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Primacy and Recency in the Continuous Distractor Paradigm

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Three experiments investigated serial position effects in immediate and final free recall. Each word in a 10-item list was both preceded and followed by a 15-sec period of distraction activity. In Experiment 1, half of the lists were immediately followed by either a recall test or a recognition test; the remaining lists were not tested, but were followed by a different distraction activity. After presentation of all lists, a final recall or recognition test was given. Primacy was observed only in immediate free recall and in all final tests following immediate free recall, demonstrating that primacy develops from a free-recall storage strategy. No recency was observed in Experiment 1. In Experiment 2, every list was followed by an immediate free-recall test, with a final free-recall test after the last list. The primacy results of Experiment 1 were replicated. Furthermore, the appearance of recency in Expriment 2 suggests that recency results from a retrieval strategy that failed to develop in Experiment 1 because some lists were not tested immediately. To eliminate an artifact account, Experiment 3 used an experimenter-paced distractor task and replicated the findings of Experiment 2, which used a subject-paced distractor task. Contrary to previous claims, the pattern of results in the continuous distractor paradigm is seen as completely consistent with the account offered by multistore models of serial position effects in standard free recall.

A crucial test of any model of human memory is its ability to account for the serial position curve obtained in single-trial free recall. Multistore models have successfully accounted for serial position effects through the operation of short-term and long-term stores (Atkinson & Shiffrin, 1968; Waugh & Norman, 1965). Briefly, multistore models explain the familiar bowed curve as follows: Superior retention of the first few list items (the primacy effect) results from differential storage. The probability of entering an item in long-term store is directly related to the amount of processing given to that item, and the amount of processing per item decreases to an asymptote as the number of presented items increases (cf. Rundus, 1971). Thus, midlist items are poorly recalled in comparison to primacy items. Superior retention of terminal list items (the recency effect) is attributed to readout of the last few items from short-term store. The absence of recency when a filled delay separates study and test (Glanzer & Cunitz, 1966; Postman & Phillips, 1965) supports this account.

Until recently, the multistore explanation has fared exceptionally well in handling the large serial position literature. However, a modification of the free-recall procedure that we call the *continuous distractor paradigm* appears to pose a problem for this account. In fact, from their investigations using this paradigm, Bjork and Whitten (1974) have concluded that "the customary two-process theoretical account of immediate free recall is certainly incomplete, if not wrong" (p.

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189). This conclusion notwithstanding, inconsistencies in previous findings described below suggest that the processes involved in the continuous distractor paradigm remain inadequately understood. In the present article, we seek to resolve these inconsistencies and to account for serial position effects in the continuous distractor paradigm through subject strategies that are consistent with two-process theories.

The continuous distractor paradigm was invented by Whitten and Bjork (Note 1) to examine certain within-list effects freed from the confounding of serial position effects. The only difference between the continuous distractor paradigm and the standard free-recall paradigm is in the manner in which lists are studied. Basically, the paradigm involves preceding and following each item in the list by 12–20 sec of distractor activity like that typically used in the Brown–Peterson paradigm. This procedure has the effect of embedding each item in an otherwise uninterrupted distractor task, thereby isolating one item from the next. The isolation is further accentuated by instructions encouraging the subject to rehearse only the current item. Each of several lists is followed by an immediate free-recall test on only that list. As with the standard free-recall paradigm, after all of the lists have been studied and tested, an unexpected final test over all of the items may be administered.

The aim of the continuous distractor procedure was to prevent operation of the processes proposed by multistore models to account for serial position effects. Consider the serial position function for immediate free recall. If subjects obey the instructions to rehearse only the current item, then each item should receive the same amount of processing and therefore have an equal chance of entering long-term store. Thus, the differential storage responsible for primacy in free recall should be eliminated; there should be no effect of serial position at the beginning of the list. Furthermore, at the end of the list, the distractor activity separating list items should eliminate the opportunity for recall of items from short-term store; no effect of serial position should be found at the end of the list. In short, the serial position curve should be essentially flat in the continuous distractor paradigm. Instead, in three separate studies using this paradigm (Bjork & Whitten, 1974; Tzeng, 1973; Whitten & Bjork, Note 1) the familiar bowed serial position curve has emerged completely intact!

The predictions regarding serial position in final free recall are identical to the predictions for immediate free recall. The only additional stipulation required is that the negative recency observed in the usual free-recall paradigm (Craik, 1970) should not appear, because negative recency relies on the short-term readout strategy prevented by continuous distraction. Therefore, the serial position function for the final test should also be flat. Here, the results obtained by previous investigators are inconsistent. Whereas Bjork and Whitten (1974) obtained virtually flat serial position curves in final free recall, Tzeng (1973) found bowed curves identical in shape to those obtained in immediate recall (but depressed in terms of proportion correct). However, this inconsistency may have resulted from procedural differences. Bjork and Whitten presented eight lists with 10 word pairs in each, so final recall required retrieval of 160 words. Tzeng argued that the procedure used by Bjork and Whitten led to excessive output interference in final recall such that the resulting floor effect masked serial position effects. Consequently, Tzeng's results were obtained by requiring final recall of only 40 words. Because his study was designed to remedy this interference problem, Tzeng's final recall results are probably more indicative of the processes underlying the continuous distractor phenomenon.

How should this pattern of results be interpreted? Consider recency first. Positive recency in immediate recall appears to be inconsistent with the explanations given above for recency in the standard free-recall paradigm. On the basis of finding recency in both immediate and final recall, Tzeng (1973) concluded that recency results from the operation of a "long-term retrieval process." Although Tzeng fails to specify this retrieval process, there is a more critical problem with his conclusion. A storage process could also account for Tzeng's results. In fact, there are no means for separating the effects of storage and retrieval processes in Tzeng's experiment.

Bjork and Whitten (1974) also concluded that recency results from a retrieval process, but for the opposite reason. Finding *no* recency in final free recall in Experiment 2, they reasoned that recency could not be due to differential storage but must result from a retrieval process. This conclusion relies on the questionable finding that recency is absent in final recall, a finding requiring acceptance of the null hypothesis. Given that output interference may have masked serial position effects, Bjork and Whitten also failed to present results that separate the effects of storage and retrieval processes.

Now consider primacy. While Tzeng found primacy in both immediate and final recall, he offered no explanation for his finding. Bjork and Whitten, on the other hand, found primacy only in immediate recall and therefore attributed primacy to the operation of retrieval processes. Again, their conclusion is based on the questionable finding of no serial position effect in final recall. If Tzeng's final recall results are accepted instead, then primacy may result from either storage or retrieval processes.

In summary, neither Tzeng (1973) nor Bjork and Whitten (1974) obtained results indicating whether storage or retrieval processes are responsible for the observed serial position effects. In this article we report three experiments designed to reveal the processes underlying primacy and recency in the continuous distractor paradigm. Our first experiment provides an independent assessment of the contributions of storage and retrieval processes by using recall and recognition tests and by initially testing only half the lists. The second experiment focuses on the recency effect as a possible outgrowth of a developing output strategy. In the third experiment, the possibility that subject-paced distractor tasks have produced artifactual primacy and recency is tested. Finally, in the general discussion section, we present an overall account of serial position effects in the continuous distractor paradigm in terms of processing strategies operating in free recall.

Experiment 1

Previous research with the continuous distractor paradigm has almost exclusively used the free-recall test procedure, which depends on both storage and retrieval processes. To the extent that recognition tests minimize (Kintsch, 1968; Murdock, 1968) or eliminate (Anderson & Bower, 1972) the retrieval component, the use of a recognition test permits assessment of the contribution of primarily storage processes to serial position effects. If a serial position effect is observed both in free recall and in recognition, then storage processes are implicated. However, when an effect is found only in free recall and not in recognition, then retrieval processes are more likely to be the source. In Experiment 3 of their study, Bjork and Whitten (1974) did include immediate recognition tests. Their finding of recency in immediate recall but not in immediate recognition provides strong inductive support for the hypothesis that recency in free recall is due to a retrieval strategy.

Comparisons of performance on immediate and final tests can also help to reveal the processes responsible for serial position effects. For instance, a long-term storage process should affect both immediate and final performance, while a short-term retrieval process should affect only immediate performance. One problem with comparisons of immediate and final test performance is that performance on the final test may be affected by performance on the immediate test (cf. Dark & Loftus, 1976; Modigliani, 1976). Consequently, to permit unconfounded comparisons of immediate and final tests, only half of the lists in Experiment 1 were initially tested. Final performance on the nontested lists should be uncontaminated, and a comparison of final performance for tested and nontested lists should indicate the extent to which immediate testing contaminated final performance.

In Experiment 1, immediate and final recall and recognition tests were combined factorially between subjects. Each subject received the same type of immediate test on three of six lists and no immediate test on the three remaining lists. Thus, there were four combinations of testing: (a) immediate free recall–final free recall, (b) immediate free recall–final recognition, (c) immediate recognition–final free recall, and (d) immediate recognition–final recognition.

Examination of the serial position functions obtained in these four types of test (i.e., immediate and final recall and recognition) should reveal the processes responsible for serial position effects. If a serial position effect, either primacy or recency, results from a long-term retrieval process as Tzeng (1973) argued, then on both immediate and final tests that effect should be maximized in free recall and minimized in recognition because retrieval processes play a lesser role in recognition. If a serial position effect is due to a transient retrieval process as Bjork and Whitten (1974) argued, then the effect should be observed only in immediate free recall. If differential storage operates while a list is being studied in the continuous distractor paradigm, any resulting serial position effects should be observed on all tests, since a storage process will influence both recall and recognition performance. Finally, consider the possibility that a serial position effect could result from a storage process used during study for a particular type of test, recall or recognition (cf. Tversky, 1973). If a test-specific storage strategy were responsible for a serial position effect, then the effect should be observed in only that type of immediate test. Furthermore, the effect should be observed on both types of final test, but only for those subjects who studied for that type of immediate test.

Method

Subjects. The subjects were 60 students in introductory psychology at the University of Washington, who participated for extra course credit. For purposes of testing, subgroups of 1 to 4 subjects were assigned randomly to one of the four experimental conditions, with the constraint that 15 subjects were assigned to each condition.

Stimuli and apparatus. A pool of 150 words was selected from the Paivio, Yuille, and Madigan (1968) norms; all were common A and AA words from four to seven letters long. Choice of study word lists, recognition test lists, and distractor materials was under the control of a program implemented on a NOVA 820 computer. The program randomly selected six unique 10-word lists for each subject from the word pool. Distractor words for immediate and final recognition were randomly selected from the remaining 90 words. The recognition tests were YES–NO and used all list items plus an equal number of distractors, presented in random order.

Stimuli were presented to subjects in individual soundproof booths on Tektronix 602 display scopes under computer control. Recall tests were written; recognition test responses were collected by the computer.

Procedure. The four experimental conditions consisted of all factorial combinations of immediate and final test type (recall or recognition, in both instances). Of the six lists studied by each subject, three were tested immediately and three were not tested immediately. Tested lists were selected randomly with the requirement that not more than two consecutive lists could be tested or nontested.

Each of the 10 words in a list was presented for 1.5 sec. Before the first word and after every word in the list, a three-digit number was presented that stayed on the screen for 15 sec. The instructions were to memorize each word as it appeared and to count backward by threes as rapidly as possible from the number, beginning as soon as the number appeared. The subject was told that several lists would be presented in this way but that only certain randomly selected lists would be tested. No mention was made of the final test. Furthermore, no instructions regarding rehearsal were given, since Brodie and Prytulak (1975) have shown that these instructions are not as effective as had been previously assumed.

On nontested lists, subjects spent 1 min shadowing digits presented at the rate of two per second. To indicate nontested lists, the computer displayed the words *shadow digits.* Subjects in the two immediate-recall conditions were given free-recall instructions and were told that the word *recall* following a list was a signal that during the next minute they were to write down as many words as they could remember from the current list. Subjects in the two immediate recognition conditions were given YES–NO recognition in-

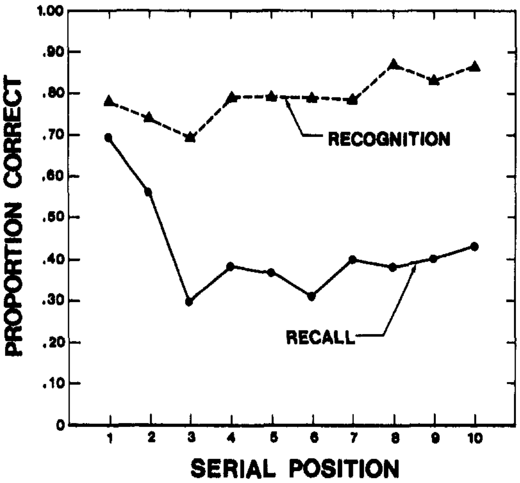

Figure 1. Proportion correct in immediate free recall and immediate recognition as a function of input serial position in Experiment 1.

structions and were told that the word *recognition* would signal a tested list. Subjects indicated their responses by key presses; a 3-sec limit was imposed on response time to permit the test to be completed in 1 min. No feedback was provided following tests, and the recall protocols were removed after each test.

A phony debriefing, lasting approximately 2 min, followed the last immediate test (or digit-shadowing) period. Following this, instructions were given for the final test, half of the subjects switching to the other type of test and half continuing with the same type of test. Final recognition tests were computer-paced at 5 sec/word; final recall tests were subject-paced.

Results and Discussion [1]

Immediate tests. Figure 1 presents the serial position curves for proportion correct in immediate recall and recognition, each curve based on the performance of 30 subjects. The results are straightforward: As expected, recognition performance was considerably superior to recall performance, as indicated by the highly significant main effect of test type, $F(1, 58) = 137.25$, $MS_e = 1.46$. Most important, there was also a highly significant effect of serial position, $F(9, 522) = 3.68$, $MS_e = .60$, and a significant Test Type × Serial Position interaction, $F(9, 522) = 3.09$. Together, the serial position effects reflected the different patterns of serial position in immediate recall and recognition. Immediate recognition performance increased slightly over serial position, while immediate free recall demonstrated a strong primacy effect and no recency effect.

The presence of primacy in free recall but not in recognition replicates Bjork and Whitten's (1974) findings and requires rejection of the hypothesis that primacy results from a differential storage process that necessarily occurs during study in the continuous distractor paradigm. However, these data are consistent with two of the hypotheses advanced earlier, that primacy results from some type of retrieval strategy (whether long-term or short-term) and that primacy results from a storage strategy used specifically during study for a free-recall test. Discrimination between these hypotheses must await examination of performance on the final tests.

The surprising aspect of the immediate test results is the complete absence of recency in immediate free recall. Perhaps recency depends on the development of a free-recall strategy, as Wing and Thomson (1965) found in the standard free-recall procedure. Two procedural differences between our paradigm and that of earlier investigators may have prevented that strategy from developing. First, the presence of the nontested lists may have been disruptive. Second, the omission of item-by-item rehearsal instructions may have been critical (cf. Brodie & Prytulak, 1975). We examine these possibilities in Experiment 2.

Final tests. Figure 2 presents the serial position curves for final recall and recognition as a function of the type of immediate test. The results for tested and nontested lists are presented in the upper and lower panels of Figure 2, respectively. A 2 × 2 × 2 × 10 analysis of variance was conducted on the number of correct responses in the final tests. The two between-subjects factors were type of immediate test and type of final

[1] All significant statistics are reported for at least $p < .05$; all nonsignificant statistics represent a $p > .10$.

test (recall or recognition, in both instances). The two within-subjects factors were serial position (10-word lists) and whether a given list was tested or nontested initially.

The main effects of immediate and final test type were both significant. Obviously, final recognition performance was far better than final recall performance, $F(1, 56) = 577.25$, $MS_e = 1.43$. Also, final performance was generally better following study for an immediate recall test rather than for an immediate recognition test, $F(1, 56) = 4.93$. However, most of the advantage of prior recall learning is in final recall, not in final recognition, as indicated by the significant interaction of immediate and final test type, $F(1, 56) = 6.54$.

Our greatest interest in final performance is in the effects of serial position. However, we first point out that, as expected from other studies of the effects of test trials on retention (Birnbaum & Eichner, 1971; Darley & Murdock, 1971; Hogan & Kintsch, 1971), previously tested items were better retained than previously nontested items, $F(1, 56) = 46.79$, $MS_e = .73$. This finding is qualified by two significant interactions, the Immediate Test Type × Tested–Nontested interaction, $F(1, 56) = 18.79$, and the Immediate Test Type × Final Test Type × Tested–Nontested interaction, $F(1, 56) = 14.90$. The interpretations of these interactions are necessarily post hoc and are not relevant to the issues considered in this article. The important finding is that all the interactions of the tested–nontested variable with serial position were nonsignificant (all $Fs \leq 1.24$), indicating that the immediate tests did not influence the shape of the serial position functions obtained in final tests.[2] Thus, results are reported below for both tested and nontested lists.

Finally, we turn to the effects of serial position. The main effect of serial position was highly significant, $F(9, 504) = 5.64$, $MS_e = .47$, as was the Immediate Test Type × Serial Position interaction, $F(9, 504) = 3.75$. The only serial position effects evident in Figure 2 are primacy effects oc-

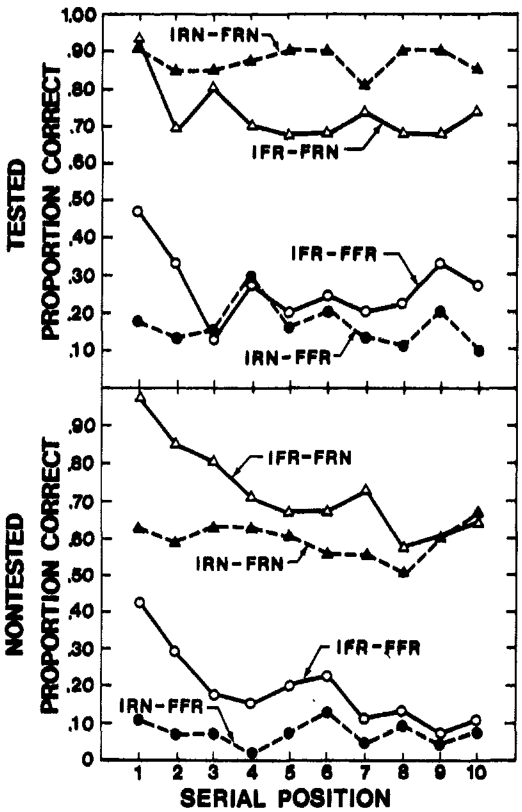

Figure 2. Proportion correct in final recognition (FRN) and final free recall (FFR) as a function of input serial position and type of immediate test, recognition (IRN) or recall (IFR) in Experiment 1. (The top panel represents tested lists; the bottom panel represents nontested lists.)

curring in every condition involving immediate free-recall tests. The absence of any other interactions with serial position (all $Fs \leq 1.24$) indicates that primacy did not depend on the type of final test nor on whether lists were originally tested. To the extent that recognition is a retrieval-minimizing process, a primacy effect in final recognition cannot reflect a retrieval process. Therefore, contrary to Bjork and Whitten (1974), primacy must reflect differential

[2] After immediate recall testing, both types of final test show a slight "negative recency" for nontested lists. Although nonsignificant, we thank one of our reviewers for noting this trend, which is consistent with findings in standard free recall (cf. Craik, 1970).

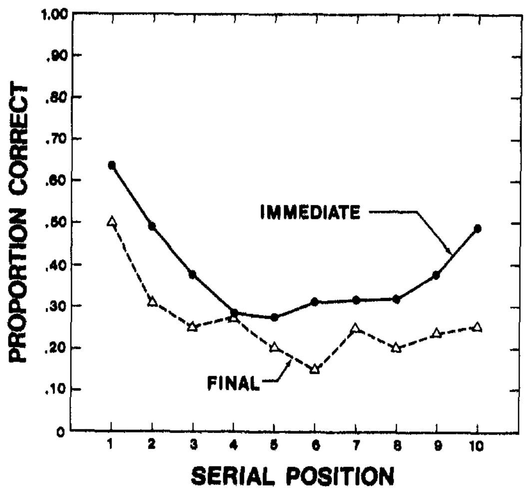

Figure 3. Proportion correct in immediate and final free recall as a function of serial position in Experiment 2.

storage resulting from a strategy used during study for free-recall tests (cf. Tversky, 1973). This result is consistent with the notion proposed by Loftus (1971) that storage differences account at least in part for differences in recall and recognition performance.

Experiment 2

The most surprising finding in Experiment 1 was the absence of recency, a result conflicting with those of Bjork and Whitten (1974) and Tzeng (1973). To examine this finding further, Experiment 2 was a replication of Tzeng's study, but without item-by-item rehearsal instructions. The purpose of Experiment 2 was to assure that recency is a replicable finding in the continuous distractor paradigm when all lists are tested.

Brodie and Prytulak (1975) have shown that the instruction to rehearse each item equally leads to increased recency in standard free recall. Perhaps, then, this instruction accounts for the recency observed by Tzeng (1973) and Bjork and Whitten (1974) in the continuous distractor paradigm. If so, recency should still be absent in Experiment 2, since no rehearsal instructions were given. On the other hand, if recency stems from a developing retrieval strategy that was impeded by nontested lists in Experiment 1, then recency should appear in Experiment 2 despite the absence of rehearsal instructions. Furthermore, a developing retrieval strategy should lead to an increase in recency over lists in immediate recall, as demonstrated in standard free recall by Wing and Thomson (1965).

Method

The subjects were 22 students from the same pool as in Experiment 1 who had not participated in that experiment. The apparatus and stimulus-word pool were unchanged from Experiment 1. The procedure was very similar to that of Experiment 1, with the following three changes: (a) Each subject studied only four 10-word lists, (b) every 10-word list was tested immediately, and (c) all tests, immediate and final, were free-recall tests. To maintain comparability with Experiment 1, the four immediate tests each lasted 1 min, while the final test was subject-paced.

Results and Discussion

The serial position curves for immediate and final recall are presented in Figure 3. A 2×10 analysis of variance was conducted that involved two within-subjects factors, time of test (immediate vs. final) and serial position (10 items). As expected, immediate recall was better than final recall, $F(1, 21) = 64.09$, $MS_e = .42$. More important, the main effect of serial position was highly significant, $F(9, 189) = 5.78$, $MS_e = 1.24$, as was the Time of Test $\times$ Serial Position interaction, $F(9, 189) = 2.68$, $MS_e = .27$.

The interpretation of these results is straightforward. The presence of strong primacy in both immediate and final recall replicates the findings of Experiment 1, as well as those of Tzeng (1973), and strengthens the argument that primacy is the result of a storage phenomenon. More important, the presence of recency in immediate free recall also replicates Tzeng, but stands in sharp contrast to the absence of recency in Experiment 1. Thus, the recency effect in immediate recall is replicable in the continuous distractor paradigm even without item-by-item rehearsal instructions.

However, one necessary condition for recency to appear is a relatively continuous sequence of immediate recall tests. Apparently, recency results from a strategy that develops after practice at recall, a notion to which we will return shortly.

Other aspects of the results presented in Figure 3 are quite different from those obtained by Tzeng. Compared with Tzeng's (1973) results for immediate recall, the present results demonstrate much less recency and more primacy. Our results in final recall are also quite different from Tzeng's; he found a positive recency effect, whereas Figure 3 reveals no recency in final recall. This lack of recency in final recall supports the argument that recency in immediate recall resulted from a transient retrieval process, at least in our experiment. On the other hand, Tzeng's finding of recency in final recall could have resulted from a differential storage process or perhaps from a long-term retrieval process, as he argued. However, we must point out that the meaning of the concept "long-term retrieval process" is badly in need of explication. Our experiment differs in procedure from Tzeng's experiment primarily in the absence of rehearsal instructions. Item-by-item rehearsal probably decreases the likelihood of implementing a short-term readout strategy, thereby improving storage of terminal list items. This interpretation is consonant with the results of Brodie and Prytulak (1975) for standard free recall. Furthermore, the fact that terminal items are recalled correctly in the immediate test more often than items at other positions provides an additional benefit in storage. This better storage should in turn result in the greater recency observed by Tzeng on final free-recall tests.

Comparison of immediate and final test performance suggests that a retrieval process is responsible for recency in immediate recall, whereas comparisons with Experiment 1 suggest that recency depends on free-recall experience. If recency results from a developing retrieval strategy, then recency should increase over lists. To evaluate this prediction, an analysis of variance was conducted on immediate-recall performance with list (1–4) as a factor. The main effect of list was nonsignificant ($F < 1$), but the effect of list on recency was confirmed by the significant List × Serial Position interaction, $F(27, 567) = 2.12$, $MS_e = .21$, and the significant serial position effect, $F(9, 189) = 5.74$, $MS_e = .21$. Inspection of individual list serial position functions indicates that recency increases steadily over lists, whereas primacy decreases only between Lists 1 and 2. This result supports the prediction regarding increasing recency over lists.

Goodwin (1976) has found very similar changes in primacy and recency over lists in standard free recall. He attributes the decrease in primacy to the buildup of proactive interference and the increase in recency to an early-output retrieval strategy that develops over lists. Thus, Goodwin maintains that the gains in recency and losses in primacy represent coincident independent processes rather than aspects of a single process. Unfortunately, considerable variance in output order in the present experiment prevented observation of any consistent relationship between recency and output order, but in other respects Goodwin's interpretation is consistent with our findings. The relationship between output order and increasing recency is considered further in Experiment 3.

Experiment 3

Both Experiments 1 and 2 used a subject-paced backward-counting task as the continuous distractor activity during list acquisition, as Tzeng (1973) had done previously. Such tasks permit the subjects to allocate processing effort (cf. Kahneman, 1973) differentially to the list-learning and distractor tasks at their discretion. Conceivably, then, the serial position effects observed in the continuous distractor paradigm could result from less attention begin given to the distractor task and more to the items themselves at the beginning and end of a list.

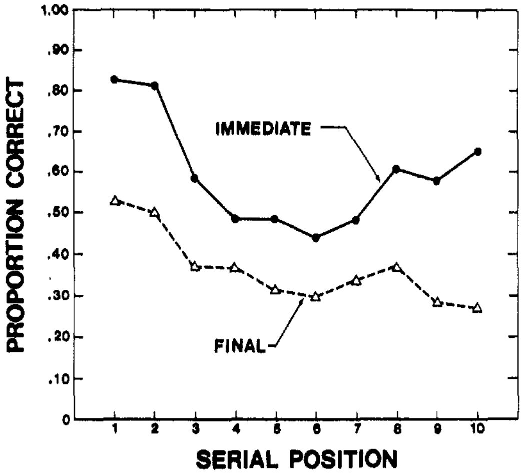

Figure 4. Proportion correct in immediate and final free recall as a function of serial position in Experiment 3.

An informative procedural change would be the substitution of an experimenter-paced distractor task for the subject-paced task.[8] Here, the processing demands of the distractor task would be constant across serial positions. Any serial position effects obtained could not subsequently be ascribed to shifting resource-allocation strategies within the distractor segments (e.g., Norman & Bobrow, 1975), but must be due to ongoing list-learning strategies. Consequently, Experiment 3 used a rapid, experimenter-paced distractor task (digit shadowing at the rate of 3/sec) in 15-sec segments to examine the possibility that previous attempts at continuous distraction may not have been entirely successful in eliminating procedural artifacts.

Method

The subjects were 22 students from the same pool as Experiments 1 and 2 who had not participated in the earlier experiments. The apparatus and stimulus-word pool were identical to those in Experiments 1 and 2. Additionally, the procedures of Experiments 2 and 3 were very similar, with only the following two changes: (a) Each subject studied six 10-word lists (as in Experiment 1), and (b) a number-shadowing task replaced the backward-counting task. In the number-shadowing task, subjects were required to repeat aloud single digits as they appeared; three randomly selected digits were presented each second.

Results and Discussion

The serial position functions for immediate and final recall in Experiment 3 are presented in Figure 4. A 2 × 10 analysis of variance was conducted with time of test (immediate vs. final) and serial position (10-item lists) as within-subjects factors. The analysis revealed the same pattern of results as obtained in Experiment 2. Again, immediate recall was better than final recall, $F(1, 21) = 102.76$, $MS_e = 2.11$. Of more importance, the main effect of serial position was highly significant, $F(9, 189) = 8.85$, $MS_e = 1.89$, as was the Time of Test × Serial Position interaction, $F(9, 189) = 4.32$, $MS_e = .62$.

The serial position curves for Experiment 3 (Figure 4) are very similar to those for Experiment 2 (Figure 3), although performance is somewhat better overall in Experiment 3. Because the same pattern of results emerges in both experiments, it is clear that serial position effects in the continuous distractor paradigm are not artifacts of a changing allocation strategy. Processing effort across serial position on the distractor task is roughly constant when the task is experimenter-paced, yet the same serial position pattern emerges for the list items as when distraction is subject-paced. Specifically, primacy appears in both immediate and final recall, with recency only in immediate recall. Again, the evidence is in accord with the hypothesis advanced earlier that primacy is a storage phenomenon and recency is a retrieval phenomenon.

In Experiment 2, examination of changes in serial position over lists indicated that primacy decreased and recency increased. Although the same pattern of changes in serial position occurred in Experiment 3, an analysis of variance indicated that the List × Serial Position interaction was non-

[8] Bjork and Whitten (1974) did use an experimenter-paced distractor task, consisting of simple arithmetic problems presented at a 2-sec rate. However, other procedural differences (e.g., their use of word doubles) complicate comparisons between studies.

significant, $F(45, 945) = 1.22$, $MS_e = .21$. The better overall performance in Experiment 3 than in Experiment 2 permits evaluation of the early-output account of developing recency. Analyses of output order indicate that terminal list items were indeed recalled progressively earlier over lists in Experiment 3. The average output percentiles (see Bjork & Whitten, 1974) of the last 3 items in Lists 1 through 6, respectively, were 79, 71, 60, 60, 61, and 57. Taken together, then, the results of Experiments 2 and 3 provide evidence that recency in the continuous distractor paradigm involves a retrieval strategy of the sort proposed by Goodwin (1976) in his study of standard free recall.

General Discussion

The three experiments reported in this article replicate and extend the finding of serial position effects in the continuous distractor paradigm (Bjork & Whitten, 1974; Tzeng, 1973). As mentioned earlier, the goal of this paradigm was to eliminate the sources of serial position effects in standard free recall (Whitten & Bjork, Note 1). However, despite the marked procedural differences in the two paradigms, the pattern of results is virtually identical. Two conclusions are possible, given this outcome. First, assuming the distraction procedure was successful, multistore models cannot account for the unanticipated serial position effects. In accord with this conclusion, Tzeng (1973) and Bjork and Whitten (1974) proposed that their observed primacy and recency were the result of unspecified long-term retrieval processes. The second conclusion provides a more parsimonious interpretation. Assuming that the distraction procedure (including the rehearsal instructions) was not successful, multistore models account for the serial position effects in both paradigms without modification. Unfortunately, the critical assumption that the procedure failed is not directly testable within the continuous distractor paradigm. We therefore examine the evidence from other studies of distraction activity and rehearsal instructions.

There are several reasons why, a priori, the continuous distractor paradigm might be expected to fail. First, consider the separate effects of rehearsal instructions and of distraction on storage processes in long-term store. Fischler, Rundus, and Atkinson (1970) have shown that primacy in standard recall is reduced but not eliminated when subjects are told to rehearse only the current item. In replicating this finding, Brodie and Prytulak (1975) observed that subjects covertly use a differential rehearsal strategy even while overtly rehearsing only the current item. Thus, item-by-item rehearsal instructions do not eliminate primacy resulting from differential storage. Furthermore, the effectiveness of distraction in preventing rehearsal is questionable; Reitman (1974) has shown that subjects do rehearse during distraction, despite instructions to avoid rehearsal. Taken together, these studies suggest that a differential storage strategy could be adopted in the continuous distractor paradigm despite the ongoing distraction.

Now consider the effects of rehearsal instructions and distraction on retrieval of recency items from short-term store. Certainly, longer periods of distraction result in reduced recall from short-term store (Peterson & Peterson, 1959). Furthermore, a single terminal distractor period eliminates recency completely in standard free recall (Glanzer & Cunitz, 1966; Postman & Phillips, 1965). But Murdock (1961) and Melton (1963) demonstrated that forgetting from short-term store under distraction conditions decreases as the number of items in that store decreases. Thus, in the continuous distractor paradigm, retrieval from short-term store may not be prevented if few items are held there. In fact, instructions to rehearse only the current item should encourage such a strategy.

These considerations suggest that the distraction procedure was not successful, and multistore models *can* account for serial position effects in the continuous distraction paradigm. Furthermore, several aspects of the results of Experiments 1–3 suggest that the same processes are responsible for serial position effects in the continuous distractor paradigm as in standard free recall. Experiment 1 demonstrated that primacy results from a storage strategy operating during study for a free-recall test. The absence of recency in Experiment 1 and in the final recall of Experiments 2 and 3 suggests that recency results from a short-term retrieval process. Recency tended to increase over lists in both Experiments 2 and 3, and in Experiment 3 the increase in recency was accompanied by earlier output of the terminal list items, supporting the hypothesis that a developing retrieval strategy is responsible for recency. Similarly, in standard free recall, recency is found in immediate recall but not in final recall (Craik, 1970), recency increases over lists (Wing & Thomson, 1965), and recency appears to result from earlier output of the last items in the list (Goodwin, 1976).

The only difference in form between the serial position functions obtained in standard free recall and in Experiments 2 and 3 is in the magnitude of the *recency* effect. In comparison to Murdock's (1962) results using the same list length in standard free recall, the recency effect in the continuous distractor paradigm extends over fewer items and is considerably attenuated. This finding is consistent with the notion suggested earlier that distraction activity reduces the number of items held in short-term store. In addition, the slight negative recency in the final recall of Experiments 1 and 3 is also consistent with the account of recency in terms of readout from short-term store (cf. Craik, 1970).

In several respects, the present results are different from those of previous investigators. In the introduction, we noted Tzeng's (1973) suggestion that excessive output interference could account for the discrepancy between his results and the results of Bjork and Whitten (1974), so we will not consider the latter further. The important point is that multistore models do provide a reasonable explanation of differences between the results obtained in our Experiments 2 and 3 and those of Tzeng (1973). Tzeng (like Bjork and Whitten) instructed subjects to rehearse only the current list item, whereas the present study omitted rehearsal instructions. Although the precise effect of rehearsal instructions is somewhat unclear, early list items should be rehearsed less often, reducing the primacy effect, and terminal list items should be rehearsed more often, increasing the probability that these items will enter long-term store. Consistent with these hypotheses, Tzeng found a much larger recency effect and a smaller primacy effect than we obtained in Experiments 2 and 3. The results of Brodie and Prytulak (1975) suggest that instructions to rehearse each item equally have the same effect in standard free recall; recency is increased and primacy is decreased. Furthermore, Tzeng found positive recency in final recall as well as in immediate recall, suggesting that rehearsal instructions affect storage strategies, increasing storage of terminal list items. While we know of no studies that have addressed this issue, we predict that similar rehearsal instructions would lead to positive recency in final recall in the standard free-recall paradigm.

The initial intention of the present research was to examine the processes underlying serial position effects in the continuous distractor paradigm. At the outset, it appeared that the familiar multistore explanation used in standard free recall could not be invoked due to the major procedural differences. It now appears, however, that the addition of rehearsal instructions and continuous distraction was not very effective. Rather, these changes simply altered the magnitude of serial position effects in a way consistent with the multistore account. That the storage and retrieval strategies underlying primacy and recency persisted indicates that these strategies are quite robust. In so demonstrating, the continuous distractor paradigm has served a useful purpose. However, the paradigm has failed in its original aim (cf. Bjork & Whitten, 1974) of eliminating unwanted serial position effects. In addition, we have shown that the observed serial position effects do not conflict with the multistore explanation. Therefore we suggest that future research examine the active roles of rehearsal and short-term memory processes in the continuous distractor paradigm and not assume that the paradigm eliminates these processes.

Reference Note

1. Whitten, W. B., & Bjork, R. A. *Test events as learning trials: The importance of being imperfect.* Paper presented at the Midwestern Mathematical Psychology Meetings, Bloomington, Indiana, April 1972.

References

Anderson, J. R., & Bower, G. H. Recognition and retrieval processes in free recall. *Psychological Review,* 1972, *79,* 97–123.

Atkinson, R. C., & Shiffrin, R. M. Human memory: A proposed system and its control processes. In K. W. Spence & J. T. Spence (Eds.), *The psychology of learning and motivation: Advances in research and theory* (Vol. 2). New York: Academic Press, 1968.

Birnbaum, I. M., & Eichner, J. T. Study versus test trials and long-term retention in free-recall learning. *Journal of Verbal Learning and Verbal Behavior,* 1971, *10,* 516–521.

Bjork, R. A., & Whitten, W. B. Recency-sensitive retrieval processes in long-term free recall. *Cognitive Psychology,* 1974, *6,* 173–189.

Brodie, D. A., & Prytulak, L. S. Free recall curves: Nothing but rehearsing some items more or recalling them sooner? *Journal of Verbal Learning and Verbal Behavior,* 1975, *14,* 549–563.

Craik, F. I. M. The fate of primary memory items in free recall. *Journal of Verbal Learning and Verbal Behavior,* 1970, *9,* 143–148.

Dark, V. J., & Loftus, G. R. The role of rehearsal in long-term memory performance. *Journal of Verbal Learning and Verbal Behavior,* 1976, *15,* 479–490.

Darley, C. F., & Murdock, B. B., Jr. Effects of prior free recall testing on final recall and recognition. *Journal of Experimental Psychology,* 1971, *91,* 66–73.

Fischler, I., Rundus, D., & Atkinson, R. C. Effects of overt rehearsal procedures on free recall. *Psychonomic Science,* 1970, *19,* 249–250.

Glanzer, M., & Cunitz, A. R. Two storage mechanisms in free recall. *Journal of Verbal Learning and Verbal Behavior,* 1966, *5,* 351–360.

Goodwin, C. J. Changes in primacy and recency with practice in single-trial free recall. *Journal of Verbal Learning and Verbal Behavior,* 1976, *15,* 119–132.

Hogan, R. M., & Kintsch, W. Differential effects of study and test trials on long-term recognition and recall. *Journal of Verbal Learning and Verbal Behavior,* 1971, *10,* 562–567.

Kahneman, D. *Attention and effort.* Englewood Cliffs, N. J.: Prentice-Hall, 1973.

Kintsch, W. Recognition and free recall of organized lists. *Journal of Experimental Psychology,* 1968, *78,* 481–487.

Loftus, G. R. Comparisons of recognition and recall in a continuous memory task. *Journal of Experimental Psychology,* 1971, *91,* 220–226.

Melton, A. W. Implications of short-term memory for a general theory of memory. *Journal of Verbal Learning and Verbal Behavior,* 1963, *2,* 1–21.

Modigliani, V. Effects on a later recall by delaying initial recall. *Journal of Experimental Psychology: Human Learning and Memory,* 1976, *2,* 609–622.

Murdock, B. B., Jr. The retention of individual items. *Journal of Experimental Psychology,* 1961, *62,* 618–625.

Murdock, B. B., Jr. The serial position effect in free recall. *Journal of Experimental Psychology,* 1962, *64,* 482–488.

Murdock, B. B., Jr. Modality effects in short-term memory: Storage or retrieval? *Journal of Experimental Psychology,* 1968, *77,* 79–86.

Norman, D. A., & Bobrow, D. G. On data-limited and resource-limited processes. *Cognitive Psychology,* 1975, *7,* 44–64.

Paivio, A., Yuille, J. C., & Madigan, S. A. Concreteness, imagery, and meaningfulness values of 925 nouns. *Journal of Experimental Psychology Monograph,* 1968, *76*(1, Pt. 2).

Peterson, L. R., & Peterson, M. J. Short-term retention of individual items. *Journal of Experimental Psychology,* 1959, *58,* 193–198.

Postman, L., & Phillips, L. W. Short-term temporal changes in free recall. *Quarterly Journal of Experimental Psychology,* 1965, *17,* 132–138.

Reitman, J. S. Without surreptitious rehearsal, information in short-term memory decays. *Journal of Verbal Learning and Verbal Behavior,* 1974, *13,* 365–377.

Rundus, D. Analysis of rehearsal processes in free recall. *Journal of Experimental Psychology,* 1971, *89,* 63–77.

Tversky, B. Encoding processes in recognition and recall. *Cognitive Psychology,* 1973, *5,* 275–287.

Tzeng, O. J. L. Positive recency effect in a delayed free recall. *Journal of Verbal Learning and Verbal Behavior,* 1973, *12,* 436–439.

Waugh, N. C., & Norman, D. A. Primary memory. *Psychological Review,* 1965, *72,* 89–104.

Wing, J. F., & Thomson, B. P. Primacy-recency effects in free recall. *Proceedings of the 73rd annual convention of the American Psychological Association.* Washington, D.C.: American Psychological Association, 1965.

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