on the left, upper-middle portion of the screen. All stimulus events (except as indicated below) were presented for 500 msec, and successive presentations were separated by an interstimulus interval of 50 msec. Each to-be-remembered digit string was composed of five digits, randomly selected from the range of zero to nine. The digits were presented in succession with the requirement that the same digit could not be presented twice in a row. Word stimuli were single-syllable, four-letter nouns.

Procedure. The subjects were told that they were participating in an experiment on short-term memory for digit strings. A typical Brown-Peterson trial was described, during which repetition of a word pair was to serve as a distracting activity between presentation and recall of a digit string. No mention was made of a subsequent word recall test.

A total of 39 Brown-Peterson trials was presented. A short break occurred for questions between 3 initial practice trials and the remaining 36 experimental trials. Each trial began with three asterisks, presented in succession, to ready the subject for the beginning of the digit list. The five digits were then presented, in succession and in the same location, followed by each member of the word pair. The subject was instructed to repeat aloud, each stimulus event as it occurred on the screen. The word pair, with the first and second terms occurring in succession, was presented twice to ensure that the subject had correctly perceived the words and to initiate a rhythm for the following rehearsal cycle.

After the second word had been presented for the second time, the screen went blank, and buzzers began sounding from the terminal at 1-sec intervals. The subject was instructed to continue repeating the words, in order, synchronous with the buzzers. On a given trial, the buzzer sounded 2, 6, or 14 times; as a result, the word pair was spoken 4, 8, or 16 times. Each rehearsal interval occurred equally often, and in random order, during the 36 experimental trials. The rehearsal interval was terminated with the appearance of the word RECALL on the screen for 3 sec. The subject was allowed 10 sec to recall the digits aloud in their proper order before the onset of the next trial. All responses were recorded by the experimenter.
Immediately following the final Brown-Peterson trial, the experimenter engaged in conversation with the subject for about 1 min. The subject was then asked to count backward from 100 as rapidly as possible. The conversation and the counting task were included to prevent any primary memory component from influencing the subsequent testing phase. Half of the subjects were then given the recognition test preceded by the free-recall test. The remaining subjects received the paired-associate transfer test.

Subjects receiving the free-recall test were handed a lined sheet of paper and were instructed to write down the individual words that they had rehearsed. There were no time constraints, and the subjects were told that the order of word recall was not important. After completion of this task, they were handed another sheet of lined paper, with numbers from 1 to 36. They were then presented 18 paired and 18 unpaired test pairs individually, and in random order, on the terminal screen and were instructed to write Y if they thought they had rehearsed the two words of a pair together (i.e., on the same trial) and N if they thought they had not. Each of the unpaired test pairs contained two words of the same trial type (4-, 8-, or 16-pairing interval) rather than two words of mixed durations. All subjects were told explicitly that each of the words in a pair had been rehearsed during the first part of the experiment, and for the same length of time, and that correct responding could not be based on recognition of individual words. For each pair, the two words were presented side by side and separated by a hyphen; each pair appeared on the screen for 4 sec. In addition, the experiment was counterbalanced such that all of the pairs seen during the recognition test participated in each of the conditions; that is, a given pair was rehearsed at all three intervals across subjects and was both a paired and an unpaired test pair.

Subjects receiving the paired-associate transfer test were given four study-test trials. Each study trial consisted of the presentation of 36 word pairs on the terminal screen, of which half were paired and half were unpaired. The method of presentation was the same as in the recognition test except that each pair was presented for only 2 sec. The subjects were instructed to try to remember each of the pairs such that they could recall the right-hand member of the pair when given the left-hand member. At the conclusion of each study trial, they were handed a sheet of paper that contained the 36 left-hand terms with blanks provided for the respective right-hand terms. Five min. were allowed for recall. Individual word pairs were presented in a different random order on each trial. As in the recognition test, all pairs participated in all experimental conditions.

For all statistical analyses, an effect was considered to be significant if $p$ was less than .05, marginally significant if $p$ was greater than or equal to .05 but less than or equal to .10, and nonsignificant if $p$ was greater than .10.

Results and Discussion

Digit recall. The digit recall was scored as correct only when a subject recalled each of the five digits in proper order. The mean proportions of correct recall for the 4-, 8-, and 16-pairing intervals were .33, .24, and .21, respectively; the decline was statistically significant, $F(2, 34) = 6.81, p < .01, MS_e = 1.51$. Although this result agrees with most data collected in the short-term memory distractor paradigm (e.g., Peterson & Peterson, 1959), it is inconsistent with the results obtained by Glenberg and Bradley (1979). In their study, subjects recalled about 80% of the digit sequences correctly, and the level of recall did not change as a function of rehearsal interval. These discrepancies can probably be attributed to one of the several procedural differences that exist between the present study and the Glenberg and Bradley study; for example, subjects in Experiment 1 received five digits presented in succession at a rate of 500 msec per item, whereas the Glenberg and Bradley subjects received only four digits presented simultaneously for 2 sec. It is conceivable that digit recall functions may depend importantly on such factors as digit load or ease of initial encoding.

Free recall. The mean proportions of correct free recall for the three rehearsal intervals were .06, .09, and .11. Although the mean data suggest the possibility of an increase, it was not statistically significant, $F(2, 34) = 1.95, p > .15, MS_e = 3.76$. If one examines the individual subject data for the 4- and 16-pairing intervals, 11 of the 18 subjects recalled more words from the 16-pairing interval, and 7 subjects recalled more words from the short rehearsal period ($p = .24$ by a sign test). Therefore, any effect of rehearsal length on individual item recall, if present, is probably rather small. As such, these data are consistent with those in a number of earlier studies in finding that item recall shows little or no increase over rehearsal interval when that rehearsal is simple rote repetition (e.g., Craik & Watkins, 1973; Woodward et al., 1973).

Pair recognition. The data of principal interest are displayed in Figure 1. The left panel of that figure shows the results of the pair recognition test in which subjects attempted to discriminate paired from unpaired test pairs. The mean percentage of items given a Y response is plotted separately for paired (i.e., hits) and unpaired (i.e., false alarms) pairs. As the figure clearly shows,
there were large differences in recognition performance as a function of pair type; the main effect of pair type was highly reliable, $F(1, 17) = 16.27, p < .001, MS_E = 3.55$. Subjects were able to discriminate reliably the paired from the unpaired test pairs, which indicates substantial memory for co-occurrence. However, as the parallel lines suggest, there was no interaction. The duration of pair rehearsal failed to affect the strength of the discrimination, $F(2, 34) < 1$. Despite a fourfold increase in the number of contiguous pairings, the extent of the paired-unpaired discrimination remained approximately the same.¹

On the other hand, the overall tendency for subjects to respond “yes” to a presented pair increased over those same intervals, $F(2, 34) = 5.62, p < .01, MS_E = 1.34$. This result was also reported by Glenberg and Bradley (1979) and suggests that some aspect of individual item memory may have increased over rehearsal interval. It is an important finding because it verifies that the present experiment was sensitive with respect to the range of sampled rehearsal intervals. In addition, it represents an apparent dissociation between memory for the individual words and memory for co-occurrence (i.e., associations).

*Associations?* Although it is tempting to conclude that subjects used associative information to mediate performance on the recognition test, there is another possible strategy. Subjects may have based their responding on a comparison of individual item recency information, rather than on some kind of associative structure connecting the words of a test pair. Specifically, if subjects perceived that the two words of a test pair had widely different recencies, then they could reject the pair; similarly, when subjects perceived like recencies, they could conclude that the two words must have been presented together. The use of this kind of decision rule is a viable possibility because the lags separating the unpaired test words varied more or less randomly across a wide range in this experiment. Some unpaired test pairs contained words that occurred on adjacent short-term memory trials, and other test pairs contained words that were separated by as many as 24 short-term memory trials.

![Figure 1. Final test performance in Experiment 1. (The left panel shows the results of the pair recognition test in which subjects attempted to discriminate paired from unpaired pairs. The right panel shows mean percentage of correct recall for the first trial of the paired-associate transfer test.)](image)

Fortunately, this test strategy makes a rather clear prediction: Subjects ought to be less likely to make false alarms (i.e., mistake unpaired test pairs for paired test pairs) when the words from the unpaired test pairs have occurred far apart during the short-term memory trials. In other words, there should be a significant negative correlation between test-pair false-alarm rates and the lags separating the unpaired test words. This latter measure was obtained by simply counting the number of short-term memory trials that intervened between the presentations of a particular unpaired test pair’s two words. Thus, each of these test pairs had an associated false-alarm rate and a measure of individual word discrepancy; these measures were then correlated across all of the unpaired test pairs. The resulting correlation did not differ significantly from zero ($r = .07$). To be more specific, a mean of 3.3 false alarms were made for unpaired test pairs whose words were separated by 20 or more short-term memory trials, whereas pairs with item discrepancies of 5 or fewer trials yielded a mean of only 3.2 false alarms. Thus, the data pro-

¹ A similar conclusion is reached when one analyzes the data according to signal detection procedures. The mean $d'$s for the 4-, 8-, and 16-pairing intervals were .66, .72, and .60, respectively.
vide no real support for a test strategy based on a comparison of individual item recencies.

Transfer test. The right panel of Figure 1 shows the results of the paired-associate transfer test. For this measure, it was expected that any prior associative learning resulting from the pair rehearsal would enhance the learning rate for the paired test pairs. The mean percentage of recall is plotted for the paired and unpaired pairs for the first testing trial. (The results are shown only for the first testing trial because subjects learned rapidly in this task and were at ceiling by the second study–test trial.) For all three rehearsal intervals combined, 51% of the paired responses were correctly recalled, and 44% of the unpaired responses were correctly recalled. This difference proved to be marginally significant, $F(1, 17) = 2.98, p = .10$, $MS_e = 1.64$; for the individual data, 10 of the 18 subjects recalled more paired than unpaired responses, 4 showed the opposite pattern, and there were 4 ties ($p = .09$ by a sign test). The data are consistent therefore with the results of the recognition test in suggesting the presence of some memory for co-occurrence. Moreover, as in the recognition test, the Pair Type $\times$ Rehearsal Interval interaction was not significant, $F(2, 34) < 1$.

These data replicate and extend the results of Glenberg and Bradley (1979) and suggest that although there can be substantial memory for the particular pairings, this paired memory is unaffected by the duration of pair rehearsal. In addition, the present results were obtained over a range of rehearsal intervals different from those sampled by Glenberg and Bradley, which suggests that the null effect of interval can probably not be treated as an artifact of the particular intervals selected. Rather, it seems that an increase in the number of pairings may not be a sufficient condition for growth in the pair memory.

Experiment 2

Experiment 2 was designed to examine associative learning under incidental rehearsal conditions that have previously been shown to improve long-term recall as a function of rehearsal interval. Dark and Loftus (1976) reported the results of a pair of experiments in which subjects were instructed to remember short lists of from three to five words for brief periods of time. The retention intervals were filled with either (a) simple overt repetition of the stimulus list or (b) some kind of distractor task (e.g., arithmetic computations). At the conclusion of an interval, subjects either immediately recalled the current stimulus words or engaged in a digit shadowing task until presentation of a new list (i.e., there was no immediate recall); these latter trials, or no-recall trials, were included to control for the possible beneficial effect of an initial immediate recall on a delayed recall (see Modigliani, 1976). Because subjects were not expecting long-term recall, Dark and Loftus expected the subjects to use Type 1 rehearsal for maintenance. So, after a number of short-term memory trials, all subjects were given an unexpected final free-recall test. The results revealed a significant relation between the length of the rehearsal interval and free recall for those words receiving overt repetition during the retention interval.

This kind of experimental design differs from that used in Experiment 1 in a number of interesting ways. First, immediate memory for the rehearsal words is the primary requirement that the subject faces. This differs from the preceding experiment and from other experiments using the digit-distractor paradigm (e.g., Glenberg et al., 1977; Rundus, 1977) in which subjects merely rehearse words as a secondary activity that is direct competition with the primary task of digit recall. It may be that when subjects are anticipating recall of what is being rehearsed, even immediate recall, they process information associatively. Second, overt word rehearsal in the Dark and Loftus (1976) study occurred in the absence of any concurrent memory load. Because subjects in Experiment 1 were concerned about the digit recall, they may have rehearsed the word pairs in a way that used only a minimal amount of processing capacity; as a consequence, long-term memory for the words may have been hampered relative to a situation in which words are rehearsed as the primary task. Finally, the major variable of interest in Experiment 1 was associative learning. If the difference between Type 1 and Type 2 re-
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hearsals is that the former is nonassociative, then rehearsal conditions that can lead to increases in the memorability of individual words (Dark & Loftus, 1976) might not necessarily lead to increases in the strength of associative learning.

Subjects in the present experiment overtly rehearsed pairs of common nouns for varying intervals prior to either immediate recall of the pair or rapid generation of a three-digit number; this latter manipulation was designed to resemble the no-recall trials of Dark and Loftus. All subjects were informed that the experiment was concerned with short-term memory for words in order to ensure that the word rehearsal was the primary experimental task. At the conclusion of a series of these short-term memory trials, an unexpected pair recognition test was administered.

Method

Subjects. The subjects were 24 Yale undergraduates who participated for course credit.

Materials and apparatus. Word stimuli were identical to those used in the preceding experiment. All stimulus events were presented and controlled by a Radio Shack TRS-80 microprocessor. Individual letter characters were approximately 1 x .6 cm and were presented in the middle of the terminal screen.

Procedure. All subjects were told that they were participating in an experiment on short-term memory for words. Sixty-six experimental trials were presented, in addition to 6 initial practice trials. Each trial began with the word READY presented for approximately 2 sec, followed by the presentation of the to-be-rehearsed word pair for another second. The word pair was then removed, and individual four-letter nouns began to appear in succession in the middle of the screen; each single word remained on for about 1 sec. These single words served as pacers for overt rehearsal of the word pairs. Subjects were instructed to repeat the word pair aloud any time one of these single pacer words appeared on the screen. Pair rehearsal continued until one of two events occurred: If the word RECALL appeared on the screen, the subject was told to write down the rehearsed word pair on a lined sheet of paper; 8 sec were allowed for immediate recall before the onset of a new trial. Alternatively, if a line of asterisks appeared on the screen, the subject was to generate aloud the first three-digit number he could think of. Approximately 1 sec later, the line of asterisks was removed and a new trial began. Of the 66 experimental trials, 36 were no-recall (i.e., digit generation) trials and 30 were recall trials.

The main variable of interest was the length of the repetition interval as defined by the number of single pacer words that appeared on a trial. On each of a random 12 of the 36 no-recall trials, 4, 8, or 16 individual words appeared. Similarly, the recall trials were divided equally among these three intervals. The generation of the single words was randomly determined for each trial by sampling with replacement from a pool of 30 words. Although each word was a single-syllable, four-letter noun, none was related in any obvious way to the words contained in the pairs. The order in which a particular trial was presented was random except that precautions were taken to ensure that a given trial (e.g., a no-recall, four-word interval) was preceded and followed by each of the other trial types.

Immediately following the final memory trial, all subjects were required to count backward from 100 as quickly as possible to prevent any primary memory component from influencing the subsequent test. Each subject next received a pair recognition test similar to that used in Experiment 1 except that this test was a forced-choice one: A paired and an unpaired pair were presented simultaneously, and the subject simply had to choose the paired pair. Subjects responded by circling either an R or an L (for the right or left pair) in a space provided on a sheet of paper. They also indicated their confidence by responding on a scale ranging from 1 (guess) to 3 (positive). The test list was structured such that each of the four words comprising the two pairs on a test trial had been rehearsed and for an equal number of times in the experiment. In addition, and what is important, only those words that had not been recalled during the first part of the experiment (i.e., words from pairs rehearsed on the no-recall trials) appeared on the recognition test; this included the two words from the paired pairs and the two words from the unpaired pairs. Only these items were included on the test to prevent initial recall from influencing performance on the final recognition test. Finally, the experiment was counterbalanced such that each of the test pairs participated in all conditions; that is, each pair was either paired or unpaired and was rehearsed at each of the three intervals. Subjects were given as much time as they needed to make each choice and to indicate their confidence level.

Results and Discussion

Immediate recall. As expected, subjects were quite proficient during immediate recall of the word pairs. Of the 720 possible recall opportunities (24 subjects and 30 recall trials), only 5 errors were made. This finding is hardly surprising given the fact that the subject was repeating the word pair aloud right up to the point of recall. However, these results do confirm that the subjects were following instructions by maintaining the word pairs throughout the rehearsal interval. Similarly, on those trials in which no recall was required, subjects readily generated a variety of three-digit numbers. It is important to emphasize that the number generation, though not a difficult task, was sufficiently taxing to consume the 1 sec that intervened between the end of the rehearsal interval (i.e., the line.
of asterisks) and the beginning of the next trial (i.e., the word READY). Thus, it seems unlikely that the subject could have spent the no-recall period thinking about the just-rehearsed word pair.

**Pair recognition.** The results of primary interest are displayed in Table 1. The table shows the mean recognition performance and the mean confidence scores, both as a function of rehearsal interval. In scoring the confidence ratings, each rating was multiplied by a +1 or a −1, depending upon whether the correct pair had been chosen; this had the effect of creating a potential 6-point scale ranging from +3 to −3. The values for each of the three conditions were then summed, and averages were calculated. This means that the table displays derived confidence scores rather than raw confidence ratings. The data were analyzed in this manner to provide a more sensitive measuring scale for a given item; similar techniques have been used before (e.g., Crowder, 1979).

The first thing to note about the recognition data is that the mean performance levels are all substantially above the chance level of 50%. These data are consistent therefore with those of Experiment 1 because they indicate the presence of substantial memory for co-occurrence in this task. In addition, examination of the mean data as a function of rehearsal interval reveals a replication of the pattern of Experiment 1 in suggesting that a four-fold increase in the number of pairings has little, if any, effect on the strength of pair memory; the interval effect did not approach significance, $F(2, 46) < 1$. This null effect of interval is perhaps easier to see in the present context because the forced-choice recognition procedure masked any changes in individual item memory like those found in Experiment 1.

Examination of the confidence scores in Table 1 reveals a similar pattern. Although there was a small and consistent increase in the mean scores over retention interval, again the effect did not approach significance, $F(2, 46) < 1$. Specifically, when one considers only the largest difference, between the 4 and the 16 pairing intervals, 13 of the subjects scored higher on the long-interval pairs, 10 subjects scored higher on the short-interval pairs, and there was 1 tie. Thus, these data fail to support in this context a positive relation between rehearsal interval and the growth of associative learning.

Moreover, there is again little indication in the data that subjects used a comparison of individual item recency information as the basis for their recognition performance. An analysis similar to the one described in Experiment 1 was conducted, in which test-item error rate was correlated with a measure of the lag between initial occurrences of unpaired words. Because the present experiment used a forced-choice procedure, each test choice had an associated error rate and a measure of distractor-pair discrepancy; these measures were correlated across all test choices. The final correlation was essentially zero ($r = −.05$). As a result, these data provide support for the conclusion offered in Experiment 1 that subjects probably do not use a test strategy based on a comparison of individual item recencies.

It appears, therefore, that although overtrote rehearsal of single words can sometimes lead to increases in individual item memorability over interval (e.g., Dark & Loftus, 1976), similar rehearsal conditions fail to effect much change in the strength of pair memory. This conclusion gains added significance when one considers that the present experiment used a recognition procedure, which typically has shown the most sensitivity to interval effects (Woodward et al., 1973), and yet still failed to find an increase in pair memory. Of course, the present experiment did not replicate the Dark and Loftus procedure exactly; for example, subjects in the present experiment repeated the word pairs aloud throughout every interval. It is possible, therefore, that the individual words might not have been recalled more frequently as a function of the length of the rehearsal interval, as they were in the study by Dark
and Loftus. However, it seems clear that the anticipation of immediate recall of rehearsal items does not necessarily mean that the subject will show a positive effect of rehearsal interval. Rather, it seems that subjects can choose to use Type 1 rehearsal in many tasks because it is an effective strategy for maintaining information over short periods of time.\footnote{It is perhaps problematic that rehearsal in Experiment 2 was paced by the appearance of single words throughout each interval. It could be argued that no increase in memory for association was found because some kind of additional interference was caused by the pacing words in the longer intervals. To counter this criticism, Experiment 2 was replicated with unpaced rehearsal. Sixteen subjects repeated word pairs for 4 or 16 sec, followed by immediate recall or generation of a three-digit number; each subject was instructed simply to rehearse the pairs aloud at a fairly rapid pace. For the final recognition test (which was identical to the one used in Experiment 2), the mean recognition level was 70 for both the short and the long rehearsal intervals. Of the 16 subjects, 6 recognized more of the long-interval pairs correctly, 5 recognized more short-interval pairs, and there were 5 ties. Thus, pacing words does not appear to be a necessary condition for producing the null effects.}

Experiment 3

As much of the preceding discussion suggests, these experiments have provided, at least on the operational level, good evidence for associative learning. Each study has demonstrated memory that is a unique function of a previous pairing. In what sense then is it correct to classify Type 1 rehearsal as non-associative? One possibility is that the associative processing is limited to the initial setting up of the rehearsal cycle. The above-chance levels of pair recognition, for example, may have been the result of the short-term contiguous processing that is necessary for the subject to encode that a given two words need to be rehearsed together (for a similar account, see Glenberg & Bradley, 1979). However, once the rehearsal cycle is initiated, no further associative processing occurs. Such an interpretation is at least consistent with the pattern of data reported in the previous experiments.

With this in mind, Experiment 3 sought to examine the effect of presenting a given rehearsal pair on two separate trials rather than simply for a single trial. In this case, it would be necessary for a subject to initiate a specific pair rehearsal twice in the experiment. Any beneficial effects that might result from the beginning of the pair rehearsal would then be expected to lead to especially good memory for those pairs presented twice. This expectation of a repetition effect in the present context follows from a finding reported by Rundus (1977) that single words receiving Type 1 rehearsal may benefit from the amount of rehearsal if that rehearsal is distributed across discrete trials. Rundus found significantly higher performance in final free recall for words rehearsed on two trials than for words rehearsed for the same period of time but on a single trial. Thus, one important function of Experiment 3 was to replicate Rundus’s findings, with the recognition of associations used as the dependent variable.

Subjects in the present experiment rehearsed pairs of common nouns for either short or long intervals in a fashion similar to that of Experiment 1. Half of these pairs were then presented again for a medium rehearsal interval at a later point in the session. Following the presentation of a series of these digit-distractor trials, all subjects were given a surprise forced-choice pair recognition test.

Method

Subjects and apparatus. The subjects were 32 Yale undergraduates who participated for course credit. The apparatus and the stimulus materials were those used in Experiment 1.

Procedure. The general procedure was similar to that used in Experiment 1. Subjects received a series of short-term memory digit-distractor trials while under the impression that the experimenter was interested only in the digit recall. This was followed by a surprise forced-choice recognition test in which subjects attempted to discriminate target (i.e., paired) pairs from pairs containing words that had been rehearsed but never together (i.e., unpaired pairs). For this test, these latter pairs always contained two words that had received the same rehearsal treatment as the target pairs; that is, the words had been rehearsed on one or two trials and for a short or a long interval. For each choice, subjects indicated their degree of confidence on a 3-point scale that ranged from 1 (guess) to 3 (positive).

Subjects received 96 experimental trials. Thirty-two of these trials contained pairs that were presented only once for a short (4 pairings) or a long (12 pairings) interval. A second 32 trials consisted of the first exposure of pairs that were to be rehearsed twice, and the remaining 32 trials were repetition trials of a medium length (8 pairings). Rehearsal was paced, as in Experiment 1, by buzzers that sounded at 1-sec intervals. The first presentation of the twice-presented pairs was equally often a short or a long interval. In addition, the distri...
bution of trials was random except that care was taken to ensure that the lag between the first and second presentations of a pair did not differ for pairs rehearsed initially for a short or a long interval. Finally, as in the previous experiments, all pairs participated in all conditions of the experiment.

Results and Discussion

Digit recall. The mean values for the digit recall were .37, .34, and .30 for the short, medium, and long rehearsal intervals, respectively; the decline was statistically significant, \( F(2, 46) = 5.43, p < .01, MS_e = 4.62 \).

Pair recognition. The recognition levels for the pairs presented once (control) or twice (2-trials) are displayed in the left panel of Figure 2. The results are plotted as a function of rehearsal interval. Thus, for the twice-presented items, recognition performance is separated according to whether the pair was rehearsed initially for a short or a long interval. The first thing to note about these data is that the overall level for the control pairs is clearly above the chance level of 50%. This replicates the previous experiments and shows once again that subjects are able to remember what words have been experienced together under these kinds of incidental learning conditions. In addition, there was again little indication that subjects used individual item recency information as the basis for their recognition performance. As in Experiment 2, test-item error rate showed little, if any, correlation with the lag between initial occurrences of the unpaired words (\( r = -.13 \)). For this analysis, the unpaired lags were correlated with error rates only for those pairs presented once (i.e., control pairs). Second, there is no indication in the mean data that the length of the rehearsal interval had any effect on the subsequent recognition performances; this was confirmed statistically, \( F(1, 31) < 1 \). The confidence scores, which are shown in the right panel of Figure 2, showed a comparable null effect of interval, \( F(1, 31) < 1 \).

However, the comparison of principal interest is that between the once- and twice-presented pairs. The results revealed a highly reliable main effect of this manipulation: Subjects correctly recognized a greater number of the twice-presented pairs, \( F(1, 31) = 9.81, p < .005, MS_e = 1.27 \), and were more confident in their decisions about these pairs, \( F(1, 31) = 13.30, p < .001, MS_e = .504 \). These results replicate those of Rundus (1977) except that in the present experiment subjects presumably recognized associations rather than single words. In addition, the number-of-presentation manipulation failed to interact reliably with rehearsal interval in either the recognition data or the confidence scores (both \( F_s < 1 \)). This finding further supports acceptance of the null effect of interval because the null effect is replicated at different overall recognition levels.

An additional point of interest centers on a comparison between those pairs rehearsed once for a long interval and those pairs rehearsed twice but for a short interval during the initial presentation. This comparison is interesting because the pairs in these two conditions received exactly the same number of rehearsals; they differed only in that the pairings were distributed in one case. As the mean values suggest, there was a significant difference between these points, \( t(31) = 2.6, p < .01 \). Among other things, this finding can be interpreted as a violation of the total-time hypothesis (Cooper & Pantle, 1967); however, such a violation is not surprising if associative learning in this context is limited to the initiation of the rehearsal cycle.

Although the number of pairings per se appears not to be a potent variable under
ASSOCIATIONS AND REHEARSAL

these rehearsal conditions, Experiment 3 suggests that when those pairings are distributed across two separate trials, associative learning is enhanced. There are a number of possible interpretations of this result. As Rundus (1977) suggested, for example, it may be that when items are presented on two trials, a greater variety of temporal-contextual cues are encoded as part of the memory trace. These additional cues could then aid discrimination of the paired from the unpaired test pairs on the final recognition test. However, it should be emphasized that each of the four words comprising the two presented pairs on the recognition test had been rehearsed for the same length of time and in the same variety of contexts. Thus, the beneficial effect of the contextual encoding would have to be assigned specifically to the relation between the words (i.e., the association) rather than to the individual words themselves. Alternative explanations might place the locus of the repetition effect at more global levels of stimulus processing. Subjects might find, for example, the repetition of a pair to be a particularly surprising event; consequently, they might process the second presentation of a pair more “deeply” (Craik & Lockhart, 1972) or with a higher interest-arousal level (Jacoby, 1978). There is nothing in the present data to disconfirm such interpretations.

However, the fact that pair memory fails to be affected by the length of rehearsal seems to suggest the importance of the initial stages of the rehearsal process. It is at this point that the subject has to encode that a given two words need to be rehearsed together; perhaps to the extent that this process occurs twice, memory for co-occurrence improves. However, once the initial setting up of the rehearsal cycle is achieved, subsequent processing may no longer be associative. Consider, for example, the possibility that the subject controls overt rehearsal through the initiation of an auxiliary storage loop, perhaps similar to the kind of articulatory storage loop described by Baddeley and Hitch (1974). Such a system may demand little, if any, attentional resources, and thus it may be an adaptive response in a situation in which the capacity of short-term memory is strained. In the digit-distractor paradigm used in the present experiment, the pair rehearsal task is constructed to be a secondary activity that can substantially interfere with the primary task of digit recall. Thus, it is not unreasonable to expect subjects to exert the maximum amount of their attentional resources to the digit task rather than to repeating the word pairs. Consequently, it might be beneficial to dump the words into a buffer system that reduces distractor interference with a minimum of processing effort.

Furthermore, if activation of such a storage loop is under the strategic control of a central executive (Baddeley & Hitch, 1974), then one must assume that its activation has to follow some direct processing (i.e., storage or rehearsal) by the central processor; that is, the “looping subroutine” needs to be established. If one assumes that when information is processed by the central executive, it is processed associatively, then it is at the stage prior to activation of the loop that associations are established. Such an account is consistent with the pattern of results obtained in the present experiment in which word pairs were presented on two separate trials. In this case, because the loop has to be activated twice, the total amount of storage time by the central executive increased, and subsequent associative learning was enhanced.

Experiment 4

If Type 1 rehearsal can be identified with the activation of an auxiliary storage loop, then Type 1 rehearsal may be engaged only in situations in which the subject can expect a period of continuous, uninterrupted information storage. That is to say, the subject cannot be expected to initiate a rehearsal process that requires little attentional resources under conditions in which any substantial processing of the rehearsed information is continuously required. Perhaps it is for this reason that subjects are unlikely to show a null effect of incidental rehearsal interval when comparing a maintained item with other items in a search list (e.g., Darly & Glass, 1975; Maki & Schuler, 1980). To the extent that attention has to be directed toward the word rehearsal task, then activation of the loop, and hence a null effect of interval, may not be obtained.

In order to investigate this possibility, in Experiment 4 the amount of attention that
subjects needed to direct toward rehearsal of the words was manipulated. It was hoped thereby to influence whether subjects would choose to initiate a pair rehearsal strategy that required little attentional capacity (e.g., an articulatory loop). In common with the previous experiment, subjects in Experiment 4 rehearsed pairs of common nouns for different intervals between the presentation and the recall of a digit string. However, in the present experiment, there were four types of rehearsal trials: On two trial types, the subject continuously rehearsed a word pair for either a short or a long interval (continuous trials); for the remaining two, pair repetition was interrupted either once or twice in the interval by the appearance of an additional word pair (or pairs) that had to be repeated aloud (interrupt trials). The important manipulation varied was whether the subject was informed about which trials would be interrupted. Although all subjects received exactly the same four trial types, only half of the subjects (signaled) were cued at the beginning of each trial about its status. The remaining subjects had no way of predicting the nature of a particular rehearsal interval.

The critical comparison examines performance on the continuous trials for the signal and unsigned groups. Presumably when subjects are cued that a trial is continuous (no interruptions), they will be more likely to set up an articulatory loop to control overt rehearsal. This is due to the fact that they anticipate an interval in which attention may be freely directed toward the digit task and away from the pair rehearsal. These subjects should then show no improvement in pair recognition as a function of rehearsal duration. On the other hand, the unsigned subjects cannot predict when an interruption will occur and hence must attend more closely to their word rehearsal. Unsigned pair rehearsal should therefore be controlled by the central processor rather than by the articulatory loop. This predicts that unsigned subjects should be more likely to show reduced digit performance and an increase in pair memory over interval.

Method

Subjects and apparatus. The subjects were 48 Yale undergraduates who participated for course credit. The apparatus and general materials were the same as in the previous experiment.

Procedure. All subjects were told that the experiment was concerned with short-term digit recall. As in the previous experiments, a trial consisted of the presentation of five single-digit numbers followed by a word-repetition distractor task until digit recall was required. However, in contrast to the previous experiments, all to-be-rehearsed words were flashed on the terminal screen in succession throughout the entire rehearsal interval; subjects were told to say the words aloud as they appeared. In addition, each subject was told that there would be two types of distractor trials, those with the continuous repetition of two words and trials in which pair repetition would be interrupted momentarily by the appearance of additional words. Thus, in general, subjects were aware that they would be rehearsing a word pair during most of the distractor interval. The between-groups instructions did not differ except with respect to the appearance of the signals indicating the particular trial type. Subjects in the signaled group were told only to attend to the signals when they occurred; they were given no instructions about potential word-pair rehearsal strategies.

Signaled trials began with the appearance of the word CONTINUOUS or the word INTERRUPT for 3 sec. For subjects in the unsigned group, a line of asterisks replaced the signal. Next, three asterisks and the five digits were presented in a manner identical to that described in Experiment 1. Following the fifth digit, single words began to appear in succession and in the same location until the appearance of the word RECALL; 7 sec elapsed before the onset of a new trial. For the continuous trials, only two words were repeated for either a short (4 pairings) or a long (12 pairings) interval. During interrupt trials, pair repetition was interrupted either once or twice by the appearance of new pair; that is, two new words appeared on the screen in succession and with the same timing parameters as the original words. The new pair was always repeated twice except that on a random half of the trials, the order of the two words was switched across the two repetitions; this was done to increase the unpredictability of the interruption. When the rehearsal interval contained two interruptions, two different pairs were always inserted into the interval. All interruption trials were created by substituting new words for old ones on the background of a continuous, 12-pairing interval; thus, all interrupt trials contained 24 words. An example of each of the trial types is shown in Table 2.

Each subject received 72 trials including 8 initial practice trials and 64 experimental trials. The 64 experimental trials were divided equally into the four trial types, which were then randomly distributed throughout the session. Although all trials were signaled for half of the subjects, no information was given concerning the length of the continuous trials (i.e., short or long) or whether one or two interruptions would occur; these subjects knew only the general trial type (i.e., continuous or interrupt). At the conclusion of the experimental trials, each subject counted backward from 100 to remove any primary memory component and was given a forced-choice pair recognition test. The general structure of the test was the same as in Experiments 2 and 3. Subjects chose intact rehearsal pairs from mismatched pairs containing words of the same trial type. Finally, subjects indicated their confidence in their choice on a 3-point scale.
Table 2  
**Trial Types for Experiment 4**  

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**Results and Discussion**

**Digit recall.** The main results of interest are shown in Table 3. The table displays the proportion of correct recall as a function of group and trial type. An overall analysis of variance (ANOVA) on these data revealed a significant main effect of trial type, $F(3, 138) = 41.22$, $p < .001$, $MS_e = 3.75$, and a significant Group × Trial Type interaction, $F(3, 138) = 3.27$, $p < .05$, $MS_e = 3.75$: the main effect of group was not significant, $F(1, 46) = 1.81$, $MS_e = 35.51$. As the data clearly indicate, there was a decline in successful recall as the rehearsal interval increased; this is a result that is consistent with findings of previous experiments. Moreover, it is apparent that the interruption manipulation had a significant impact on recall, but only in the signaled group. A Newman-Keuls analysis revealed that the recall levels between the uninterrupted long interval and the once-interrupted interval were significantly different only for the signaled subjects; this particular comparison is appropriate because it is not confounded by the overall length of the interval.

This general pattern of recall is of interest for several reasons. First, the pattern verifies that the interruption manipulation was sufficiently powerful to affect behavior in this context, at least for the signaled group. Similarly, the significant interaction supports the claim that subjects attended to the signals when they occurred. More important, however, is the finding that the interaction appears to be due uniquely to the high levels of recall on the continuous trials for the signaled subjects; all other conditions showed similar levels of recall. If subjects in the signaled group were using the continuous trials to switch to a pair rehearsal strategy that required low attentional capacity, then the resultant pattern of recall is one that might have been expected. In other words, because these subjects were aware that their rehearsal would not be interrupted, more effort was directed toward the digits and away from the pair rehearsal.

**Pair recognition.** The results of interest are plotted in Figure 3, which shows the overall recognition and confidence scores for the continuous and interrupt trials as a function of group. These data were first subjected to an overall group by trial type ANOVA. For the recognition data, the analysis revealed a significant effect of group, $F(1, 46) = 8.06$, $p <$

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<th>Short</th>
<th>Long</th>
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<td>.36</td>
<td>.21</td>
<td>.17</td>
</tr>
<tr>
<td>Unsigned</td>
<td>.36</td>
<td>.22</td>
<td>.20</td>
<td>.15</td>
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*Note. Values are proportion correct.*
.01, $MS_e = 2.33$, a significant effect of trial type, $F(3, 138) = 3.68, p < .02, MS_e = 1.85$, and a marginally significant Group $\times$ Trial Type interaction, $F(3, 138) = 2.42, p < .07, MS_e = 1.85$. The confidence ratings showed similar results; however, the Group $\times$ Trial Type interaction met conventional levels of significance with this analysis, $F(3, 138) = 2.78, p < .05, MS_e = .593$. Finally, there was no indication that comparisons of individual item recency information played any important role in the recognition test, as measured by the correlation between test-item error rate and the lag between initial occurrences of unpaired words. The correlation was computed across all conditions and was essentially zero ($r = -.05$).

There are two major findings of interest to note in the overall data. First, the main effect of group presumably reflects the fact that subjects in the signaled group were performing at higher levels, but this is true only on the interrupt trials. Moreover, only the signaled group showed a significant difference between the continuous long interval and the once-interrupted interval, $t(23) = 2.48, p < .02$. This pattern is important because it suggests, like the digit recall, that subjects in the signaled group might have been processing the pairs differently on continuous and interrupt trials. It is possible, for example, that these subjects tended to pay more attention to the pair rehearsal when an interruption was expected. As a result, their digit recall performance was weakened, but their pair recognition performance improved. These results can be contrasted with those for the unsignaled group, which was unable to predict when an interruption might occur. It is unlikely that subjects in this group were able to use any relatively beneficial digit strategy on continuous trials; therefore, they showed similar test performances on continuous and interrupt trials.

On the other hand, one might have expected to see some differences between the continuous and the interrupt trials for the unsignaled subjects on the final recognition test. Because pair rehearsal on some trials was interrupted, subjects had to initiate a given pair rehearsal twice. Experiment 3 showed, for example, that when the same pair is rehearsed on two different trials, pair recognition improves. However, there is no suggestion in the present data that a similar improvement occurs when the pair rehearsal is initiated, twice within the same interval. There is also no indication in the present data that the number of interruptions has any effect on final recognition performance; however, this comparison is confounded with the overall number of pair repetitions.

The result of principal interest is the comparison of performance on the continuous trials alone as a function of rehearsal interval and group. The important thing to note is that associative learning increases as a function of rehearsal duration for the unsignaled subjects but not for the signaled subjects. For the recognition data, an ANOVA on the continuous trials revealed a significant effect of rehearsal interval, $F(1, 46) = 5.91, p < .02, MS_e = 1.69$, and a marginally significant Group $\times$ Interval interaction, $F(1, 46) = 2.71, p = .10, MS_e = 1.69$. For the confidence scores, again the interval effect was significant, $F(1, 46) = 5.59, p < .05, MS_e = .853$, and the Group $\times$ Interval interaction was marginally significant, $F(1, 46) = 3.06, p = .08, MS_e = .583$. Subsequent planned comparisons revealed a highly reliable effect of rehearsal interval for the unsignaled subjects, $t(23) = 2.93, p < .01$, and no such effect for the signaled subjects, $t(23) = .55, p > .05$.

This pattern is important because it suggests that different rehearsal processes were
engaged between the two groups on the continuous trials. Both groups received the same events on these trials, yet only subjects who knew that the trial would be continuous showed a null effect of interval. This was the predicted result: Because subjects in the signaled group expected a period of unhampered information storage, they may have switched to a pair rehearsal process that required no significant attentional resources; the result was improved digit performance and no effect of rehearsal interval. However, there is one problem with this account: On the short continuous trials, pair recognition is higher in the signaled than in the unsignaled condition. Because greater attention to pair rehearsal was presumably required in the unsignaled condition, it is unclear why the overall level of performance should be so low. Still, despite this anomaly, it seems clear that the subject’s specific expectations about the content of the rehearsal interval may importantly influence the qualitative features of the rehearsal process that he or she engages.

In addition, some consideration needs to be given to the possibility that the unsignaled subjects were simply reading the words during the continuous trials. It could be argued that these subjects were not rehearsing the distractor words because the stimulus words were always available on the terminal screen to be read aloud; that is, task demands did not dictate that they maintain the information continuously in memory in the absence of the initial stimulus (Glenberg & Adams, 1978). Although it is conceivable that all subjects could have read the words, perhaps only the signaled subjects “rehearsed” because they alone knew what would be appearing on the screen throughout the continuous trials. It seems likely that attention to the screen was differential for the two groups, and this may help account for the differing pattern of results.

However, there is nothing inherent in the differentiation between reading and rehearsing that predicts the form of the interaction obtained in this experiment. Why should reading rather than rehearsal lead to an interval effect? In fact, one could argue that rehearsal should have been the effective learning procedure because “rehearsed” words, by definition, would have had to be generated continuously through internal rather than external means (e.g., Jacoby, 1978). According to the present account, word processing was associative for the unsignaled subjects because information was being stored by the central executive in working memory rather than in an auxiliary storage buffer. At present, the account remains silent on the distinction between reading and rehearsing.

General Discussion

These experiments were conducted to investigate associative learning during rote Type 1 rehearsal of word pairs. The empirical questions of interest were two-fold: First, can associations be formed during Type 1 rehearsal? In each of four experiments, subjects demonstrated substantial memory for which words had been given paired presentations. Consequently, the results are clear in showing that at least some associative learning can occur despite the incidental nature of the rehearsal task. The second question asked whether the amount of associative learning improves with an increasing rehearsal interval. One of the consistent results of the present experiments was the null effect of rehearsal interval on the long-term recognition of the word pairs. Each of the four experiments contained evidence suggesting that the sheer amount of Type 1 rehearsal, as defined by the number of contiguous pairings, has little effect on the strength of pair memory. Despite up to four-fold changes in the length of the rehearsal interval, pair recognition performance remained unchanged; this general finding replicates data reported earlier by Glenberg and Bradley (1979). Thus, although substantial associative learning may occur during the initiation of Type 1 rehearsal, little additional associative processing seems to occur once the rehearsal has begun.

Moreover, it appears unlikely that this null effect of interval can be attributed to a general lack of power or to the range of sampled rehearsal intervals. For example, the significant increase in individual item memory in Experiment 1 shows that these intervals were sufficient to produce changes in memory over time. In addition, the significant increase in pair memory found for the unsignaled con-
tinuous trials in Experiment 4 further supports the particular selection of rehearsal intervals. The present experiments can also be shown to possess reasonable levels of statistical power: A formal analysis of power in Experiment 2, which showed the largest mean differences without significance, revealed a 90% chance of detecting a true difference between means as small as 7%. Such a difference is within a reasonable range, given the kind of increases that are normally found in intentional learning experiments (i.e., Bjork, 1970). This reduced effectiveness of rehearsal time as a determinant of memory therefore replicates the majority of Type 1 rehearsal experiments (e.g., Craik & Watkins, 1973; Glengberg et al., 1977; Rundus, 1977; Woodward et al., 1973), which have shown some observable level of long-term memory but no change in that memory as a function of the time an item has been maintained.

On the other hand, the significant effect of rehearsal interval that was found for the unsigned group in Experiment 4 indicates that incidental rehearsal may sometimes lead to improvements in associative learning. There is little reason to expect, for example, that subjects in this group would have chosen to engage an associative control process simply because they were expecting their rehearsal to be interrupted. In addition, because no information was given about the final memory test, it is unlikely that these subjects would have made any intentional attempt to form associations between the co-rehearsed words. Rather, these results suggest that so-called “associative rehearsal,” although perhaps qualitatively different from the rehearsal of the signaled subjects, does not depend exclusively on the long-term intentions of the subject.

Experiment 4 is important for another reason. Because all subjects received the same stimulus materials and rehearsed them at the same rate, Experiment 4 reduces the possibility that specific procedural factors could have been responsible for the null effect of interval found in the preceding experiments. For example, the majority of Type 1 rehearsal experiments, including Experiment 4, have used highly massed repetitions of stimuli as the rehearsal task. It has been known for some time that massed practice is a poor learning procedure relative to distributed practice (Hintzman, 1974). Experiment 3, in fact, can be described as an experiment demonstrating the advantage of distributed over massed repetition under incidental learning conditions. It could be argued then that the specific quantitative features of the learning curve are simply limited under Type 1 rehearsal conditions; for example, the learning curve could peak at a relatively low asymptote or rise at an extremely low rate. However, the results of Experiment 4 indicate that simply massing the rehearsal cannot completely account for the null effect. Subjects in the unsigned group overtly repeated the word pairs at the same rate and for the same length of time as did subjects in the signaled group and yet showed a quite different pattern of results.

Of course, this observation does not eliminate the possibility that rehearsal rate plays an important role in reducing the effectiveness of repetition in these experiments; in fact, it seems likely that the continuous, or massed, nature of the rehearsal will prove to be a prominent feature in theoretical accounts of Type 1 rehearsal (see, e.g., Glencberg & Adams, 1978). Experiment 4 does show, however, that massed repetition like that used in the present experiments is not a sufficient condition for producing a null effect of interval.

So, it remains a major problem for theory to specify why, in most instances, the extent of associative learning that occurs during Type 1 rehearsal is limited to the first one or two repetitions of the word pair. One possibility is that the initial associative learning results from a process that is not active during the entire rehearsal interval. It seems likely, for example, that subjects may encode a proposition connecting co-rehearsed words at the beginning of each rehearsal interval (Glencberg & Bradley, 1979). Such an encoding may be an automatic consequence of perceptual processing and, in some sense, unrelated to the rehearsal activity that follows. Still, despite the plausibility of such a mechanism, automatic perceptual processing fails to provide insight into why associative learning does not continue throughout the rehearsal interval. Nor does it explain the contrasting data pattern found in Experiment 4:
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Why should associative learning increase when subjects are expecting to be interrupted? What is needed is a theoretical proposal that can specify the various conditions during which increases in associative learning will and will not occur. Perhaps a more complete account can be constructed by discriminating between the types of information storage that might occur in short-term memory; the distinction between storage in an articulatory loop and storage by the central executive may prove to have some predictive power.

Why assign Type 1 rehearsal to a phonemically based, articulatory loop? First, the existing evidence suggests that traces encoded as a result of Type 1 rehearsal may possess primarily phonemic attributes. Glenberg and Adams (1978) recently showed that subjects are more likely to mistake items rehearsed for maintenance with phonemic distractors than with semantic distractors on a recognition test. Second, the available evidence suggests that free recall improves with an increasing rehearsal interval when items are processed at other than phonemic levels during incidental rehearsal. In a study by Maki and Schuler (1980), subjects maintained individual words for various intervals while searching for semantically similar words in a list. Subsequent tests showed a positive effect of rehearsal time, as measured by the number of words searched before a semantic match, on free-recall performance; somewhat similar results were obtained earlier by Darly and Glass (1975). It appears therefore that the important null effect of interval that is often a defining feature of Type 1 rehearsal may not be demonstrated when items are not processed phonemically.

This could suggest that recall limitations are not the result of a special kind of rehearsal process but rather are due to the type of stimulus attributes that are encoded during processing; that is, experiments that promote "maintenance rehearsal" may simply lead the subject to store low-level codes (e.g., phonemic) which do little to aid recall performance (see Shiffrin, 1976) or to promote the formation of interitem associations. However, Maki and Schuler (1980) also showed a positive effect of rehearsal time when subjects searched for acoustically related words in a search list. Thus, while phonemically based processing may be a necessary condition for producing Type 1 rehearsal effects, it may not be a sufficient condition. It may prove necessary to consider other factors, such as whether attention is selectively directed toward the maintained items throughout the entire rehearsal period. In those situations in which nothing but true maintenance is required, subjects may use special storage systems that serve to protect the work of a control executive but at the expense of long-term recall.

To summarize, four experiments have been reported that investigated whether associative learning would occur during rote Type 1 rehearsal. Each of the experiments demonstrated that subjects do form interitem associations incidentally; however, the extent of that learning appears, in most cases, to be limited to the initial stages of the rehearsal interval. This latter conclusion suggests a limitation on the role of contiguity per se in the development of associative learning. Although contiguity in the absence of intention to learn may be a sufficient condition to form an association (see also, Underwood & Lund, 1980), it is not always a sufficient mechanism for improving associative learning. On the other hand, intentionality does not always have to be present for contiguity to show a more direct relation with associative learning. As Experiment 4 showed, subjects who are not directly attempting to learn interitem connections will continue to do so under a specific type of task demand.

References


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