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ENCODING AND RETRIEVAL PROCESSES IN LONG-TERM RETENTION

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Retention effects of retrieval practice and of predictability of recall delay were investigated in 2 experiments. Several 5-word lists were recalled initially after no delay or delay filled with number subtraction; delay type was predictable for *Ss* in a precue but not in a postcue condition. Words from all lists were tested in final free recall (FFR). The advantage of filled over no delay in FFR was greater in the precue than in the postcue condition. This result was taken as evidence that attributes selected for encoding depended on the type of delay anticipated. In Experiment II only half of the lists were recalled initially. Initial recall aided FFR more for filled- than for no-delay words. It was concluded that retention benefits from initial retrieval to the extent that retrieval cues used at initial and final recall are similar.

Rehearsal has been used extensively as an explanatory concept in recent analyses of memory processes. In Atkinson and Shiffrin's (1968) 2-store theory of memory, rehearsal serves the dual purpose of maintaining items in short-term store (STS) and of determining the amount of information about an item transferred to long-term store (LTS). Serial position effects including the negative recency effect found in final free recall (FFR), have been interpreted in terms of the positive relationship between rehearsal frequency and transfer to LTS (Atkinson & Shiffrin, 1971; Craik, 1970). More recent results suggest, however, that rehearsal might only serve the function of maintaining items in STS (Jacoby, 1973; Jacoby & Bartz, 1972; Meunier, Ritz, & Meunier, 1972). In the Jacoby and Bartz study, 3 groups of *Ss* were presented with several 5-word lists; each list was recalled initially, either immediately after its presentation, after a silent-delay interval, or after a delay filled with number subtraction. Initial recall int he subtraction condition was well below that in the other 2 conditions, supporting the contention that rehearsal is necessary to maintain items in STS. However, in an unexpected FFR test for all presented words, recall after silent delays was lower than after number subtraction; amounting to an inverse relationship between rehearsal opportunity and storage in LTS. This and the finding that silent-delay items were not better recalled than no-delay items led to the conclusion that rehearsal frequency does not determine transfer to LTS. As possible explanations for the final-recall advantage of filled-delay items, the authors suggested differential encoding during study and differential retrieval practice at initial recall.

According to the differential encoding interpretation, the coding of items during study was dependent on the nature of delay anticipated. For immediate recall or recall after a silent delay, it would be sufficient to keep list items in STS by means of rehearsal with no necessity to generate more permanent retrieval cues. The *Ss* in the subtraction condition were likely to organize items or process them to a "deeper level" (Craik & Lockhart, 1972) to insure that they would be retrievable after the filled delay. Thus, subtraction *Ss* generated longer lasting retrieval cues that more likely would be still accessible at the time of FFR. The second interpretation appeals to the influence of retrieval practice on later free recall (e.g., Lachman & Mistler, 1970). Immediate recall or recall after a silent delay might only make use of short-lived retrieval cues such as the acoustic trace

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of an item (Tulving, 1968), corresponding to retrieval from STS. In contrast, retrieval after a filled delay might necessitate the use of more permanent retrieval cues. Filled-delay items would thus benefit more from retrieval practice since the retrieval cues employed would be more similar to those accessible at the time of final recall. Since differential encoding is assumed to depend on *S*'s ability to anticipate the nature of the delay interval, removal of this ability should nullify the difference between filled-delay and no-delay items in final recall. Differential retrieval practice would be expected to operate regardless of *S*'s ability to anticipate the nature of the delay preceding initial recall. Predictability of delay preceding initial recall was manipulated in the present investigation in order to separate the effects of differential encoding and differential retrieval.

In Experiment I, short lists were presented and free recalled either immediately or after a period of number subtraction. In a precue condition, *S*s were informed prior to list presentation concerning which of the 2 delay conditions would follow. Thus, they had the opportunity to encode words more permanently preceding a filled-delay interval. Final recall for the precue condition was expected to replicate the earlier reported superiority of filled over no delay. In a postcue condition, information about delay type was not available until after list presentation. Since delay type was not predictable during study, the final recall advantage of filled-delay items should be absent if differential encoding was the only factor responsible for the earlier results. No effect of the cuing manipulation would be expected if only differential retrieval was operative in the earlier experiment.

Experiment I

Method

Materials and procedure. Two sets of 150 words with A and AA ratings were randomly selected from the Thorndike and Lorge (1944) wordbook, and used to form 2 replications of the basic design. Within each set, words were assembled into 30 5-word lists and tape recorded for auditory presentation at a 2-sec. rate. The *S*s' oral recall was recorded by *E*. Half of the lists were recalled immediately (no delay, ND) after their presentation while the other half were recalled after a filled-delay (FD) interval. The sequence of immediate and delayed recall was randomized separately for each of 2 sets of lists. The task employed in FD intervals consisted of auditory presentation of randomly selected 2-digit numbers. Numbers were presented at a 2-sec. rate, with the first number occurring 1 sec. after the last word in a list; 7 numbers were presented within the 15-sec. delay interval. The *S*s were instructed to subtract 1 from each number and say the result aloud prior to the presentation of the next number. For all conditions, the word "go" signaled the beginning of the recall interval; recall was spoken. The 7.5-sec. recall interval was terminated by the word "ready" which preceded the first word of the next list by 2 sec.

The *S*s in a precue condition were informed prior to the presentation of each list concerning the nature of the delay that would follow. A stack of 3 × 5 in. note cards was placed before *S*s in that condition; each list was represented by a card. Printed on each card was either the word delayed or immediate, indicating the nature of delay. Upon hearing "ready" preceding list presentation, *S* read the top card and then placed it next to the stack; the card read corresponded to the list that was to be presented. In a postcue condition, *S*s learned about delay after presentation of each list by hearing either the signal for recall or the first of the 2-digit numbers for subtraction.

Following recall of the last list, all *S*s were read 3 sets of 9 digits and asked to recall each set in order. Next, *S*s were instructed to write down all the words they could remember from all lists. Prior to these instructions there was no reason for *S*s to anticipate the FFR test. There was no time limit on the final test. The digit span task was employed as an attempt to minimize the effects of retrieval from STS in FFR.

Subjects and analyses. The *S*s were 20 volunteers from undergraduate courses at Iowa State University; 10 *S*s were assigned to each of the cue conditions according to a prearranged random schedule with the restriction that the ratio of males to females must be constant across conditions. The *S*s were tested individually and received extra course credit for their participation. For each *S*, recalled words were classified according to delay condition and serial position.

Analyses to be reported employed a 2 × 2 × 5 (Cue × Delay × Serial Position) analysis of variance with repeated measures on the last 2 factors; initial and final recall were analyzed separately. Replications were not included as a factor since a preliminary analysis indicated that results did not differ across replications.

Results and Discussion

Initial recall. Recall probability as a function of input position, delay, and cue

condition is displayed in Figure 1. The FD items were recalled at a lower level than ND items, F (1, 18) = 313.67, $p < .001$, indicating that interpolated subtraction interfered with the maintenance of list items in STS. Recall probability was slightly higher in the precue (.74) than in the postcue (.67) condition, F (1, 18) = 4.80, $p < .05$. The main effect of serial position, F (4, 72) = 14.72, and the Delay × Serial Position interaction, F (4, 72) = 9.02, were also significant (ps < .001). Recall probability declined steadily across serial positions in the FD condition while remaining relatively stable in the ND condition.

Final recall. Final recall probability was higher for FD than for ND items, F (1, 18) = 33.00, $p < .001$. As predicted by the differential encoding hypothesis, the recall advantage of FD over ND items was greater in the precue (.18, .06) than in the postcue (.15, .12) condition, F (1, 18) = 9.66, $p < .01$. Overall, recall probability declined across input serial positions, F (4, 72) = 6.51, $p < .001$. Although the appropriate interaction was not significant, the decline across positions was almost totally absent for recall of ND items in the precue condition.

Results of the present investigation provided support for the differential encoding hypothesis. When *S*s could anticipate delay type, FD items were coded in a more permanent fashion than were ND items. Coding of the 2 types of items was necessarily the same when *S*s could not predict delay type; coding when delay was unpredictable appears to have been intermediate to the 2 forms of coding employed in the precue condition. The decline in recall probability across input positions can be attributed to the study of earlier items during the presentation of later ones (e.g., Atkinson & Shiffrin, 1971). The absence of serial position effects when *S*s anticipated an immediate recall test suggests that the cumulative study strategy was primarily used to prepare for delayed recall.

The failure to obtain an effect of delay in the postcue condition can be taken as evidence against the differential retrieval

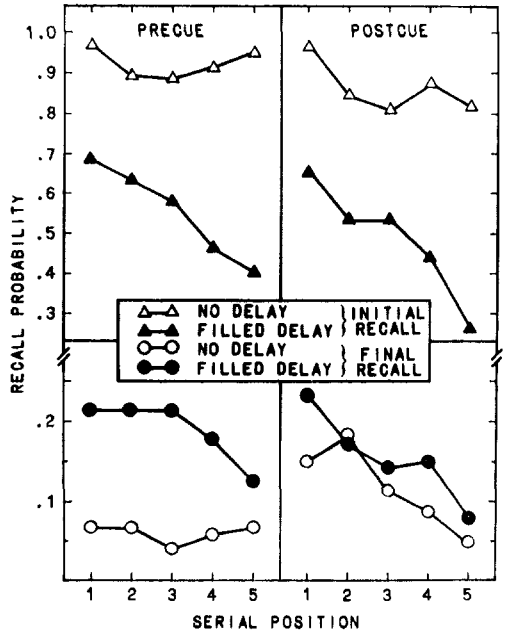

FIGURE 1. Probability of initial and final free recall as a function of serial position, cue, and delay condition in Experiment I.

hypothesis. However, the use of different retrieval cues after the 2 types of delay might develop gradually across the test session. In addition, retrieval cues employed after an FD would at best be expected to be only relatively permanent and might not survive the presentation of a large number of later lists. Both considerations suggest that an advantage for FD items might be more likely in final recall of lists presented near the end of the experimental session. Filled delay and ND in the postcue condition were therefore compared separately for the first 8 and second 7 lists of each type. Final recall probabilities were nearly identical for FD and ND items presented in the first lists studied (.10, .11). However, recall probability from the last study lists was higher for FD than for ND items (.21, .12), t (18) = 2.83, $p < .05$. Thus, the differential retrieval hypothesis cannot be totally dismissed.

Similar comparisons in the precue group reveal higher recall of FD over ND in the first lists studied (.15, .05), t (18) = 3.54, $p < .01$, as well as in the last study lists

(.22, .07), t (18) = 4.78, $p < .001$. Apparently, in contrast to differential retrieval strategies, differential encoding is established early in the course of the experiment.

Experiment II

Experiment II was designed to further separate the effects of differential encoding and differential retrieval. As in Experiment I, *Ss* in a precue and postcue condition were exposed to lists followed by either an FD or ND. Now, however, *Ss* recalled only half of the lists initially; recall vs. no recall was factorially combined with cue and delay conditions. In all conditions, *Ss* were unable to predict whether or not recall would be required. Thus, study encoding should be constant across recall conditions. The effects of differential encoding can be observed uncontaminated by retrieval practice in the no-recall conditions. Comparisons of the final-recall effectiveness of initial recall in the 2 delay conditions yield information that is relevant to the differential retrieval hypothesis. Initial recall after an FD should have a larger effect in FFR if the differential retrieval hypothesis is accurate.

Method

Materials and procedure. A set of 200 words with A and AA ratings were randomly selected from the Thorndike–Lorge (1944) wordbook. These words were assembled into 40 5-word lists and tape recorded for auditory presentation at a 2-sec. rate. The *Ss*' oral recall was recorded by *E*. Half of the lists were followed by FD while the other half were followed by ND. Each half was further subdivided into an equal number of lists initially recalled (IR) vs. not initially recalled (NIR). Four delay–recall combinations resulted: FD–IR, FD–NIR, ND–IR, and ND–NIR. Ten lists were randomly assigned to each delay–recall combination; the presentation order of lists was also randomized. Four replications of the basic design were constructed so that each list represented each delay–recall combination equally often. The distractor task employed in FD intervals was the same as in Experiment I, as were the arrangements for recall in the FD–IR and ND–NIR conditions. In the FD–NIR condition, the word "ready" occurred 2 sec. after the last 2-digit number and signaled the beginning of the next list. The word "ready" served the same purpose in the ND–NIR condition but occurred 1 sec. after the last word of the preceding list.

Cuing arrangements for a precue and postcue condition were the same as those in Experiment I. None of the *Ss* was precued with regard to recall condition. The recall–no-recall manipulation was explained to *Ss* by describing the investigation as being concerned with the effects of disruption on memory. Other procedural details including arrangements for digit span tests and final recall were identical to those in Experiment I.

Subjects and analyses. The *Ss* were 40 volunteers enrolled in psychology courses at Iowa State University and received extra course credit for their participation. Twenty *Ss* were assigned to each cue condition according to a prearranged random schedule with the restriction that the ratio of males to females must remain constant across conditions.

Study lists were divided into 2 blocks of equal size for preliminary analyses of initial and final recall. The 20 lists of Block 1 were the first 5 lists representing each of the 4 delay–recall combinations while those in Block 2 were the second 5 lists from each combination of conditions. The analysis of initial recall failed to reveal any significant effects of input block. In final recall, the probability of recall was higher for lists presented in the second (.11) than in the first (.06) block, F (1, 266) = 67.94, $p < .001$; effects of other variables were generally consistent across blocks but more pronounced in Block 2. The finding of more pronounced effects in final recall of later presented lists is similar to that reported in Experiment I and may be due to either recency of presentation or the development of study strategies. Since effects in recall of early lists were less clear and did not contribute additional information, results will be reported only for lists presented in Block 2. Initial recall data were treated as in Experiment I. Final recall scores were entered into a 2 × 2 × 2 × 5 (Cue × Delay × Initial Recall × Serial Position) analysis of variance with repeated measures on the last 3 factors.

Since in earlier experiments, including Experiment I, interactions of *Ss* with other factors did not reach significance ($\alpha = .05$), it was decided a priori to use the pooled interactions with *Ss* as the denominator for F tests. The appropriateness of this procedure was checked for the analyses of initial and final recall. Only 1 of the 8 interactions involving *Ss* exceeded the .10 level, F (38, 152) = 1.39, indicating that the assumptions necessary for pooling were met.

Results and Discussion

Initial recall. Initial- and final-recall probabilities for each combination of conditions are plotted in Figure 2. As expected, recall was lower in the FD than in the ND condition, F (1, 342) = 336.70, $p < .001$. The Delay × Serial Position interaction was also significant, F (4, 342)

= 3.72, $p < .05$. Recall probability declined across input positions in the FD condition while showing a slight increase for ND items. Intrusion errors were infrequent; intrusions from lists that were not recalled were only slightly more frequent (2.2%) than those from recalled lists (1.7%). Thus, it appears that *Ss* successfully differentiated lists.

Final recall. The effects found in Experiment I were replicated. As shown in Figure 2, recall probability declined across serial positions, F (4, 722) = 15.20, $p < .001$, and was higher for FD than for ND items, F (1, 722) = 18.59, $p < .001$. The recall advantage of FD over ND items was larger in the precue (.14, .08) than in the postcue (.12, .11) condition, F (1, 722) = 9.68, $p < .01$, again supporting the differential encoding hypothesis. For lists not initially recalled, final recall in the precue condition was higher for FD than for ND items (.10, .05), t (722) = 2.70, $p < .01$. Thus, the effect of differential encoding manifested itself in pure form. Lists that were recalled initially showed higher final recall than did lists that were not initially recalled, F (1, 722) = 29.20, $p < .001$. In addition, the differential retrieval hypothesis predicts that FD items should benefit more from initial recall than should ND items. The corresponding Initial Recall × Delay interaction was significant, F (1, 722) = 4.53, $p < .05$, and showed that initial recall was most beneficial for FD items. As shown in Figure 2, the advantage of FDs was larger in the precue than postcue condition but present in both among items that had been recalled initially. The present investigation thus provided evidence of both differential encoding and differential retrieval.

The results are also relevant to a third possible interpretation of the final-recall advantage of FD items. It might be argued that the subtraction task was not demanding enough to completely eliminate rehearsal, and that the higher final recall of FD items was produced by this additional rehearsal. This interpretation would predict higher recall of FD items even for lists that were postcued and not recalled initially; neither differential encoding nor differential retrieval would predict an effect of delay for these lists. The results showed that final-recall performance was nearly identical for FD and ND items (.09, .10) in the postcue condition that had not been tested initially. Thus, there was no evidence that rehearsal during subtraction aided final recall.

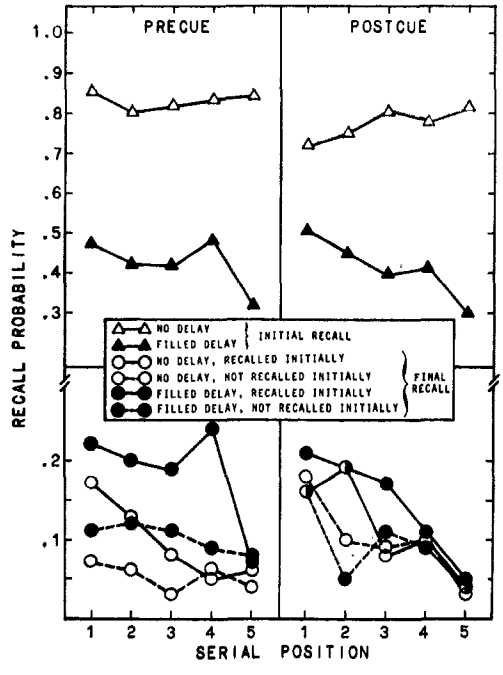

FIGURE 2. Probability of initial and final free recall as a function of serial position, cue, delay and initial recall condition in Experiment II.

GENERAL DISCUSSION

Among the most widely observed effects in studies of memory is the dependence of recall probability on study opportunity (e.g., Cooper & Pantle, 1967). One possible explanation of this effect is that rehearsal frequency determines the probability of delayed recall or, in the context of a 2-store theory, the transfer of information to LTS. While the term "rehearsal" has been defined in a variety of ways, it is used in this discussion to denote *Ss*' overt or covert repetition of items.

Memory theorists holding widely divergent orientations (e.g., Atkinson & Shiffrin, 1968; Underwood, 1972) have agreed concerning

the central role played by rehearsal frequency. The rehearsal frequency interpretation also has the advantage of parsimony and has been applied to a wide variety of phenomena. Despite its wide acceptance, there is no firm evidence of a causative relationship of rehearsal frequency to delayed-recall probability. The most convincing evidence has come from experiments that have required overt rehearsal and have related rehearsal frequency to recall probability (Atkinson & Shiffrin, 1971; Rundus, 1971; Rundus & Atkinson, 1970). It should be recognized, however, that overt rehearsal only renders observable *Ss*' vocalization of study items; rehearsal might be accompanied by considerably more complex processing that is not observable. The relationship of overt rehearsal frequency and recall probability that has been found might be due to the correlation of both factors with underlying coding processes.

Recent evidence suggests that explanations of long-term memory effects in terms of rehearsal frequency are insufficient. Several studies (Jacoby, 1973; Jacoby & Bartz, 1972; Meunier et al., 1972) have found no effect of variations in rehearsal opportunity or frequency of overt rehearsal in long-term memory performance. Moreover, the present investigation found differences in final recall for conditions that were equated with regard to rehearsal opportunity during study; final recall in the precue condition was higher for lists followed by FD rather than ND. It might be argued that the subtraction task employed did not eliminate rehearsal so that the FD condition had additional opportunity for rehearsal. However, further analyses revealed that rehearsal was either absent during delays or did not aid final recall. These results can be accounted for if rehearsal, defined as repetition of items, is assumed to be only one of several types of processing available to *Ss*. Rehearsal may be sufficient to maintain items for immediate recall while additional processing is required to aid performance on a long-term memory test (Craik & Lockhart, 1972; Jacoby, 1973).

The trace resulting from the encoding of an item can be conceptualized as a set of attributes, with the level of processing determining the particular attributes included in the set (Craik & Lockhart, 1972). Processing in addition to rehearsal will lead to the inclusion of attributes that are more resistant to loss. If an item is studied under the expectations of immediate recall, its memory trace will contain fewer and less permanent attributes than if it is studied with the anticipation of delayed recall. More permanent attributes are encoded, including organization of list items, when delayed recall is anticipated. Consistent with the preceding statement are *Ss*' descriptions of their study activities. When asked after the experiment, several *Ss* in the precue condition reported making up sentences, stories, or mental images involving list items when an FD was anticipated, and merely repeating list items when they expected an immediate-recall test. The nature of delay preceding recall was not predictable in the postcue condition. The *Ss* in that condition may have either adopted an intermediate level of processing for all lists or vacillated between rehearsing items and attempts to organize them. It should be noted that the relating of processing to *Ss*' expectations and cognitive states is not a new development, and gains support from an older literature. Müller (1911, pp. 11–20) listed a number of variables that he found to influence study strategy; the time interval between study and test was among those listed.

Data from the present experiments also provided support for the differential retrieval hypothesis. The final-recall effects of initial recall can be interpreted within the memory attribute framework. Attributes used as retrieval cues experience an increase in cue effectiveness as a consequence. The use of short-lived attributes requires less effort so that they are employed as retrieval cues when there is a choice; immediate recall primarily uses short-lived attributes such as the acoustic trace of an item. If an FD precedes recall, short-lived cues will not be available and initial recall will be based on more durable attributes. Later recall will benefit from initial recall only to the extent that both can use the same attributes as cues. Initial recall after an FD was more advantageous, since the attributes employed for retrieval were more likely to be also available at the time of final recall, than were those used in the ND condition. It would be predicted that the effectiveness of initial recall could be even further enhanced by increasing the duration of the FD interval.

Recall differences observed in the present experiments cannot be explained in terms of amount of study opportunity or rehearsal frequency. Rather, recall performance appears to be a function of the attributes that are accessible at the time of test. Accessi-

bility in turn depends on 2 factors: (*a*) Differential encoding during study determines which attributes are used originally to form the trace of an item, and (*b*) the cue effectiveness of attributes is enhanced by their prior use as retrieval cues. Long-term recall performance will be aided by an earlier recall to the extent that the same attributes can be used as retrieval cues on both tests.

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