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An examination of the continuous distractor task and the "long-term recency effect"

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The continuous distractor task has yielded a so-called "long-term recency effect" that appears to call into question the dual-storage explanation of serial position effects in free recall. In this study, we show that the "long-term recency effect" is really a short-term storage effect, resulting from adaptation to the repeated presentation of a particular type of distractor throughout the list. This adaptation, a time-sharing process, permits short-term storage to carry out its normal functions. Experiment 1 shows that an appropriate postlist distractor task does in fact eliminate the "long-term recency effect." This finding supports the assertion that the effect is a product of short-term storage. Experiment 2 demonstrates the benefits and costs of the time-sharing process, relative to standard free recall, for both long-term and short-term storage. The findings support the time-sharing hypothesis. Experiment 3 replicates Experiment 2, with a change in procedure that rules out output interference as a mechanism responsible for the results of Experiment 2. Data are also presented on the development of the adaptation over trials. It is concluded that the adaptation and time-sharing processes need to be included in the dual-storage model of short-term storage.

In 1974, Bjork and Whitten introduced a special memory task to analyze factors underlying free recall. The task, called a continuous distractor task, consisted of a list of to-be-recalled items presented successively. The interitem intervals were, however, not left empty, as in ordinary free recall, but contained a distractor task (in their work, an arithmetic task). They set up the task to test the dual-storage model of memory. In this model, distractor tasks remove items from short-term storage. Therefore, the end peak of the serial position curve, which is interpreted as primarily output from short-term storage, should be severely depressed in this task. The recall of earlier list items—output from long-term storage—should also be impaired, since the distractor task reduces the transfer of items into long-term storage by curtailing their stay in short-term storage.

Contrary to these expectations, Bjork and Whitten (1974) found that, for this task, (1) serial position curves showed an end peak—the "long-term recency effect"—and (2) subjects apparently learned much of the early parts of the lists. The authors concluded that the end peak in the continuous distractor paradigm arises from long-term, recency-sensitive retrieval processes. Glenberg and his associates replicated these effects (Glenberg, Bradley, Kraus, & Renzaglia, 1983; Glenberg et al., 1980) and built a theory to cover them, particularly the long-term recency effect. That theory, the contextual retrieval hypothesis, maintains that list words, spread out in time by the distractor intervals, become differentially associated with temporally changing context cues. List words in terminal positions share the greatest number of temporally distinctive cues also present at the recall test. This overlap of cues serves a recency-sensitive, long-term retrieval mechanism, which results in the greatest recall for the latest list items—the long-term recency effect. The hypothesis also includes a ratio rule, asserting that the longer the interitem interval and the shorter the retention interval, the greater the recency effect.

The present work will subject the continuous distractor task to further detailed analysis. The following will be shown: (1) The long-term recency effect is more transitory than the preceding literature indicates. It depends on a special characteristic of the Bjork and Whitten (1974) procedure—namely, the identity of the intralist and postlist distractor task. (2) Registration in long-term storage is clearly impaired by the distractor task. This impairment has not been fully demonstrated up to now. It supports the idea that short-term storage plays a major role in transfer to long-term storage, as claimed in dual-storage theory. (3) The pattern of performance on the distractor task represents a special adaptation by subjects to the continuous distractor task. Evidence of subjects' learning of that adaptation will be presented.

An explanation for the continuous distractor task effect in terms of that adaptation will be offered. The explanation leaves the dual-storage theory viable but adds special adaptive mechanisms to handle the complexities introduced by the continuous distractor task.

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EXPERIMENT 1

A key piece of evidence relevant to the dual-storage theory was the demonstration of an end peak that survived a distractor task, the long-term recency effect. That it is not really long-term is clear, since it does not last into final free recall (Bjork & Whitten, 1974; Poltrock & MacLeod, 1977). We will show that the term "long-term" has to be qualified even more severely, because the effect appears only when the postlist delay task is the same as the intralist distractor task.

The hypothesis tested in this experiment was: The long-term recency effect is a product of a special characteristic—the identity of the intralist and postlist (delay) task—that permits subjects to adapt to the distractor task. We will show that when the subject cannot adapt, when the delay task is different the long-term recency effect disappears. We will also, in passing, show that the effects of the continuous distractor task generalize across distractor tasks, that word-distractor tasks, as well as arithmetic tasks, produce the effects.

The two distractor tasks we used, arithmetic computation and word reading, were chosen because they have both been used in short-term memory work, and they both produce regular effects on the recency portion of the serial position curve (Glanzer & Cunitz, 1966; Glanzer, Gianutsos, & Dubin, 1969; Glanzer, Koppenaal, & Nelson, 1972; Glanzer & Razel, 1974; Glanzer & Schwartz, 1971).

Method

In this and the subsequent experiments, the subjects saw a series of lists. Each list contained 12 to-be-recalled words, with a distractor task before and after each list word. The distractor task that followed the last word was varied experimentally. It will be distinguished by a special label, "postlist delay task," although in length it was identical to the intralist distractor task and in content it was, in two conditions, also identical to that task.

The subjects were closely watched by the experimenter to make sure that they carried out the distractor task during list presentation. After each list, the subjects recalled as many of the to-be-recalled words as they could, in any order. At the conclusion of these free-recall trials, there was an unexpected final free-recall trial. The subjects were asked to recall all the words they could remember from all the lists, again in any order. Then they were interviewed concerning the methods they used.

The postlist delay task was varied so that it was either the same as or different from the task used as the within-list distractor (same delay task or different delay task). There were four groups, two with the same delay task and two with the different delay task. For the same delay task, one group had, for example, an arithmetic within-list distractor with the same task continuing as the postlist delay task. The other group had word reading as both the within-list distractor task and the postlist delay task. For the different delay task, the distractor task was switched in the postlist delay from arithmetic to word reading or from word reading to arithmetic. This gave a total of four testing conditions: within-list arithmetic distractor task, same postlist delay task; within-list arithmetic distractor task, different (word) postlist delay task; within-list word-distractor task, same postlist delay task; and within-list word-distractor task, different (arithmetic) postlist delay task. The condition in which the postlist delay task was the same arithmetic task used throughout the list (arithmetic distractor, same delay) is similar to the arrangement in the Bjork and Whitten (1974) continuous distractor paradigm, except that single words rather than word pairs made up the recall list.

Bjork and Whitten's (1974) procedures differed from those of the present study in three ways: (1) their subjects were instructed not to rehearse across input positions, (2) word pairs or "doubles" were used as list items, and (3) the length of the postlist delay interval was extended, so that it was at least 30 sec longer than the within-list distractor intervals. Since the present procedures replicate the Bjork and Whitten findings, these differences appear not to be critical.

The design of the present study was a 2 × 2 × 12 mixed factorial, with delay conditions (same or different task) and intralist distractor type (arithmetic or word) as between-subject variables, and serial position (1-12) as the repeated measure, within subjects. (The statistical analysis will, however, as indicated later, depart from the simple application of an overall analysis of variance to this design.) In all four conditions, the delay task occurred immediately after the last list word and was followed immediately by recall. The length of distractor and delay intervals was identical (12 sec). All subjects saw the same set of to-be-recalled words in their two practice lists and six experimental free-recall distractor lists. A single subject, however, experienced only one of the four distractor-delay conditions described above.

Materials

List words. The to-be-recalled list words were high-frequency, concrete, one- and two-syllable singular nouns with a mean frequency of 110 per million. The frequency of a word was determined by summing the counts for its singular, plural, and possessive entries in the Kučera and Frances (1967) listing. There were six basic lists of 12 words each. The lists were matched for frequency and number of one- and two-syllable words, and were constructed so that obvious associative relations within any list were minimal. The assignment of words to the six basic lists remained unchanged. However, the order of words within each list, and the order of presentation of lists across trials, was randomized 24 times, once for every set of 4 subjects. Each set of 4 subjects consisted of 1 subject from each of the four experimental conditions. All to-be-recalled words were presented for 2 sec each, and were read aloud by the subject.

Arithmetic-distractor task. This task consisted of sets of six addition problems presented at a 2-sec rate. For each problem, the subject was required to add 1 to a three-digit number (100 to 999). The subject read the number and gave its sum aloud. The three-digit numbers were taken from a table of random numbers, with repetitions of the same number within any set of six problems eliminated. In the arithmetic-distractor, same delay-task conditions, sets were presented before and after every word of the list. (This is similar to the Bjork and Whitten, 1974, condition.) In the arithmetic-distractor, different delay-task condition, sets were presented before every list word and after every list word except the last. That word was followed by the word-distractor task.

Word-distractor task. This task consisted of six pairs of unrelated words presented at a 2-sec rate. The subject read each pair aloud as presented. In one (word-distractor, same delay-task) condition, this task preceded and followed every list word. In the word-distractor, different delay-task condition, the distractor task following the last word was switched to the arithmetic distractor task.

The words for the distractor task were one- and two-syllable nouns, matched to the list words for concreteness. However, the large number of words (936) required the inclusion of lower frequencies than for list words. Distractor and delay words were drawn from a larger pool to construct six delay sets of 12 words each and six distractor sets of 144 words each. Each set was composed of an equal number of one- and two-syllable words, with associative relations kept to a minimum. The mean frequency for the distractor and delay words was 60 per million.

Subjects

Ninety-six undergraduates participated in the experiment to fulfill a course requirement. The subjects in this and the experiments that follow were native speakers of English.

Procedure

The subjects were tested individually. The subjects were told that they would learn and recall lists of words and would also perform an arithmetic or word task. The importance of a high level of performance on both the recall and the distractor tasks was stressed. All subjects were given, in succession, practice with the main distractor task for their condition (either arithmetic or word), two practice recall lists that included the delay task for the condition, and then six experimental lists. There was 1 min for written free recall after each list. After the six lists, the subject was given a final free-recall test and an interview.

The 12 list items, the 12 distractor tasks, and the final delay task were presented using packs of 3 × 5 in. cards. Each card had on it either a single to-be-recalled list word or a distractor task (a set of six addition problems, one per line, or a set of six pairs of distractor words, a pair on each of six lines). The cards bearing to-be-recalled words and distractor tasks alternated. The subject moved each card from the top to the bottom of the pack, paced by a metronome that beat at a 2-sec rate. The subject read the items on all cards aloud at the rate of one line every 2 sec. Thus, each to-be-recalled word was presented for 2 sec, after which the subject advanced the card. Distractor and delay words, with a pair per line, were read at the rate of two words every 2 sec. The six addition problems, with one per line, were carried out, one every 2 sec. Thus, each distractor (or delay) card took 12 sec to complete. At the end of the list, the postlist delay card was followed by a blank card, which signaled the start of recall.

In the first phase of practice for the distractor conditions, the subjects were given training with the metronome and the distractor cards appropriate for their distractor-task condition (either arithmetic or word). The subject learned to be precise in the rate and regularity of reciting the distractor items and in advancing the cards. This phase varied in length, depending on the performance of the individual subjects, so that all subjects could be brought to proficiency on the distractor task.

During this initial arithmetic distractor-task training, and for the two practice lists that followed, the experimenter corrected addition errors immediately to ensure accuracy. Typical errors, induced largely by the rapid presentation rate, were mispronunciations or reverse readouts of numbers and their sums. During the initial distractor-training phase and for the two practice lists, the subjects in the word-distractor conditions were also told of any reading errors. Such errors were rare. In these conditions, the subjects were also asked at the end of each of the two practice recalls to indicate which recalled words, if any, they thought were intrusions (that is, not from the to-be-recalled list). The subjects correctly identified most distractor intrusions. The intrusions they identified were confirmed, and those they missed were indicated. Very few distractor intrusions occurred beyond the practice lists.

Monitoring of the subject continued throughout the experiment to make sure that the distractor task was carried out fully, accurately, and in time with the metronome. Finally, detailed interviews were conducted with each subject after completion of the experiment.

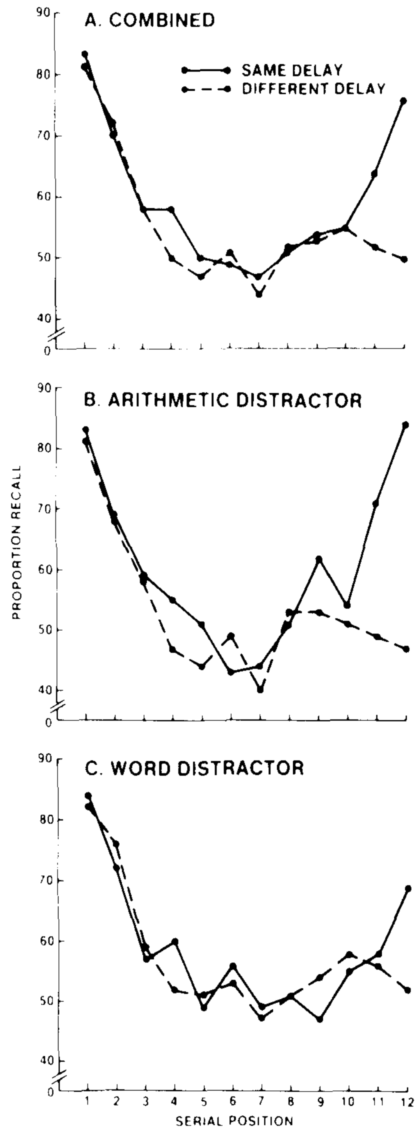

Figure 1. Proportion recalled as a function of serial position and delay condition (same delay task or different delay task) in Experiment 1. (A) Arithmetic- and word-distractor data combined. (B) Arithmetic-distractor data only. (C) Word-distractor data only. Solid lines represent the same delay task; broken lines represent the different delay task.

Results

The serial position curves for the arithmetic- and word-distractor conditions are presented separately in the lower two panels of Figure 1. The arithmetic distractor with the same delay task, which is basically the original Bjork and Whitten (1974) condition, produced the standard long-term recency effect. This effect disappeared when the postlist delay task was not the same as the intralist task (arithmetic-distractor, different delay-task condition). This pattern is replicated, although not as strongly, in the word-distractor conditions. The end peak in the word-distractor, same delay-task condition is not as prominent as that in the arithmetic-distractor, same delay-task condition. We will show, however, in Experiments 2 and 3, that this end peak is strong and reliable for the word-distractor task over two additional replications.

The combined results are shown in Panel A of Figure 1. Although the effects differ somewhat in magnitude in Panels B and C, the pattern is the same. The remainder of the discussion will focus on the combined data, displayed in Panel A. The focus on the combined data is justified by the statistical analysis, as indicated below. The two curves of Panel A represent immediate recall in each of the 12 input positions for the same and different delay-task conditions, with arithmetic- and word-distractor data combined. The end peak in the same delay-task curve exhibits a recency effect typical of the continuous distractor task. Thus, the same delay-task conditions replicate the finding of recency effects in this paradigm with the customary use of identical distractors and delays. However, although the two curves are virtually identical in the early and middle positions, no recency effect is observable in the curve for the different delay task. Rather, for this task, the final positions of the two curves show the characteristic wipeout of recency found with the imposition of postlist delay tasks in standard free recall.

In this and the subsequent experiments, our interest is in two parts of the data: the early serial positions, associated with long-term storage, and the final serial positions, associated with short-term storage. Therefore, two separate analyses will be carried out, here and in Experiments 2 and 3. One analysis is of the short-term or recency component—Serial Positions 9-12. The other analysis is of the long-term component—Serial Positions 1-8.

The primary focus of the statistical analyses is on Serial Positions 9-12, the recency portion, where the long-term recency effect occurs. The analysis of variance of these positions found the effect of different versus same delay condition to be statistically significant [$F(1,92) = 6.939$, $p = .01$]. There was an interaction of distractor condition with delay condition [$F(1,92) = 4.519$, $p = .037$]. This reflects the difference in the effect of the delay condition on the two types of distractor conditions—it is more pronounced with the arithmetic distractor. Another measure of the short-term storage component is the Tulving-Colotla estimate—here, the number of words in each recall list that had six or fewer words intervening between its list position and its output position. (For further details, see Watkins, 1974.) Using the Tulving and Colotla (1970) estimates removes this interaction. Parallel analyses using those estimates give the same information as that summarized above for Positions 9-12 on the main effect of different versus same delay [$F(1,92) = 11.823$, $p = .001$]. They do not, however, show an interaction of distractor × delay [$F(1,92) = 1.687$, $p = .198$]. The analysis of Positions 1-8, the long-term component, found no statistically significant effect for either of the main variables—distractor condition or delay condition—or for their interaction (all $Fs < 1$).

Other data of interest are the serial position curves for final free recall. Preceding investigators (Bjork & Whitten, 1974; Poltrock & MacLeod, 1977) found that the long-term recency effect vanished in final free recall. The serial position curves for final free recall are shown for the four experimental conditions in Figure 2. Panel A shows the curves for the arithmetic- and word-distractor data combined. Panels B and C show the arithmetic- and word-distractor data separately. None of the serial position curves shows an end peak. For the same delay conditions, this replicates the preceding findings. The absence of the end peaks here underscores the instability of the recency effect in the continuous distractor task. It behaves just like the recency effect in ordinary free recall.

The subjects' self-reports during the postexperimental interview session proved helpful in getting a picture of how subjects handle the continuous distractor task. Most

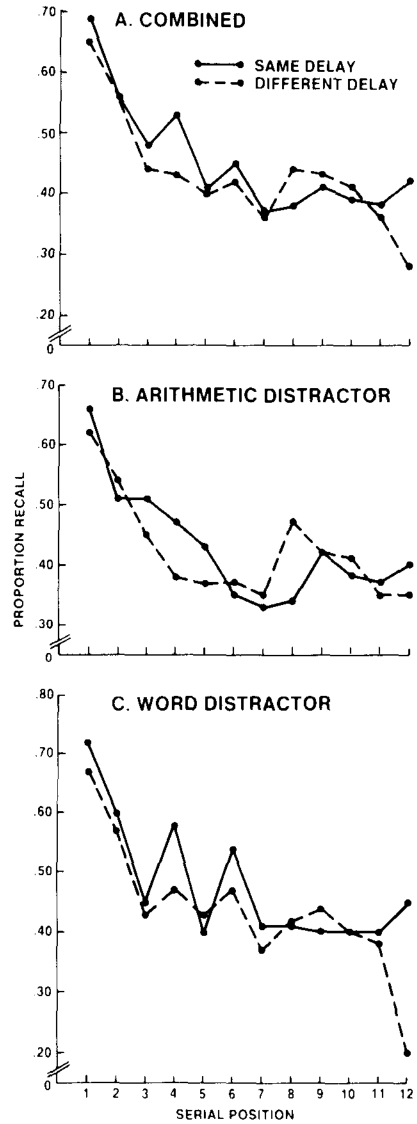

Figure 2. Final recall data for Experiment 1, showing proportion recalled as a function of serial position and delay condition (same delay task or different delay task). (A) Arithmetic- and word-distractor data combined. (B) Arithmetic-distractor data only. (C) Word-distractor data only. Solid lines represent the same delay task; broken lines represent the different delay task.

subjects reported that they continued to work on list words during the distractor intervals, at the same time that they were carrying out the distractor task. This practice arose "accidentally," usually with the association of two consecutive list words that "reminded" the subjects of some salient aspect of their personal lives. The subjects' accounts suggested that their strategies arose initially from automatic processes, activated in short-term storage in response to the distractor task itself. On successive lists, many subjects then actively expanded on this association of two words by incorporating a larger number of words in the rehearsal group.

On the basis of the subjects' statements about learning to cope with the continuous distractor task, we examined the subjects' performance on their successive lists by computing the mean proportion of words recalled for each list. If the subjects learned to adapt to the distractors during the repetitive, sequential continuous distractor list, then this process should have improved across lists. Since the adaptation could occur in the early trials, we included the practice lists in the set examined.

Statistical analyses showed that the subjects did improve in recall across lists, primarily in the practice lists. This experiment was, however, not designed to evaluate the effects of practice across lists, and the effects were difficult to interpret because the practice lists (included in the analyses) differed from the main experimental lists. The question of changes in performance on successive lists was, therefore, followed up more completely in Experiment 2, in which material for the practice and experimental lists were made homogeneous.

Discussion

The results indicate that the long-term recency effect is not really a long-term effect. We knew that it did not survive to final free recall. We now know that it does not survive a change in the distractor task. This finding and the subjects' statements suggest the following: (1) Subjects, when given a repeated intralist distractor, adapt to the disruptive effect of the distractor task, preserving short-term storage to some extent. They evidently develop some type of time-sharing mechanism. (2) This adaptation continues during a postlist distractor task only if the task is the same as the intralist task.

This adaptation produces both of the main findings—the preserved end peak and the registration of material in long-term storage—generally observed with the continuous distractor task. We will show later that both the preservation of items in short-term storage and their registration in long-term storage are, however, impaired in the continuous distractor paradigm as compared with ordinary free recall.

The subjects' self-reports suggested that the time-sharing process may arise initially under the control of automatic processes of short-term storage, induced by the task, rather than by the subjects' intent. Strategies elicited by these processes may then be actively pursued by the subjects. However, automatic processes may continue to play a role in time sharing throughout the task, in, for example, certain aspects of the allocation of attention.

Poltrock and MacLeod (1977) suggested that retrieval from short-term storage might not be prevented in the continuous distractor list if few items are being held. In that case, they argued, the distraction procedure might not be effective. Glenberg et al. (1980) rejected Poltrock and MacLeod's proposal on the grounds that such a mechanism would result in only a one-position recency effect, whereas those observed in this paradigm often span several positions. We develop further Poltrock and MacLeod's argument with the assertion that the special character of the continuous distractor task, with repeated, extensive practice on the distractor task, reduces the displacement effects of the distractors and produces a time sharing that allows the subject to hold several items across the distractors. This produces an end peak that does in fact span more than one position.

Moreover, the main finding of Experiment 1—the absence of the end peak with a shift in the postlist delay task—raises problems for the hypotheses presented to handle the effects of this paradigm, the recency-sensitive retrieval hypothesis (Bjork & Whitten, 1974) and its extension, the contextual retrieval hypothesis (Glenberg et al., 1983; Glenberg et al., 1980). The ratio rule, central to both hypotheses, predicts no difference in end peaks for the two delay types of the present experiment, since the delay and the ratio of the interitem interval to the retention interval (here, the distractor and delay intervals) are the same in both conditions. The present finding of elimination of recency effects with no increase in delay interval contradicts the emphasis on temporal factors alone in the recency effect.

It cannot be argued on the basis of the contextual retrieval hypothesis that the reason for the effect of the different distractor found here is that it changes context between the last item and the recall test. It could even be argued that the contextual retrieval hypothesis, if it predicts differences, predicts just the opposite of the obtained finding. According to that hypothesis, the distinctiveness of the last few items' context is critical. The change in the distractor task should increase the last few items' distinctiveness and should therefore increase, not decrease, the recency effect. Only the context components associated with end items, but not with earlier items, are "relevant" in producing recency.

> A relevant component is available at the recall test and is associated to some TBR [to-be-remembered] items but not to all of them. (If a component is associated to all [or none] of the TBR items it contributes equally to the recall of all [or none] of the TBR items and hence cannot change the shape of the serial position curve). (Glenberg et al., 1983, p. 253)

In the same delay-task condition, therefore, the intralist and postlist distractors, all highly similar, should have little or no effect on the shape of the serial position curve. The different delay, however, contributes contextual components that are unique to the last (delay) interval.

The contextual retrieval hypothesis "proposes that the long-term recency effect results from encoding TBR items in changing contexts (produced by the activity in the IPI [interpresentation interval]) and from using contextual information as a retrieval cue" (Glenberg et al., 1983, p. 244). "Changes in the contextual components are due to changes introduced by the experimenter (e.g., from the study episode to the test episode) and changes internal to the subject" (Glenberg et al., 1983, p. 236). The different delay provides a change in context in the final distractor (delay) interval, and should therefore affect recall of the items closest to it—the last few. Since the different delay is contiguous with the recall period, the overlap between the new, or "relevant," cues provided by the different delay (but not by the same delay) should be greatest between the recall context and the last list item.

> Because the recency items share more components with the [recall context] cue than do the middle items, they are recalled more frequently.... Also, within the set of recency items there is a positive relation between serial position and the number of components shared by the [recall context] cue and the items. This relationship corresponds to the increase in recall across the recency positions. (Glenberg et al., 1983, p. 238)

Thus, the outcome of the different delay, according to the predictions of this hypothesis, should have been a recency effect in the different delay-task condition, with the highest recall in the last (12th) serial position. Instead, recall from Serial Position 12 was the lowest among the recency positions. A reformulation of the contextual retrieval hypothesis would seem to be called for.

In summary, we have shown that the long-term recency effect is really a short-term storage effect. Contrary to arguments presented in recent literature, it is labile, like the recency effect in standard free recall. It differs only in that under the special condition of the subjects' practicing through the list on a particular distractor task, it is not completely eliminated by that distractor task. The subjects adapt to the distractor task. That subjects can do this has been demonstrated by Reitman (1974), and has been attested to by our subjects. Now we will show how the subjects learn this adaptation and what it costs them.

EXPERIMENT 2

There are two major functions ascribed to short-term storage: the maintenance of items in the system, and the transfer of these items to long-term storage. The principle aim of Experiment 2 was to furnish evidence for the following assertion: In the continuous distractor task, both functions of short-term storage are carried through the distractor interval by a time-sharing process, but at a cost. Two types of data will be used to support this assertion. One is evidence of the costs and benefits to the subject of time sharing in this paradigm. Comparison of standard free recall and the continuous distractor task will show the effects in performance, both positive and negative, induced by the distractor task. The other type of data is evidence of the improvement of performance by the subjects over successive lists. This improvement supports the subjects' testimony that they learned how to cope with the distractor task.

The cost-benefit analysis of different recall tasks focuses on the function of intervals between successive to-be-recalled list items and the effect of a distractor task. The conventional view of the continuous distractor task is that it removes each list item and completely curtails the processing of that item into long-term storage before the next list item appears. We believe, however, that in the continuous distractor task, the subjects cope with the repeated insertion of the distractor task by a time-sharing procedure that partially preserves the functions of short-term storage—that is, maintenance and transfer of list items to long-term storage. This implies that the continuous distractor task should produce lower recall than free recall of lists with the same interword interval but no intralist distractor task—that is, spaced free recall. In spaced free recall, the subject has the entire interword interval for rehearsal and registration. In the continuous distractor task, that interval also has to be used for the distractor task. This view also implies that the continuous distractor task should produce better recall than free recall with no time between words—that is, massed free recall. In massed free recall, the subject has no time between words for rehearsal and registration. In the continuous distractor task, the subject has whatever time may be freed from the distractor task for those functions. These considerations lead to predictions concerning the amount recalled in the continuous distractor task, spaced free recall, and massed free recall.

The second type of data relevant to the time-sharing hypothesis is that on the subjects' improvement over successive lists. The data of Experiment 1 suggested that this improvement did occur. The marked improvement occurred, however, early in the practice lists. Since those practice lists were drawn from a different set of material than the main experimental lists, the effects could not be clearly interpreted. We therefore changed the lists for this experiment so that the practice and main lists came from the same pool of items. We could therefore clearly trace the changes in the subjects' efficiency from the first practice trial on.

Method

There were three list conditions in this experiment: (1) standard free recall, with list presentation at the rate of 2 sec per word and no interitem interval (massed); (2) standard free recall, with words presented again for 2 sec each and a 6-sec unfilled interval between each list word (spaced); and (3) a continuous distractor list, with list words presented for 2 sec each and a 6-sec interitem distractor task (distractor). The spaced lists paralleled the distractor lists. In the spaced lists, each word was followed by an unfilled 6-sec interval. In the distractor lists, each word was followed by a 6-sec distractor task. The reason for the use of the three conditions is that it permitted the distractor task to be compared with a condition in which the subject had 6 sec completely free (spaced lists) or no time at all between list words (massed lists).

Materials

There were 12 main recall lists, drawn from the same pool of 12 lists used in Experiment 1. The construction of these lists and the characteristics of the list words were the same as in Experiment 1. List words were all concrete one- and two-syllable nouns with a mean frequency of 110 per million. Twelve words were assigned to each main list so that the lists were matched for overall frequency. Associative relations among words within lists were minimal. In the distractor lists, each list word was preceded and followed by a distractor task. In the massed and spaced conditions, only the 12 list words were presented, with no distractor material at any point.

The distractor task in this experiment was the word-reading task used in Experiment 1. However, the distractor interval was halved here (from 12 to 6 sec), and the number of lists was doubled (from 6 to 12). The main reason for halving the distractor task was to furnish a homogeneous set of words large enough for both the practice and the main lists, so that learning effects could be fully evaluated. Using the two pools of distractor and delay words from Experiment 1, the same methods were employed to construct distractor sets of six words each for the 12 lists used. Except for the smaller number of words in each set, the construction and form of both the distractor and the delay sets were the same as before. The overall frequency of distractor and delay words was constant across lists (including practice lists) and conditions. Each set had an equal number of one- and two-syllable words, and obvious associations between words within sets were eliminated. As before, the distractor and delay sets were randomly assigned to lists. Also as before, assignment of sets to lists was changed with each new randomization of the main lists to avoid systematic associations between the words in the lists, in the distractor sets, and in the delay sets.

Subjects

The subjects were 96 New York University undergraduates who participated in the experiment to fulfill a course requirement.

Design

Forty-eight subjects were assigned to each of two testing groups, for the two main comparisons of list types. Distractor and massed lists were shown to one group, and distractor and spaced lists to the second. (It was decided that giving all three experimental conditions to each subject would be cumbersome and confusing.) List presentation was blocked for each group, creating two subgroups. Half the subjects in each group saw distractor lists first. The other half saw standard lists (either massed or spaced) first and distractor lists second. The reason for grouping the conditions was that the continuous distractor task involves a special and unusual procedure. It was decided to keep it separate from the more usual free-recall procedure. In addition, if practice is an important factor in the development of time sharing, then the continuity of blocked presentation might show practice effects more clearly.

Each subject saw all 12 main lists, of which eight were presented as distractor lists and four were either massed or spaced, depending on the condition to which the subject was assigned. For each set of 4 subjects (1 from each of the above four subgroups), the same eight lists were used as distractor lists, and the remaining four lists were used as massed lists for 2 subjects and as spaced lists for the other 2.

A new random ordering of the 12 main lists, and of words within the lists, was generated for every new set of 4 subjects. At the same time, the assignment of the newly ordered lists to conditions was rotated so that, across all subjects, each list was used twice as often for distractor lists as for massed or spaced lists, and all lists were used equally often as massed or spaced lists. However, within each of the subject sets, all 4 subjects saw the same ordering of lists. In this way, characteristics of list and distractor materials associated with a specific randomization were counterbalanced.

The practice lists in this experiment were drawn from the same pool of lists as the main lists. From each subject's randomized set of 12 lists, the first standard list (massed or spaced) and the first two distractor lists were defined as practice. Following the procedure in Experiment 1, the data from these lists were not included in the experimental analyses comparing the list conditions. They were used, however, in tracking the changes in performance across lists. Including the practice-list data in the first set of analyses would not affect the pattern of results or the conclusions they lead to. Examination of the means for data that include the practice trials support this statement.

Procedure

The subjects were tested individually. They were given instructions for the list type they were to see, before each block of lists—distractor or standard (either massed or spaced). Presentation of the lists followed the basic procedure described in Experiment 1, with the following variations to accommodate the new massed and spaced conditions, and the shorter distractor sets in the distractor condition.

First, the list cards for the massed lists occurred in immediate succession, each with a single to-be-recalled list word (which was read aloud). The subjects advanced the cards at the rate of one every 2 sec, in time with the metronome. The 12 list cards were preceded by a lined blank card as a ready signal. The last list card was followed by an unlined blank card as a recall signal.

Second, for the spaced lists, each card bearing a list word was preceded and followed by a blank card. In this condition, the metronome beat in a regularly alternating sequence of 2- and 6-sec intervals, and the subjects advanced one card with each beat. The alternation of interval lengths and of interpolated blank and list cards was synchronized so that the subjects always saw a list word during the 2-sec intervals and a blank during the 6-sec intervals.

Finally, for the distractor lists, the timing and arrangement of list words and interpolated cards was the same as that for the spaced lists, except that the interpolated cards had distractor words in this condition, not a blank card. The six words of each distractor and delay set (the postlist distractor set) were presented on three lines on each card, with two words per line. One line was read every 2 sec, paced by the metronome, so that each distractor and delay card was seen for 6 sec. Except for the shorter distractor task, the lists were presented according to the procedure outlined for the word-distractor (same delay) condition of Experiment 1.

Instructions, prelist experience with experimental materials, and practice-list training for the distractor condition were the same as for the word-distractor task in Experiment 1. In the massed and spaced conditions, the instructions were for standard free recall. In the massed condition, prelist training involved practice at manipulating and reading the cards, each bearing a single, low-frequency word, which the subjects read aloud in time with the metronome. In the spaced condition, the subjects had practice on the same cards plus the interpolated blank cards, and learned to coordinate both with the 2- and the 6-sec intervals, respectively, as marked by the metronome.

The course of experimental events is outlined next for the 48 subjects who saw standard lists first and the distractor lists second. After completing the prelist training for the first scheduled (standard) list condition (massed for half the subjects, spaced for the other half), the subjects saw a total of four lists for that condition, one practice and three experimental lists, each followed by a written immediate free-recall test lasting 1 min. After the four lists had been completed, a 3-min period of debriefing conversation was followed by a final free-recall test in which the subjects wrote all the list words they could remember. A partial debriefing and rest interval of 3-5 min terminated this first part of the experiment.

Instructions and prelist training were then given for the second condition (in this case, the distractor condition), followed by four distractor lists—two practice and two experimental lists. A 5-min rest period was given before the last four experimental lists were presented. When the last immediate-recall test was completed, the subjects were asked about the strategies they used in handling the distractor lists, and how these compared with their approach to the standard lists. After this 5-10-min question period, the subjects were asked for written final recall.

Results and Discussion

We first examined the pattern of data for the distractor-first versus distractor-second conditions, in both main groups. Since the same pattern of results held for both orders and both groups, the data for both orders of presentation have been combined here and below. The decision to combine the two sets of data was fully supported by statistical analysis. A preliminary $2 \times 2 \times 12$ split-plot factorial analysis of variance was performed on the distractor data only, for all 96 subjects. Testing group (distractor vs. massed; distractor vs. spaced) and order of presentation (distractor condition first; distractor condition second) were the between-subject variables. Serial position (1-12) was the within-subject variable. There was no statistically significant effect of either testing group ($F < 1$) or presentation order [$F(1,92) = 2.00, p = .16$]. Only the effect of serial position was statistically significant [$F(1,92) = 33.66, p < .001$]. The principal findings can therefore be presented simply in Figure 3, which shows the serial position curves for the three main conditions. The distractor data for all 96 subjects are collapsed across groups and presentation order to produce the distractor curve. Overall analyses also found no order effects for the massed and spaced data. The curves for the massed and spaced conditions are therefore based on data from their combined subgroups.

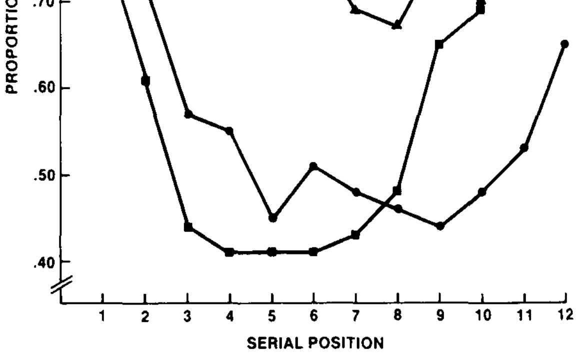

Figure 3. Proportion recalled as a function of serial position for the distractor, massed, and spaced conditions in Experiment 2. Distractor-condition data from all groups are combined (N = 96).

The data settle any question that could be raised about the relatively small end peak in the distractor condition of Experiment 1. The curve for the distractor condition in Figure 3 shows that the earlier end peak is a reliable effect, replicated here in Experiment 2. It will be replicated again in Experiment 3.

Our first main question concerned the costs and benefits of the distractor task. This question will be answered with respect to the long-term component (Positions 1-8) and the short-term component (Tulving-Colotla estimates) separately. With respect to the long-term component, the three curves in Figure 3 bear out our expectations concerning costs and benefits. First, there is the expected advantage of the distractor condition over the massed condition. This can be seen in the early and middle portions of the curves, the long-term storage component for those two conditions. Second, as expected, the distractor condition is at a severe disadvantage relative to the spaced condition, which allows all of the interitem interval to be devoted to the processing of list words. These observations were supported by statistical analyses. The mean recall for Positions 1-8 was higher in the distractor condition than in the massed condition [$F(1,46) = 7.618$, $p = .009$]. It was lower than in the spaced condition [$F(1,46) = 126.31, p < .001$].

The costs and benefits of the distractor task are evaluated next for the short-term storage component. This component has to be estimated since it does not appear by itself, but is mingled with output from long-term storage. In Experiment 1, this was not a problem because the asymptotic level of recall from long-term storage was approximately the same in all the experimental conditions. Therefore, the contribution to the recall of recency items from the underlying asymptote of long-term storage was approximately the same in all conditions. However, here the experimental manipulations produced large differences across conditions in the asymptotic level of recall from long-term storage. The contribution from long-term storage to recall of recency items (Serial Positions 9-12) in Experiment 2 would, therefore, vary widely across the three main experimental conditions. Therefore, an estimate of the short-term component that would not include output from the long-term component was used instead. Analyses by Watkins (1974) indicate that the best of the several estimates of this component is the Tulving-Colotla estimate (Tulving & Colotla, 1970). The estimates for the experimental conditions are as follows: distractor, 1.7; spaced, 1.8; massed, 2.8. The number of words held in short-term storage was lowest for the distractor condition. The distractor condition, however, is significantly different only from the massed condition [$F(1,46) = 83.61$, $p < .001$]. We expected the amount in short-term storage to be greater also in the spaced condition, relative to the distractor condition, since the subjects in the spaced condition were free of the demands of distractors and time sharing. However, the spaced versus the distractor conditions did not differ significantly [$F(1,46) = 1.084$, $p = .30$].

The reasons for the absence of a difference between the distractor and the spaced conditions will be considered now. The amount in short-term storage for the massed condition was similar to that estimated in many other free-recall studies (Glanzer et al., 1972; Glanzer & Razel, 1974; Watkins, 1974). The amount for the spaced condition was, however, low. Similar effects were obtained by Brodie and Murdock (1977), when comparing fast (1.5 sec) and slow (5 sec) presentation times in standard free recall. They found, in the slower condition, a similar increase in recall from early and middle positions, and a similar decrease in the recency effect (Brodie & Murdock, 1977, Figure 1). There is evidence that the low amount in short-term storage for the spaced condition is a result of the special recall order induced. In their interviews, our subjects said they preferred a forward order of recall in this condition. This would produce a reduced end peak, since the initial recall of early items acts effectively as a distractor task for later list items. We will consider this point further in setting up Experiment 3.

The serial position curves for final free recall in the three conditions are shown in Figure 4. The data strengthen the conclusions drawn from the immediate-recall data. The differences in recall from long-term storage in immediate recall for the three conditions were replicated in final recall. As usual, the recency effects found in all three conditions in immediate recall, including that for the distractor task, disappeared in final recall.

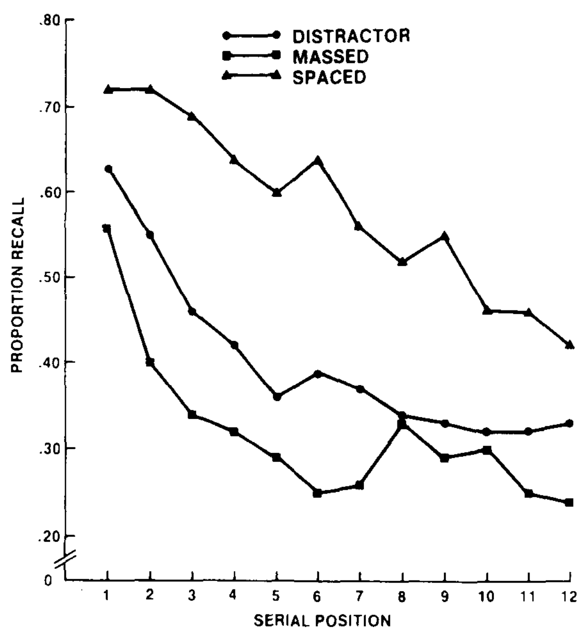

Figure 4. Final recall data for Experiment 2, showing proportion recalled as a function of serial position for the distractor, massed, and spaced conditions. Distractor-condition data from all groups are combined ($N = 96$).

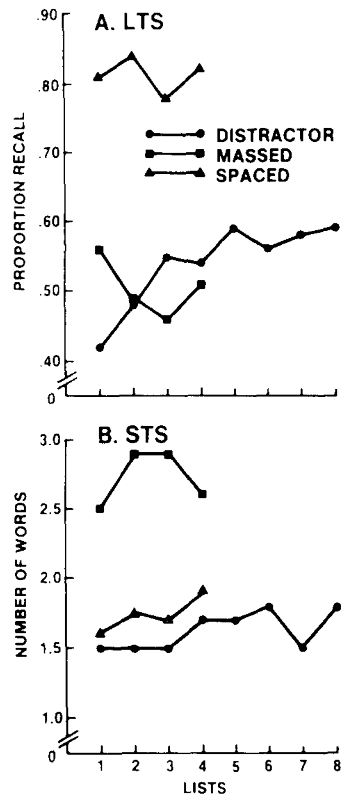

Figure 5. (A) Proportion recalled as a function of trials (lists) for the distractor, massed, and spaced conditions in Experiment 2. Recall is from long-term storage (Serial Positions 1-8). (B) Number of words in short-term storage (Tulving-Colotla estimates) as a function of trials (lists) for the distractor, massed, and spaced conditions.

In Experiment 1, performance improved across lists, particularly across practice lists. This suggested that a time-sharing process develops with repeated experience with the distractor task. In the present experiment, we examined this question more fully. The two practice lists were drawn from the common, counterbalanced pool of lists, which also furnished the experimental lists. In addition, it was possible to compare learning effects for the distractor task with those for standard free recall.

We tracked the changes in performance across lists separately for the long-term and short-term components. For the long-term component of recall, the mean proportion of words recalled from Serial Positions 1-8 was computed for each successive list in the three experimental conditions. For the short-term component, the mean number of words in short-term storage, as determined with the Tulving-Colotla estimates, was computed for each successive list. The results for the three conditions of Experiment 2 are summarized in the two panels of Figure 5. Panel A shows performance for the long-term component, Panel B for the short-term component. As expected, in the distractor condition, recall was low in initial lists and then improved across lists. This is true for both the long-term and the short-term components, although the effect shows up more strongly for the long-term component. These changes, as expected, are not evident in the massed and spaced conditions. Instead, performance in those conditions was high on the first trial and remained virtually unchanged across lists.

These observations were supported by statistical analyses of each curve in Figure 5. Evaluation of changes in the long- and short-term components over trials in terms of the linear component in each condition finds the following. In the distractor condition, there was a significant effect across lists both in the long-term component of recall [$t(96) = 7.408, p < .001$] and in the short-term component [$t(96) = 2.578, p < .02$]. As expected, in the massed and spaced conditions, there were no significant effects of lists on either the long- or the short-term component (all $ps > .20$).

The results indicate that the word-distractor task initially impairs performance. However, repeated exposure to the distractor task leads to an adaptation to this interference. A more detailed analysis of the adaptation would include a statement concerning the improvement in encoding that increases both the amount in short-term storage (see Glanzer & Razel, 1974) and the transfer to long-term storage. The development of this adaptation is markedly different from the stable performance across lists in the standard free-recall conditions. In summary, interitem processing persists even in the face of distractor tasks. This persistence becomes more marked with successive lists, reflecting the adaptation process and a robust time-sharing mechanism.

EXPERIMENT 3

There were two reasons for conducting Experiment 3. One was to clarify the reason for the small amount in short-term storage in the spaced condition of Experiment 2. The other was to counter a possible argument about the results of Experiment 2. The main results of Experiment 2—the ordering of the amount of recall with standard spaced highest, continuous distractor next, and standard massed lowest—could be questioned. It could be argued that the three conditions had their effect through the way they induced the subjects to order their recall. For example, the massed condition might influence subjects to report the last few items first, resulting in output interference for the earlier items. Therefore, the lower recall from early sections of the lists for the massed condition, as compared with the distractor condition, could be due to output interference.

Experiment 3 was therefore a replication of Experiment 2, with one change in procedure. The output order in recall was prescribed for the subjects. The subjects were instructed, as in the procedure used by Craik and Levy (1970), Dalezman (1976), and Whitten (1981), to give the last list words first in their recall. The controlled output order should, if our analysis was correct, raise the low output from short-term storage found in the spaced condition of Experiment 2. Moreover, if the same pattern as that found in Experiment 2 holds with control of output order, then there is further support for our explanation of continuous distractor-task effects, rather than an explanation based on output interference.

Method

Except for the addition of instructions concerning order of recall, the materials, method, and procedure were as described for Experiment 2.

Instructions

For all list conditions, the subjects were told to recall as many list words as possible, but to try to write the last few words first, and then the rest of the list words in any order they liked. It was emphasized that although end words should be written first, all parts of the list were equally important, and that the beginning and middle words should not be sacrificed in favor of end items.

Subjects

The subjects were 72 introductory psychology students who participated in the experiment to fulfill part of a course requirement.

Results and Discussion

The overall results of Experiment 3 are summarized in the serial position curves for the three conditions shown in Figure 6. The distractor curve is based on the data from all subjects, collapsed across testing groups and order of condition, as in Experiment 2.

The main findings of Experiment 2 are replicated here. Recall from the early and middle positions is highest in the spaced condition, lower in the distractor condition, and lowest in the massed condition, reflecting the time available in each of the three conditions for processing.

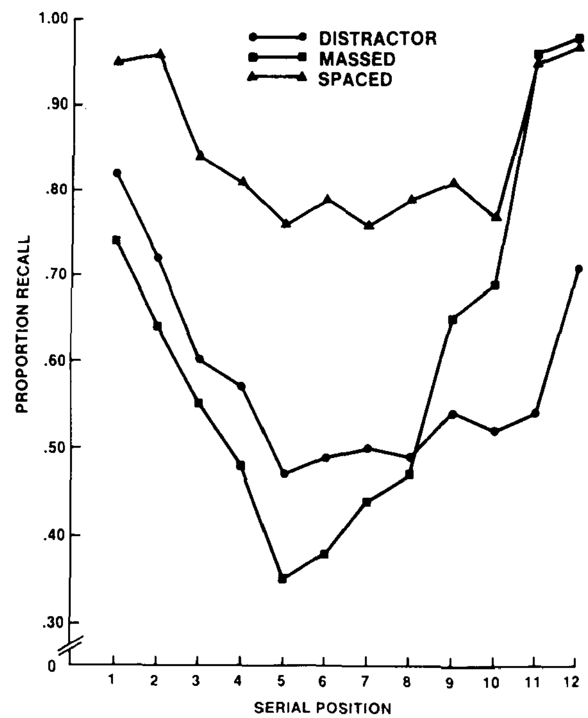

Figure 6. Proportion recalled as a function of serial position for the distractor, massed, and spaced conditions in Experiment 3. Distractor-condition data from all groups are combined ($N = 72$).

The end peak in the word-distractor condition is replicated again here, as it was in Experiment 2. It is clearly a strong and reliable effect.

Statistical analyses confirmed the picture presented in the serial position curves. Recall from Positions 1-8 was higher in the distractor condition than in the massed condition [$F(1,34) = 7.95$, $p = .008$], confirming the predicted superiority of the distractor over the massed condition in recall from long-term storage. Recall was lower in the distractor condition than in the spaced condition [$F(1,34) = 72.04$, $p < .001$].

The effect of the special recall instruction can be seen in the last few positions of the three curves in Figure 6—the recency portion. A visual comparison of these curves with those of Experiment 2 (see Figure 3) shows that the last few positions in each of the three conditions are higher in Experiment 3. The effect of the recall instruction in the present experiment, then, was a more pronounced end peak in the distractor and spaced conditions and, to a smaller degree, in the massed condition. The levels of recall in early positions, however, remained virtually the same as in Experiment 2. There is no evidence, therefore, that this pattern of results in recall from long-term storage can be attributed to output interference from early output of recency items.

The Tulving-Colotla estimates of the number of words in short-term storage for the three conditions are as follows: distractor, 2.3; spaced, 3.3; massed, 3.2. There was more output from short-term storage overall in the present procedure. More important, the means clearly show the expected order. The number of words held in short-term storage is lowest for the distractor condition. Statistical analyses show that the distractor and massed conditions differ significantly [$F(1,34) = 82.52, p < .001$]. These results replicate those of Experiment 2. Unlike Experiment 2, however, the comparison of the distractor and spaced conditions reveals a statistically significant superiority for the spaced condition [$F(1,34) = 75.68$, $p < .001$]. The instruction to recall the last words first was effective in having the subjects use the same recall order in all conditions. This resulted in a large increase in output from short-term storage for the spaced condition, now the same as that for the massed condition.

The serial position curves for final free recall in the three experimental conditions are shown in Figure 7. As in Experiment 2, differences in output for long-term storage in immediate recall are still present in final recall. As in Experiment 2, again, the end peaks found in immediate recall do not appear in final recall. All three curves show the same general shape, although at different distances from the abscissa.

The effect of practice across lists in the continuous distractor task was also examined. Again, the practice lists were included in the analysis. The results can be seen in the plots shown in Figure 8. Panel A shows recall from Serial Positions 1-8, representing the long-term component. Panel B shows the Tulving-Colotla estimates, representing the short-term component. The main result,

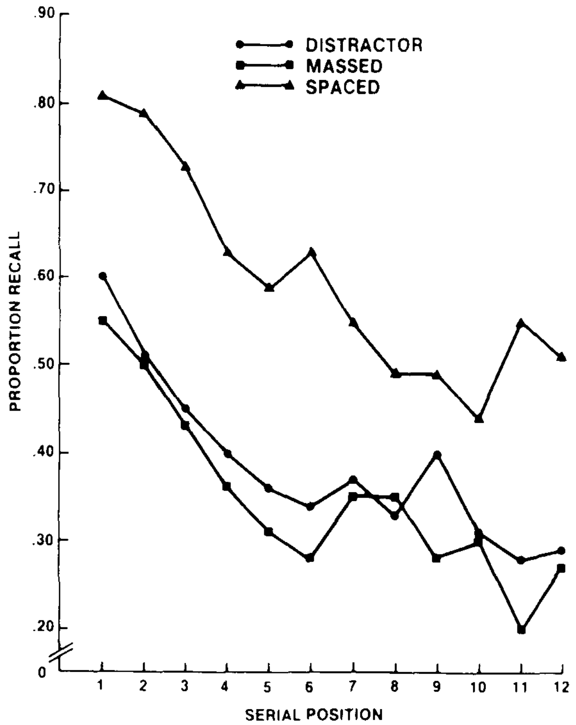

Figure 7. Final recall data for Experiment 3, showing proportion recalled as a function of serial position for the distractor, massed, and spaced conditions. Distractor-condition data from all groups are combined ($N = 72$).

as can be seen in the plots, is a confirmation of the effects obtained in Experiment 2. In output from both long-term and short-term storage, there is a large effect of practice across lists for the word-distractor condition and no parallel effect in the massed or spaced conditions. A separate evaluation of the linear component was performed for each condition on the means shown in Panels A and B of Figure 8. There was a significant effect across lists in the distractor condition for both the long-term component [$t(72) = 10.124$, $p < .001$] and the short-term component [$t(72) = 5.993, p < .001$]. Again, the effect was absent in the massed condition for both the long-term and the short-term components (both $ps > .20$). In the spaced condition also, there was no effect of lists for the long-term component ($p > .20$). The test did reveal, however, an effect of lists for the short-term component in the spaced condition [$t(36) = 2.623$, $p < .02$].

The special recall instruction brings the Tulving-Colotla estimates in the spaced condition up to the same level as in the massed condition, by reversing the subjects' output order. There is a question, however, as to why there was an effect of practice over lists for the short-term component in the spaced condition of Experiment 3. This effect was absent in the corresponding condition in Experiment 2. The special recall instruction of Experiment 3 is probably responsible for this effect as well. The spaced condition favors the recall of list words in forward order. In Experiment 3, this output preference would be at odds with the recall instruction. Therefore, the effect of the

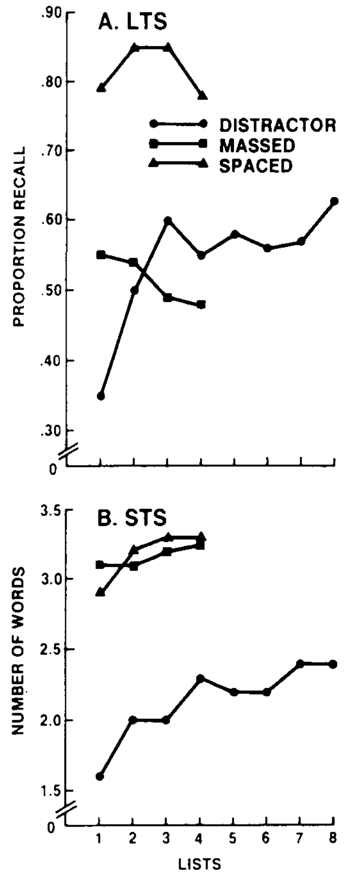

Figure 8. (A) Proportion recalled as a function of trials (lists) for the distractor, massed, and spaced conditions in Experiment 3. Recall is from long-term storage (Serial Positions 1–8). (B) Number of words in short-term storage (Tulving–Colotla estimates) as a function of trials (lists) for the distractor, massed, and spaced conditions.

recall instruction emerged only slowly, across lists, resulting in an increase in the short-term store estimates. The subjects' comments were consistent with this account.

Although adaptation to the distractor provides some benefits in list processing, the present findings indicate that list processing in short-term storage is only partially protected by time sharing. Interference effects are still evident in the level of recall of the distractor condition, relative to the spaced condition, and in recency effects which, both here and in the literature, are generally smaller than those in standard free recall. One source of this handicap is the time sharing itself, which exerts a drain on the resources of the system (the costs, described earlier).

GENERAL DISCUSSION

In Experiment 1, we showed that the long-term recency effect of the continuous distractor task was stable only as long as the delay task was the same as the intralist task. When the delay task was different, the elimination of the end peak occurred as in ordinary free recall. This led to the hypothesis that subjects cope with the continuous distractor task by developing a time-sharing arrangement so that short-term storage continues functioning for list items while the distractor task is carried out.

In Experiment 2, we tested two implications of this hypothesis. One was that the distractor condition would not block the storage and transfer functions of short-term storage completely. Therefore, if compared with a condition that is more effective in blocking these functions (as with massed presentation), the distractor condition should show superior transfer to long-term storage. This was indeed the case. Moreover, compared with a condition that did not block these functions (spaced presentation), the distractor condition showed the costs to the subjects of the time sharing required by it. Further examination of recall over lists indicated that the time-sharing skill develops over trials for the continuous distractor condition in a way that is distinct from the ordinary massed and spaced free-recall conditions. Experiment 3 replicated these results and strengthened the assertions based on them.

Two sets of data have been offered (Glenberg et al., 1983; Glenberg et al., 1980) as arguments against a dual-storage interpretation of recency effects in this paradigm: (1) the difficulty of the distractor task does not affect the end peak in the continuous distractor task, and (2) the long-term recency effect appears with incidental learning. The first argument assumes that difficulty of distractor has been shown to affect the amount held in short-term storage, as measured in standard free recall. However, there is evidence to the contrary. Glanzer et al. (1969) showed that varying the difficulty of a postlist delay task had no effect on the removal of items from short-term storage. The effect of difficulty of a distractor task is rather on the transfer of items to long-term storage, as seen when a concurrent distractor task is imposed (Silverstein & Glanzer, 1971). These findings are completely congruent with Glenberg et al.'s (1980) finding that a difficult postlist distractor task has no effect on the end peak of the serial position curve, whereas a difficult intralist distractor task has a major effect on the earlier positions. The second argument is relevant only if the adaptation by the subject to the distractor is assumed to be intentional. It is not clear that intention is necessary. Our subjects' comments indicate that adaptation to the distractor task may take place automatically.

Since the area of recency effects is one of considerable controversy, it is important to make another point before closing. Recency effects of different types exist. They do not all fall under the same explanation. For example, there are recency effects that occur in rote learning. These are long-term recency effects, and have been known for more than 50 years (Robinson & Brown, 1926; Ward, 1937). It is clear, however, that these effects require a different explanation than those that arise in free recall (Glanzer & Peters, 1962). Similarly, the range of recency effects such as those demonstrated by Watkins and Peynircioglu (1983), and others discussed by Baddeley and Hitch (1977), require further analysis to determine their relation to the recency effect in free recall and whether they demand the same explanation.

The data presented here are problematic for the contextual retrieval hypothesis. They could be accommodated by revision and extension of that hypothesis. They can be fitted into dual-storage theory by extending that theory in the following way. In ordinary free recall, short-term storage accumulates items and transfers them to long-term storage as outlined in the models presented in the literature (Atkinson & Shiffrin, 1968; Glanzer, 1972; Raaijmakers & Shiffrin, 1980). In the continuous distractor task, the subject develops time sharing by means of which some items are carried forward in short-term storage, although fewer than those in ordinary free recall. Some of those items are transferred to long-term storage. More are transferred than in massed presentation but fewer than in an equivalent spaced (empty-interval) presentation. The time sharing does not permit the subject to store as much in short-term storage. It may also cost the subject in efficiency of transfer to long-term storage (as compared with the spaced condition). Alternatively, the lesser amount in long-term storage (as compared with the spaced condition) may simply be due to the lesser amount in short-term storage.

The results of the work with the continuous distractor task indicate that a more complex picture of the dual-storage model is needed. The need for such development has, of course, been argued by other theorists (Baddeley & Hitch, 1974). The present results do not invalidate the basic model. Rather, they point to the way in which the continuous distractor-task data can be incorporated into a revised dual-storage model. The revision centers on the inclusion of adaptation and time-sharing processes.

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