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Encoding Processes, Rehearsal, and Recall Requirements

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Retention after rapid overt rehearsal was assessed in two experiments. In the first, 20-word lists were presented as four sets of five words alternating with delay intervals. Recall of items from terminal serial positions was higher when delays were either silent or filled with overt rehearsal than when delays were filled with number subtraction. However, overt rehearsal produced the poorest recall of items from early serial positions. Results of a second experiment showed that overt rehearsal did not enhance performance on either a delayed recall or a delayed recognition test. Rehearsal is less effective than other techniques of study and may be totally ineffective unless it is accompanied by additional processing.

The importance of rehearsal as a determiner of retention is fundamental to many theoretical conceptions of memory. Differences in rehearsal frequency have been assumed to underlie the relationship between study time and recall probability (Cooper & Pantle 1967), and have been used to explain the shape of the serial position curve obtained in studies of free recall (Rundus & Atkinson, 1970). The serial position effect was explained within the context of a two-store theory of memory (Atkinson & Shiffrin, 1968). According to that theory, rehearsal serves to maintain an item in short-term store and transfer information about the rehearsed item to long-term store. Transfer to long-term store is said to depend on length of stay in short-term store so that the amount of information transferred about an item is a direct function of the number of rehearsals it receives. Delayed recall is identified with retrieval from long-term store and, thus, related to rehearsal frequency. Without adopting a two-store theory, Underwood (1972) has also indicated that rehearsal frequency is of fundamental importance as a determiner of recall.

Although the above formulations have stressed rehearsal frequency, the nature of processing accompanying rehearsal is likely to be at least an equally important factor. Rehearsal of an item without additional processing may serve to maintain items in a highly accessible state for recall immediately after rehearsal but do nothing to aid recall that is delayed by rehearsal-preventing activity. The term "rehearsal" is used here to denote a subject's covert or overt repetition of an item so that increasing rehearsal frequency simply means that the person says the item more often. Jacoby and Bartz (1972) found that variation in rehearsal opportunity did not influence delayed recall when study conditions were such that activity beyond simple rehearsal of items was not encouraged. They concluded that rehearsal serves to maintain items in short-term store but does not result in transfer of information to long-term store. Deeper processing (Craik & Lockhart, in press) including organization of presented items might be required to enhance delayed recall. Stressing rehearsal frequency seems most compatible with the notion that rehearsal serves to strengthen a single trace of a presented item. In contrast, rehearsal might be effective only if it results in or is accompanied by the formation of new traces.

Rehearsal frequency has been shown to be correlated with recall probability when subjects are free to rehearse any presented item. Rundus and Atkinson (1970) instructed subjects to rehearse aloud and found that rehearsal frequency declined across list positions so that

initial items were rehearsed most often. The serial position curve for free recall after list study was typical, showing both a primacy and a recency effect. Due to the correlational nature of these data, however, it cannot be concluded that the more frequent rehearsals of items presented early in a list were responsible for their superior recall. If there was a causative relationship involving rehearsal frequency, it might be unique to the situation in which subjects are free to select any presented items for rehearsal. Studies that have constrained the selection of items for rehearsal by requiring subjects to rehearse only the most recently presented item (Fischler, Rundus, & Atkinson, 1970; Glanzer & Meinzer, 1967, Experiment II) have found that overt rehearsal is less effective than silent study. These experiments did not include conditions that would allow one to determine if rehearsal had any influence on recall. Performance might have been as high if rehearsals other than the initial rehearsal of each item were eliminated.

In the first experiment, lists of 20 words were presented in blocks of five alternating with 15-sec delay intervals. Attempted recall of all 20 words in a list was required after the delay after presentation of the last block. Delay intervals were either silent, allowing subjects to study in any manner that they chose, filled with overt rehearsal, or filled with a rehearsal-preventing task. In the overt rehearsal condition, subjects were instructed to rapidly repeat aloud the set of words immediately preceding the delay interval. A recall advantage of the silent delay condition would again demonstrate that overt rehearsal is less effective than other techniques of study. If increasing rehearsal frequency does nothing to enhance delayed recall, the overt rehearsal and filled delay conditions should not differ in their recall of items from the first blocks in a list.

EXPERIMENT I

Method

Materials. Two hundred words with A and AA ratings were selected at random from the Thorndike and Lorge word book and assembled into 10 lists of 20 words each. Lists were presented as four sets of five words with a delay interval after the presentation of each set; recall of all 20 words was attempted after the delay after the last word in a list. Between subjects, delay intervals were either silent, filled with subtraction, or filled with overt rehearsal.

Words were tape recorded for auditory presentation at a 2-sec rate; all delay intervals were 15 sec in duration. The subjects that were to rehearse during delays were instructed to rehearse aloud, as rapidly as possible, words from the set immediately preceding the delay interval. Further, they were instructed to attempt rehearsal of all words in the set of five rather than spending the whole interval rehearsing only one of the words. The subjects in the silent delay condition were instructed to study during the delay intervals but a method of study was not specified. The task employed in the subtraction delay condition consisted of the auditory presentation of randomly selected two-digit numbers. Numbers were presented at a 2-sec rate with the first number occurring 1 sec after the last word; seven numbers were presented within the 15-sec delay interval. The subjects were instructed to subtract one from each number and report the result aloud prior to the presentation of the next number. For all conditions, the word "Go" signaled the beginning of a 30-sec recall interval; spoken recall of all words in a list was to be attempted. The recall interval was terminated with the word "Ready" which preceded the first word of the next list by 2 sec.

Subjects and analyses. The subjects were 72 volunteers from psychology courses at Iowa State University and received extra course credit for their participation; 24 subjects were assigned to each of the three delay conditions. Subjects were tested individually and fully informed concerning list length and delay intervals that they would encounter.

For each subject, recalled words were categorized on the basis of study list serial position. Four input blocks were then formed by summing across recall from serial positions 1–5, 6–10, 11–15, and 16–20. Theoretically, recall from the first three blocks requires retrieval from LTS while that from the last block may involve retrieval from STS. For this reason, recall from Blocks 1–3 and recall from Block 4 were entered into separate analyses of variance.

Results and Discussion

Rehearsal frequency. Subjects in the overt rehearsal condition tended to repeat items in the order that they were presented and at a fairly constant rate. Across study lists, there was little variability in rehearsal frequency so that items from the same serial position but

different lists received a nearly equal number of rehearsals. The mean rehearsal frequency of items from Block 1 (3.63) or Block 4 (3.45) was higher than that of items from Blocks 2 or 3 (3.27, 3.21). Rehearsal frequency declined with position within each block. Collapsing across the first three input blocks, mean rehearsal frequencies for items in Positions 1–5 were: 3.65, 3.43, 3.36, 3.21, and 3.18. Rehearsal frequencies for items in Block 4 showed approximately the same decline across positions: 3.75, 3.55, 3.35, 3.27, and 3.31.

rehearsal serves to maintain items in short-term store. The effect of preceding recall with number subtraction replicates the results of earlier experiments (e.g., Glanzer & Cunitz, 1966) and can be attributed to interference of subtraction with rehearsal and subsequent loss of terminal items from short-term store The slight disadvantage of the silent delay condition might have been due to rehearsal of items in addition to those from the last input block during the delay immediately preceding recall.

Recall from Blocks 1–3. Effects of delay

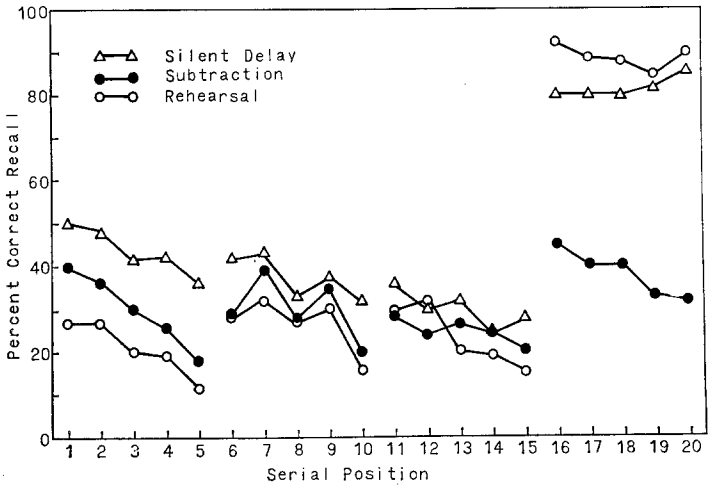

FIG. 1. Recall probability as a function of serial position and delay condition.

Block 4 recall. Recall probability as a function of input position and delay condition is displayed in Figure 1. The effect of delay condition, $F(2, 69) = 116.39$, $p < .001$, and the interaction of delay condition and serial position, $F(8, 276) = 2.50$, $p < .05$, were both significant in recall of items from the last input block. Recall probability in the subtraction condition (.37) was lower than that in either the rehearsal or silent delay condition (.89, .81) and declined across Positions 16–20; recall was relatively constant across list positions in the rehearsal and silent delay conditions.

The high recall of terminal items in the rehearsal condition supports the claim that

condition, $F(2, 69) = 16.89$, input block, $F(2,138) = 10.99$, and the Delay Condition × Input Block interaction, $F(4,138) = 6.10$, were highly significant, all $ps < .001$. Overt rehearsal produced a recall probability (.24) that was lower than that produced by either number subtraction (.28) or silent delay (.37), and recall probability for items in Block 3 (.26) was lower than those for items from either Block 1 or 2 (.32, .32). In the first block, there was a clear separation with performance being highest in the silent delay condition, next highest in the number subtraction condition, and lowest in the condition rehearsing aloud. Recall declined across Blocks 1–3 in the silent

delay condition while remaining relatively constant in the subtraction condition; there was a slight increase in recall across blocks in the rehearsal condition. Within each block, recall probability declined across positions, $F(4, 276) = 37.39$, $p < .001$. However, this decline was more consistent and pronounced in Block 1 than in either Block 2 or 3, as reflected by the interaction of position and block number, $F(8, 552) = 3.73$, $p < .001$.

In the overt rehearsal condition, there was a high correlation between rehearsal frequency and recall probability of the type observed by Rundus and Atkinson (1970); both recall probability and rehearsal frequency declined across positions within each block. However, it is unlikely that differences in rehearsal frequency caused the recall differences. Number subtraction may not have completely eliminated rehearsal but it certainly should have reduced it. If rehearsal frequency were a causative factor, recall probability should have been lowest in the subtraction condition, and the decline in recall across positions should have been flatter in the subtraction than in the overt rehearsal condition. Neither of these effects was obtained.

The decline in recall across positions within a block, and the recall decline across blocks in the silent delay condition are both in accord with the claim that recall probability is related to study opportunity. The higher recall of items presented early within a block may have been due to their study during the presentation of later presented items. In the silent delay condition, subjects were also free to study early presented items during delays in addition to the one immediately after their presentation; study of this type would be nearly impossible in the subtraction and overt rehearsal conditions. Items from the first input block were substantially better recalled than those from later input blocks only in the silent delay condition. Thus, there was a high correspondence between study opportunity and recall probability. The claim called in question by results of the present study is that rehearsal frequency alone was the factor responsible for this correspondence.

Prior studies (Fischler, Rundus, & Atkinson, 1970; Glanzer & Meinzer, 1967) have required subjects to repeatedly rehearse each item either during its presentation or during an interval preceding presentation of the next item in the list. Delayed recall was found to be lower than that produced by a condition provided with an equivalent amount of study time but allowed to study silently. The procedure employed in the present experiment might be expected to place the rehearsal condition at less of a disadvantage. Associations among items may be based on contiguity and the strength of an association may depend on the frequency of this contiguity. If so, associations among items should be stronger when items are rehearsed in sets rather than individually. However, silent delay in the present experiment still produced substantially better performance than did overt rehearsal. One explanation for the advantage of silent delay is that formation of associations is an active process and requires more than contiguity. Subjects were free during silent delays to produce mnemonic devices or in some other way organize the presented words. Rapid overt rehearsal may have been so demanding that additional associative activity of this type was impossible. As an alternative, rehearsal may have been the sole means of study in both the silent delay and overt rehearsal conditions. The distribution of rehearsal might have been the differentiating factor. Rehearsals in the silent delay condition could be more widely spaced and, as a result, might be more effective for later recall.

The recall advantage of the number subtraction as compared to the overt rehearsal condition was somewhat surprising. There should have simply been no difference between these conditions if rehearsal is totally ineffective for delayed recall. The disadvantage of the rehearsal condition may have resulted from either an inhibitory effect of rehearsal or from the subtraction task not being demanding

enough to totally eliminate study during delays. With regard to the latter alternative, subjects may have been able to rehearse occasionally during the subtraction task but the task certainly should have been demanding enough to disallow the construction of mnemonic devices. A third possible explanation is that study preceding the delay intervals differed for the subtraction and rehearsal conditions. Subjects in the rehearsal condition may have simply "held" the items in an acoustic form awaiting the rehearsal interval; semantic processing or any other type of transformation performed on the items might interfere with preparation for rapid overt rehearsal.

Experiment II

When a list is presented for study without specific instructions, subjects may choose to simply rehearse the presented items or to engage in more extensive processing. The choice of processing appears to be partially dependent on the nature of the anticipated recall interval (Jacoby & Bartz, 1972). Processing beyond rehearsal requires more effort and is beneficial only for a test that follows a delay filled with rehearsal-preventing activity. Silent delays in Experiment I were followed by the presentation of additional list words prior to recall and processing during the delays was apparently different from simple rehearsal. If items were to be recalled immediately after a silent delay and no later recall was anticipated, processing beyond rehearsal might be minimal. Performance on a delayed retention test might then be equivalent for overt rehearsal and silent delay conditions.

In Experiment II, effects of immediate recall were compared with those of delay conditions employed in the first experiment. The subjects recalled 5-word lists either immediately after presentation, after a silent delay, after number subtraction, or after overt rehearsal of list words. After the presentation and test of several lists, subjects were given an unexpected test of retention for all words from all lists. Rehearsal appears sufficient to satisfy the initial recall requirements of all conditions except the one with subtraction during delays. The immediate recall condition serves as a baseline against which the effects of rehearsal frequency can be judged.

Rehearsal might in some way serve to strengthen the trace of an item. An effect of this type would not be revealed by a recall test if retrievability is influenced by factors other than trace strength. For example, organizational activity may increase retrievability of an item trace while number of rehearsals influences the strength of that trace. An effect of rehearsal might then be found if a test was employed that minimized retrieval requirements. Since Kintsch (1970) and others have suggested that retrieval is involved in recall but not recognition, both types of tests were employed as a final test of retention in Experiment II.

Method

Materials and procedure. Thirty five-word lists were assembled from 150 randomly chosen words with A and AA ratings in the Thorndike and Lorge word book and tape recorded for auditory presentation at a 2-sec rate. For three of the conditions (silent delay, number subtraction, and overt rehearsal), a 15-sec delay was interpolated between presentation of the last word in a list and recall. Instructions for these conditions and the number subtraction task were identical to those employed in Experiment I. For a fourth condition, recall was immediately after the presentation of the last word in a list. The recall interval was 7.5 sec in duration for all conditions and recall was spoken. The recall interval was terminated with the word "Ready" which preceded the first word of the next list by 2 sec.

After recall of the 30th list, subjects were read a list of nine digits and asked to recall that list in order. This digit span test was employed in an attempt to minimize the effects of retrieval from short-term store on the final retention test. Next, instructions for the final retention test were given; prior to this time subjects had no reason to expect a final test. The subjects given a final recall test were instructed to write down all the words they could remember from all lists. For the recognition test, subjects were given a deck of 150 cards with two words typed on each card and instructed to pick the word on each card that had been presented

in a study list. The words not presented for study (new words) were selected from the same source as study words with an attempt being made to minimize similarity. The test ordering of study words and the order of study and new words within a pair was randomly determined. There was no time limit on either the final recall or the final recognition test.

Design and subjects. Type of final test (recall and recognition) was factorially combined with delay condition (no delay, silent delay, subtraction, and overt rehearsal) to form eight between-subjects conditions; position within a list (1–5) was represented in analyses as a within-subjects factor.

The subjects were 80 volunteers from psychology courses at Iowa State University who received extra course credit for their participation. Ten subjects were randomly assigned to each of the eight conditions; subjects were tested individually.

Results and Discussion

Initial recall. The effect of delay conditions was highly significant, $F(3, 76) = 76.48$, $p < .001$, in the analysis of initial recall. Recall probability in the number subtraction condition (.58) was lower than that in either the immediate recall, silent delay, or overt rehearsal condition (.86, .86, .87). The main effect of position within a list, $F(4, 304) = 16.56$ and the Delay Condition × Position interaction, $F(12, 304) = 3.93$, were also significant, both $ps < .001$; means from the interaction are presented in Table 1.

TABLE 1

IMMEDIATE RECALL PROBABILITY AS A FUNCTION OF SERIAL POSITION AND DELAY

	Serial position				
Delay	1	2	3	4	5
Immediate	.90	.84	.88	.87	.78
Silent	.91	.85	.82	.82	.89
Rehearse	.93	.86	.84	.83	.86
Subtraction	.66	.61	.59	.56	.52

Final retention test performance. Final recall and recognition probabilities for each delay condition are displayed in Table 2. The effect of delay condition, $F(3, 36) = 7.84$, $p < .001$, and list position, $F(4,144) = 3.44$, $p < .05$, were the only significant effects revealed by the analysis of final free recall. Newman–Keuls tests established the significance, $p < .05$, of the advantage held by the subtraction condition over each of the other delay conditions; remaining differences among conditions were all nonsignificant. Items holding the last position in a study list were not recalled as well as items from earlier positions. Final recall probabilities for items from Positions 1–5 were: .12, .14, .11, .12, and .10.

TABLE 2

FINAL RECALL AND RECOGNITION PROBABILITIES AS A FUNCTION OF DELAY CONDITION

	Delay			
Test	Immediate	Silent	Rehearse	Subtraction
Recall	.08	.09	.12	.18
Recognition	.74	.80	.73	.79

Recognition probabilities for each delay condition are presented in the second row of Table 2. Neither the effect of delay condition, serial position, nor their interaction was significant in the recognition analysis. The level of recognition performance was such that the lack of differences cannot be easily attributed to a ceiling effect.

Differences in rehearsal frequency have been employed to explain the negative recency effect found in final free recall of longer lists (Cohen, 1970; Craik, 1970). Cohen followed the presentation and recall of several lists with a final recall and then a final recognition test. Final recall results revealed a negative recency effect while final recognition performance was relatively uninfluenced by input serial position. To interpret these results, Cohen suggested that retrievability of an item depends on the number of rehearsals it has received during initial study. Terminal items were assumed to have received fewer rehearsals, making them more difficult to retrieve and less likely to be

recalled. The lack of a negative recency effect in recognition was attributed to the unimportance of retrievability for performance on a recognition test.

The absence of recognition effects in the present experiment also suggests that differences in retrievability were responsible for the final free recall effect of delay condition. However, retrievability must have been determined by factors other than rehearsal frequency. In agreement with earlier experiments (Jacoby & Bartz, 1972; Meunier, Ritz, & Meunier, 1972), interpolation of a silent delay between list presentation and initial recall did not enhance final recall. Final recall performance in the silent delay condition was also statistically equivalent to that of a condition that rehearsed aloud. Although there was more opportunity for study in other conditions, final recall was highest in the condition that subtracted numbers prior to initial recall. Subjects in this condition apparently engaged in processing beyond rehearsal to insure that items would be retrievable after the subtraction task and this additional processing also aided final recall performance. Thus, variation in number of rehearsals was not reflected in either final recall or final recognition performance; there was no evidence of an effect of rehearsal frequency in determining retrievability or trace strength of presented items. A difference in type of processing, not rehearsal frequency, was the important factor determining final free recall.

It should be noted that Jacoby and Bartz (1972) also offered an alternative explanation that could apply to the final recall advantage of the subtraction condition. This advantage might be due to differences in learning resulting from initial recalls. A delayed recall of the type required in the subtraction condition might provide practice in retrieval that is not afforded by either an immediate recall or one after a silent delay. However, subsequent research that is yet to be published has revealed that the delay effect is primarily due to processing differences preceding the delay interval. Final recall effects of initial recall delay were greatly diminished when delay type was made unpredictable prior to the end of list presentation.

General Discussion

Rehearsal of the type required in the present investigation did not enhance delayed recall. If left free to study silently, subjects may process items more extensively, construct mnemonic devices, or in some other way organize the presented items. These activities appear to increase the retrievability of items at the time of a delayed test. Choice of study processing depends on availability of time and anticipated recall demands. If an immediate recall test is expected, a subject is likely to simply rehearse the presented items. The time demands of rapid overt rehearsal are so great that additional processing is not possible even when a delayed test of recall is anticipated. This would explain the poor performance of the rehearsal condition in Experiment I. A higher level of performance might have been attained if the rate of rehearsal had been slower, allowing additional processing.

When rehearsal is not constrained (e.g., Rundus & Atkinson, 1970), processes governing selection of items for rehearsal are probably similar to those involved in recall. Rehearsal of an item during periods other than its presentation depends on the retrievability of that item. Items that are easier to retrieve might be rehearsed more often because of their retrievability and also be more likely to be recalled. Relationships among items are important determiners of retrievability and selection for rehearsal; earlier presented members of a category are likely to be rehearsed during the presentation of a later-presented one (Rundus, 1971). Given the similarity of processes, it should not be surprising that rehearsal frequency is an accurate predictor of delayed recall. As noted by Rundus (1971), the relationship does not allow one to conclude that differences in rehearsal frequency cause differences in recall probability. Any effect of

rehearsal that does exist might be due to accompanying practice in retrieval.

On the other hand, results of the present investigation do not imply that all types of rehearsal are ineffective. It is quite likely that rehearsal of types other than that employed in the present experiment would be beneficial for delayed recall. Rehearsal might be effective if items that are rehearsed contiguously are related in some fashion. In that case, frequency of contiguity might increase "strength" within the context of the experiment. Rehearsal might also function as another presentation of study items. Investigations varying the spacing of repeated presentations (Madigan, 1969; Melton, 1970) have found a direct relationship between degree of spacing and probability of recall. A similar function might apply to the distribution of rehearsals and recall probability. If so, cumulative rehearsal should lead to highest recall since it maximizes the average spacing of rehearsals. Palmer and Ornstein (1971) found that probed recall was higher in a condition instructed to rehearse cumulatively than in one that was to rehearse in a pair-wise fashion. The superior performance of the silent delay condition in Experiment I of the present investigation might also have been due to cumulative rehearsal rather than more extensive processing. Subjects could rehearse cumulatively throughout list presentation during silent delays but could not in the overt rehearsal condition.

The present experiments were designed to determine the retention effects of rehearsal frequency. One position is that rehearsal frequency is an independent determiner of delayed recall (e.g., Atkinson & Shiffrin, 1968). A second position is that rehearsal only serves the purpose of maintaining items so that additional processing can be performed and is totally ineffective if unaccompanied by additional processing (e.g., Jacoby & Bartz, 1972). As is often the case, the truth probably lies some place between the two extremes. Other techniques of study are more effective than rehearsal and rehearsal of the type required in the present experiment did not enhance delayed recall. However, rehearsal of some types may be beneficial. Investigations of spacing and other variables related to rehearsal are required before conclusions can be drawn. A conclusion that can be drawn from results of the present experiment is that differences in rehearsal frequency without specification of other factors cannot adequately account for effects in delayed recall.

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