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Serial Position Effects in Implicit and Explicit Tests of Memory

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The effects of serial position at study on implicit and explicit tests of memory were investigated. Both primacy and recency effects were observed in implicit tests of word-stem completion. These effects, however, were transient. No serial position effects were found in the second half of testing (Experiments 1 and 3) or when testing followed a 1-min, filled delay (Experiment 2). Serial position effects were also examined in explicit tests of cued recall. When performance on explicit cued recall was below ceiling levels, a primacy effect persisted throughout testing (Experiment 3). Similarly, in explicit tests of free recall, primacy effects were consistently observed, both with immediate testing (Experiments 1 and 3) and when testing followed a filled delay (Experiment 2).

Over the past decade, numerous studies have examined the distinction between explicit and implicit tests of memory (for reviews, see Graf & Masson, 1993; Lewandosky, Dunn, & Kirsner, 1989; Schacter, 1987). In explicit tests of memory—such as free recall, cued recall, and recognition memory—subjects are instructed to try to recollect a prior episode. In contrast, implicit tests make no reference to any prior episode, and memory is inferred from changes from baseline performance. Neuropsychological studies have shown that patients with organic amnesia exhibit impairment on explicit tests of memory, yet they perform as well as control subjects on many implicit tests of memory (for reviews see Schacter, 1987; Shimamura, 1986, 1993; Squire, 1987). Furthermore, cognitive studies have demonstrated functional dissociations between implicit and explicit tests of memory (for reviews, see Johnson & Hasher, 1987; Richardson-Klavehn & Bjork, 1988; Roediger & McDermott, 1993). That is, some variables, such as level of processing at study, typically affect performance on explicit tests of memory but have little or no effect on implicit tests (Graf & Schacter, 1989; Jacoby, 1983; Jacoby & Dallas, 1981). Other variables, such as changes in presentation modality between study and test, affect performance on implicit tests but not on explicit tests (Jacoby & Dallas, 1981; Roediger & Blaxton, 1987; Schacter & Graf, 1989).

Despite the proliferation of dissociations and associations in performance on implicit and explicit tests of memory, the variable of serial position at study has been almost entirely ignored. Serial position has a strong influence on explicit tests of memory such as free recall. With immediate testing, words presented at the beginning of a list (primacy items) and words presented at the end of a list (recency items) are recalled better than words presented in the middle of the list (see Atkinson & Shiffrin, 1968, 1971; Bousfield, Whitmarsh, & Esterson, 1958; Glanzer & Cunitz, 1966; Murdock, 1962). Such effects have also been observed on tests of cued recall and recognition memory (Tulving & Arbuckle, 1963; Wright, Santiago, Sands, Kendrick, & Cook, 1985).

Whereas there once was a great deal of study of serial position effects in the traditional memory literature, there are only three studies that provide findings concerning primacy and recency effects in implicit tests of memory (McKenzie & Humphreys, 1991; Rybash & Osborne, 1991; Sloman, Hayman, Ohta, Law, & Tulving, 1988). All three studies suggest that recency effects occur in implicit tests. In the study by McKenzie and Humphreys (1991), word stems that could be completed with either of two study words were more often completed with the word that had been presented more recently. In the study by Rybash and Osborne (1991), word-stem completion priming was greater for recency items than for words presented earlier in the study list. In those studies, however, the role of test position was not investigated. In the study by Sloman et al. (1988), word-fragment completion priming dropped rapidly over the first few minutes after study, with greater priming for the last items in the study list. This finding was limited in that test order was always a mirror image of study order; that is, recency items were tested first, and primacy items were tested last. Additionally, a primacy effect was observed by Sloman et al. (1988), but it was limited to a greater level of fragment completion for only the very first item presented at study.

In this study, we explored serial position effects in an implicit test of word-stem completion (see Graf, Squire, & Mandler, 1984). At study, subjects were shown a list of words in an incidental learning task. At test, subjects were given word stems and asked to complete each stem with the first word to come to mind. Serial position effects were also investigated in an explicit test of cued recall. The only difference between the explicit cued-recall test and the implicit stem completion test was the explicit memory instructions given at test. In the cued-recall test, subjects were told to use the word stems as retrieval aids for the studied words. In most previous studies of word-stem completion, serial position effects could not be analyzed because filler words (i.e., untested items) were inserted at the beginning and end of the study list to prevent

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possible influences of serial position. Thus, most previous reports of performance on tests of word-stem completion are based on performance for only the middle items of a study list.

The experimental design for this study was modeled after one used in a study by Tulving and Arbuckle (1963) in which serial position effects were assessed following paired-associate learning. In that study, each subject studied and was tested on 10 lists of digit–word pairs, and across the 10 test sequences, items from each study position were tested at all possible test positions. In this study, we adopted a similar design by distributing test cues (word stems) for primacy, middle, and recency study list items evenly throughout the test sequence. Across subjects, items from all positions in the study list were tested at all positions in the testing sequence. To account for changes in serial position effects over the course of testing, analyses were performed separately for items tested during the first half of testing and for items tested during the second half of testing.

In addition to the implicit stem completion and explicit cued-recall test conditions, a free-recall condition was included in this study. This condition was used to establish the nature of the serial position effects following the incidental study procedures used in these experiments. Past studies of serial position effects on explicit free-recall tests following incidental learning have revealed serial position effects somewhat different from those that are found following intentional learning. In particular, in a number of studies, the primacy effect was found to be reduced (Darley & Glass, 1975; Postman & Adams, 1957, 1960) or eliminated (Marshall & Werder, 1972; Postman & Phillips, 1965b; Rundus, 1980) by incidental learning. However, in those experiments, the incidental learning procedures promoted only shallow processing of list items. The present experiments used an orienting task that required processing the meanings of the list words.

In three experiments, we examined serial position effects in tests of implicit stem completion, explicit cued recall, and free recall. Across experiments, the delay between study and test, list length, and speed of presentation of list items was varied. The experiments provide a descriptive analysis, aimed at achieving two basic goals. The first goal was to characterize the effects of serial position at study on an implicit test of memory and to examine how those effects change over the course of testing. The second goal was to compare serial position effects in implicit and explicit tests of memory that differed only in the instructions given to subjects.

Experiment 1

Method

Subjects. Ninety-five subjects participated in the experiment. The subjects were students (undergraduate and graduate) and other volunteers recruited at the University of California at Berkeley. Subjects were paid or received course credit for participation. Fourteen subjects were assigned to the free-recall condition, 42 subjects were assigned to the implicit word-stem completion condition, and 39 subjects were assigned to the explicit cued-recall condition. All subjects were native speakers of English with no reading disabilities.

Materials and design. The word stimuli used in the study were 24 common nouns with a mean word frequency of 67 per million (range: 26–183 per million; Kucera & Francis, 1967). The words were divided into two 12-item lists matched for word frequency. Each list consisted of eight words representing nonliving things (e.g., "tractor") and four words representing living things (e.g., "lion") or parts of living things (e.g., "stomach").

For the implicit stem completion and explicit cued-recall tests, stems consisted of the first two (e.g., "li") or three (e.g., "tra," "sto") letters of each word stimulus. All of the word stems could be completed with at least 10 different English words and with only 1 of the 24 word stimuli. Each subject in the stem completion and cued-recall conditions studied only one of the lists of 12 words and completed all 24 word stems. Thus, for a given subject, half of the word stems were from studied words, and the other half were new. Studied and new stems were intermixed randomly, and completions of the new stems were used to determine baseline guessing rate, defined as the frequency with which subjects completed new stems with any of the 12 nonstudied words.

Procedure. A Macintosh SE computer was used to present stimuli and control timing. Words were presented to subjects in an incidental learning task in which they were asked to read each word aloud and then to respond yes if the word represented a living thing or part of a living thing or no if the word represented a nonliving thing. One word was presented as a practice item, and subjects were corrected if they did not follow the instructions. Following the practice item, 12 study items appeared on the computer monitor sequentially at a rate of 2 s per word. The experimenter recorded the subject's responses. Each of the two lists of study items was arranged in two different orders to control for item effects. Thus, across subjects, words appeared in different serial positions. Each subject studied one of the resulting four lists, and equal numbers of subjects were assigned to each list.

Immediately following the incidental learning task, subjects were tested in one of three conditions: free recall, implicit word-stem completion, or explicit cued recall. For the free-recall test, subjects were asked to report verbally as many of the words they had just seen as they could. Thirty seconds were allowed for recall, and responses were recorded by the experimenter. To analyze free recall as a function of serial position in the study list, we averaged recall performance across sequential pairs of study items (i.e., Items 1 and 2, 3 and 4, and so forth).

For the implicit stem completion and explicit cued-recall conditions, the test procedures were identical except for the instructions. In the implicit test condition, subjects were told that they would now perform a different task. They were asked to say the first word that came to mind for each stem presented. In the explicit cued-recall condition, subjects were instructed to try to recall the words they had just been shown and, to the extent possible, to use those words to complete the word stems. They were told to guess if they could not recall a studied word to complete a stem. Thus, the explicit cued-recall condition is comparable to what has been called an "inclusion" condition by others (e.g., Jacoby, 1991; Jacoby & Kelley, 1991). In both the implicit and explicit test conditions, the 24 word stems (12 studied and 12 new) were presented for 5 s each, and the responses were recorded by the experimenter.

The 24 word stems were arranged into six different sequences, with studied and new items intermixed. Each of these 6 test orders was paired with 2 of the 4 study orders, resulting in 12 study–test order combinations. Equal numbers of subjects were assigned to each combination. For analysis of serial position effects, study lists were divided into thirds (four primacy, four middle, and four recency items). Serial position effects on performance were analyzed separately for the first half and second half of the sequence of test stems. In each half of testing, subjects completed 12 stems, 6 studied and 6 new. Primacy, middle, and recency items were tested in both halves and spread randomly through each test half. Half of the study items from the primacy, middle, and recency positions were tested in each test half.

The counterbalancing method permitted items from each study position to be tested at each test position.

After the implicit word-stem completion test, subjects were asked whether they had noticed that some of the word stems could have been completed with words seen in the first task and, if so, whether they had either tried to recall those words or tried not to use those words. Subjects who indicated that they had not reported the first word to come to mind were eliminated from the experiment. The data from 6 of the 42 subjects tested in the implicit test condition were eliminated from analysis because those subjects indicated that they had tried to avoid using items seen in the learning task to complete word stems. The data from 3 of the 39 subjects tested in the explicit test condition were eliminated because, during or at the end of testing, those subjects indicated that they had not understood that they were to try to recall and use the studied words to complete the stems. Thus, the data from 36 subjects were analyzed for the implicit stem completion condition and for the explicit cued-recall condition.

Results and Discussion

Figure 1 displays free-recall performance following incidental learning as a function of serial position at study. The U-shaped curve represents both primacy and recency effects. A single-factor analysis of variance (ANOVA) confirmed a main effect of serial position, $F(5, 65) = 6.85, p < .01, MS_e = 1091.58$. Planned pairwise comparisons revealed that recall of the first item pair and the last two item pairs was greater than recall of each of the item pairs in between ($p < .05$). Thus, both primacy and recency effects were observed in a free-recall test following incidental learning with a semantic orienting task.

Performance in the implicit stem completion condition is shown in the upper panel of Figure 2. In comparison with a baseline guessing rate of 5.33% ($SE_M = 1.25$), significant priming was observed at all study positions. As illustrated in Figure 2, implicit testing produced primacy and recency effects

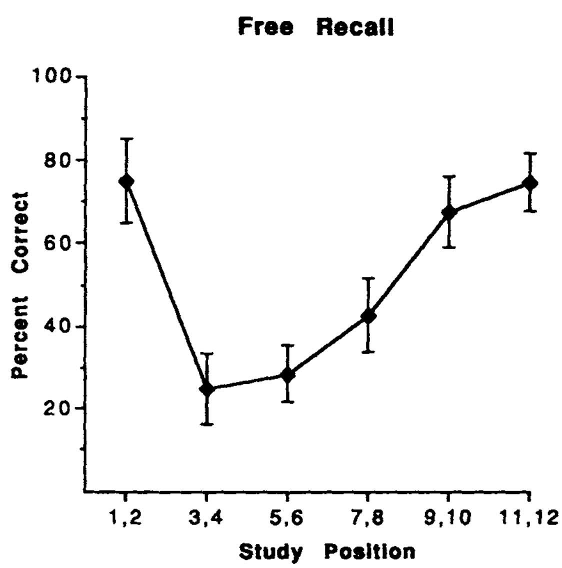

Figure 1. Experiment 1: Free recall of a 12-item list of words as a function of study position. Testing immediately followed incidental learning. Error bars indicate standard error of the mean.

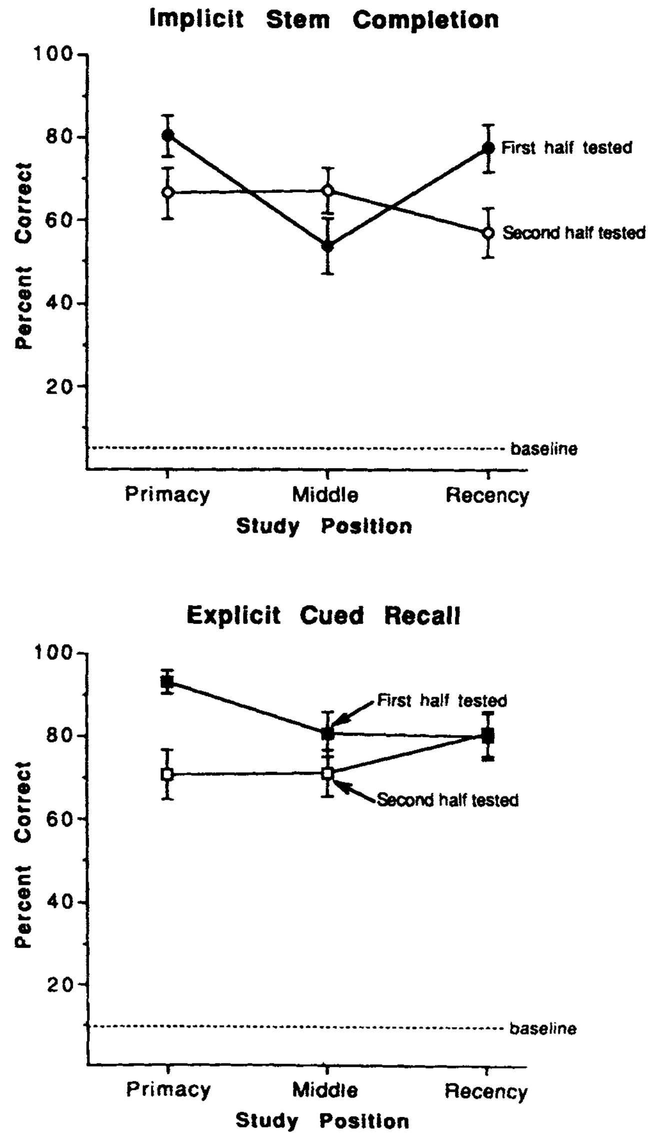

Figure 2. Experiment 1: Implicit stem completion and explicit cued-recall performance for a 12-item list of words as a function of study position and test half. Testing immediately followed incidental learning. Error bars indicate standard error of the mean.

for stems tested during the first half of testing, but those effects were eliminated in the second half of testing. A two-factor ANOVA, with three levels of study position (primacy, middle, and recency) and two levels of test position (first half and second half), confirmed these observations, revealing a significant Study Position × Test Position interaction, $F(2, 70) = 3.92, p < .05, MS_e = 1471.25$. There were two sources of this interaction. First, an analysis of simple effects showed an effect of test half only for the recency items, $F(1, 35) = 4.98, p < .05, MS_e = 1489.57$, indicating significant forgetting of recency items over the course of testing. Second, there was an effect of study position only for the first half of testing, $F(2, 70) = 5.41, p < .01, MS_e = 1399.20$. Specifically, pairwise comparisons showed that in the first half of testing, there was greater priming of both primacy and recency items in comparison with middle items ($p < .05$), whereas no such differences were found across study positions for the second half of testing. In summary, in this implicit test of memory, there were primacy and recency effects early in testing, and those effects disappeared over the course of testing.

Performance in the explicit cued-recall condition is shown in the lower panel of Figure 2. Figure 2 includes baseline guessing rate, because subjects in this condition were asked to complete all stems, even when they could not recall a studied word. Performance in this condition, especially in the first half of testing, was close to ceiling levels. In the first half of testing, 31 of the 36 subjects recalled 100% of the primacy items, 25 subjects recalled 100% of the middle items, and 25 subjects recalled 100% of the recency items. Thus, the extent to which conclusions can be drawn from these data is limited. Indeed, it should be noted that the patterns of serial position effects in the explicit cued-recall condition did not conform to expectations based on past research (e.g., Tulving & Arbuckle, 1963), which showed long-lasting primacy effects and transient recency effects. A two-factor ANOVA of these cued-recall data, with three study positions and two test positions, revealed only a main effect of test position, $F(1, 35) = 6.89, p < .05, MS_e = 832.19$. Recall performance was better for words tested in the first half of testing than for words tested in the second half, but there was no main effect of study position, $F(2, 70) = 0.77, p = .47$, $MS_e = 899.69$. There was, however, a trend toward an interaction of the two factors, $F(2, 70) = 2.50, p < .09, MS_e = 936.49$. Analysis of simple effects revealed that the effect of test half was significant only for primacy items, $F(1, 35) = 13.18, p < .01, MS_e = 674.60$, with no drop in recall of middle or recency items over the course of testing.

In summary, Experiment 1 revealed both primacy and recency effects in an implicit test of memory, but only for items tested in the first half of testing. Primacy and recency effects were also observed in a test of free recall following incidental learning. Ceiling effects in the explicit cued-recall test prevented adequate analysis of serial position effects in that condition.

Experiment 2

In Experiment 2, a 1-min, filled delay was interpolated between study and testing to allow further exploration of the changes in performance on the implicit and explicit tests over the course of the first few minutes after study. In addition, it was hoped that this manipulation would reduce performance in the explicit cued-recall condition. Subjects completed filler word stems during the delay and then were tested in one of the three test conditions used in Experiment 1: free recall, implicit word-stem completion, or explicit cued-recall.

Method

Subjects. Ninety-three subjects were paid for participating in the experiment. The subjects were students and other volunteers recruited at the University of California at Berkeley. Sixteen subjects were assigned to the free-recall condition, 41 subjects were assigned to the implicit word-stem completion condition, and 36 subjects were assigned to the explicit cued-recall condition. All of the subjects were native speakers of English with no reading disabilities. None of the subjects had participated in Experiment 1.

Materials and design. The words and word stems used in Experiment 2 were the same as those used in Experiment 1. In addition, 12 additional word stems were used as filler items during the delay between incidental learning and memory testing. These filler stems could not be completed with any of the 24 word stimuli from the study lists, and each could be completed with at least 10 different English words. Equal numbers of subjects in both the implicit stem completion and explicit cued-recall conditions were assigned to each of the 12 study–test combinations used in Experiment 1, and equal numbers of subjects in the free-recall condition were assigned to each of the four study lists.

Procedure. The procedure for Experiment 2 was the same as for Experiment 1, except that after the incidental learning task, all subjects were given instructions for word-stem completion, and they then completed the 12 filler stems. The stems were presented for 5 s each, and the experimenter recorded the subjects' responses. Immediately following completion of the 12 filler stems, each subject was tested in one of the three test conditions: free recall, implicit word-stem completion, or explicit cued recall.

As in Experiment 1, at the end of testing in the implicit word-stem completion condition, subjects were asked whether they had noticed that some of the word stems could have been completed with words seen in the first task and, if so, whether they had either tried to recall and use those words or tried not to use those words. Subjects who indicated that they had not reported the first word to come to mind were eliminated from the experiment. The implicit stem completion data from 5 of the 41 subjects tested were eliminated because 2 of the subjects indicated that they had tried to avoid using items seen in the learning task to complete word stems, 1 said she had tried to recall studied items during word-stem completion, 1 skipped an item in the incidental learning task, and 1 subject's responses in the incidental learning task suggested that he had misunderstood the instructions.

Results and Discussion

Figure 3 displays free-recall performance following the filled delay as a function of serial position at study. A single-factor

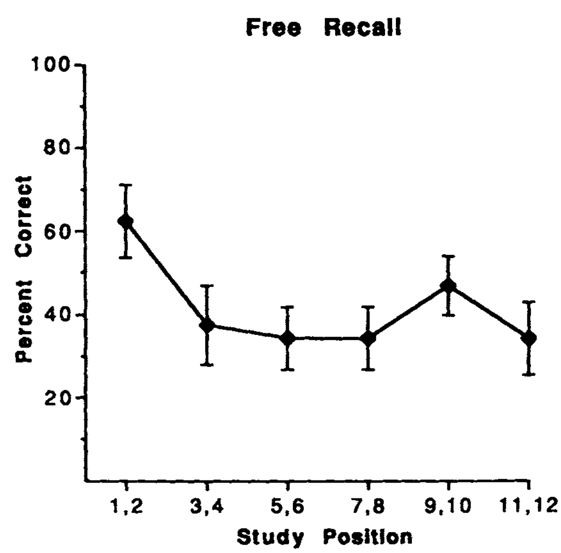

Figure 3. Experiment 2: Free recall of a 12-item list of words as a function of study position. Testing followed a 1-min, filled delay. Error bars indicate standard error of the mean.

ANOVA revealed no main effect of study position, $F(5, 75) = 1.81, p = .12, MS_e = 1130.56$. Pairwise comparisons, however, showed that recall of the first item pair was greater than recall of all other item pairs except for Items 9 and 10 ($p < .05$). Thus, in free recall following incidental learning with a semantic orienting task, the primacy effect remained after a filled delay, whereas the recency effect was eliminated. These findings conform to expectations based on previous studies of the effects of a filled delay on serial position effects following intentional learning (Atkinson & Shiffrin, 1971; Glanzer & Cunitz, 1966).

Performance in the implicit word-stem completion condition following the filled delay is shown in the upper panel of Figure 4. In comparison with a baseline guessing rate of 5.33% ($SE_M = 1.38$), significant priming was observed for all study and test positions. A two-factor ANOVA, with three levels of study position and two levels of test position, revealed a significant main effect of test position, $F(1, 35) = 16.66, p < .01, MS_e = 1056.55$. That is, priming in the second half of testing was reduced in comparison with the first half of testing at all study positions. Neither the main effect of study position, $F(2, 70) = 1.41, p = .25, MS_e = 1407.74$, nor the interaction of study position and test position, $F(2, 70) = 0.27, p = .77, MS_e = 909.72$, was significant, and pairwise comparisons showed no serial position effects for either test half.

Performance in the explicit cued-recall condition following the filled delay is shown in the lower panel of Figure 4. Note that despite the interpolation of a filled delay between study and test, cued-recall performance in the first half of testing for primacy and middle items was nearly as high as in Experiment 1. In the first test half, 25 of 36 subjects recalled 100% of the primacy items, and 21 subjects recalled 100% of the middle items. Thus, interpretation of these data, especially regarding the presence of a primacy effect in the first test half, is again somewhat clouded by ceiling effects. Nevertheless, a two-factor ANOVA revealed significant main effects of both test position, $F(1, 35) = 10.40, p < .01, MS_e = 752.65$, and study position, $F(2, 70) = 4.26, p < .05, MS_e = 912.70$, as well as an interaction of these factors, $F(2, 70) = 3.23, p < .05, MS_e = 959.00$. An analysis of simple effects revealed that there was a significant effect of study position only for the first half of testing, $F(2, 70) = 8.97, p < .01, MS_e = 777.12$. In particular, pairwise comparisons indicated greater recall of both primacy items and middle items in comparison with recency items in the first test half ($p < .01$). Furthermore, the effect of test half was significant only for primacy items, $F(1, 35) = 8.62, p < .01, MS_e = 1031.75$, and middle items, $F(1, 35) = 7.78, p < .01, MS_e = 642.86$. Thus, in the explicit cued-recall condition after a filled delay, there was an effect of study position in the first half of testing in the form of relatively poor performance for recency items, but recall of recency items did not change over the course of testing.

In summary, in Experiment 2, in which there was a 1-min, filled delay between study and test, serial position effects were found in the explicit free-recall and cued-recall tests but not in the implicit word-stem completion test. Yet, the cued-recall data were still clouded by ceiling effects. The next experiment increased list length and presentation rate to reduce cued-recall performance.

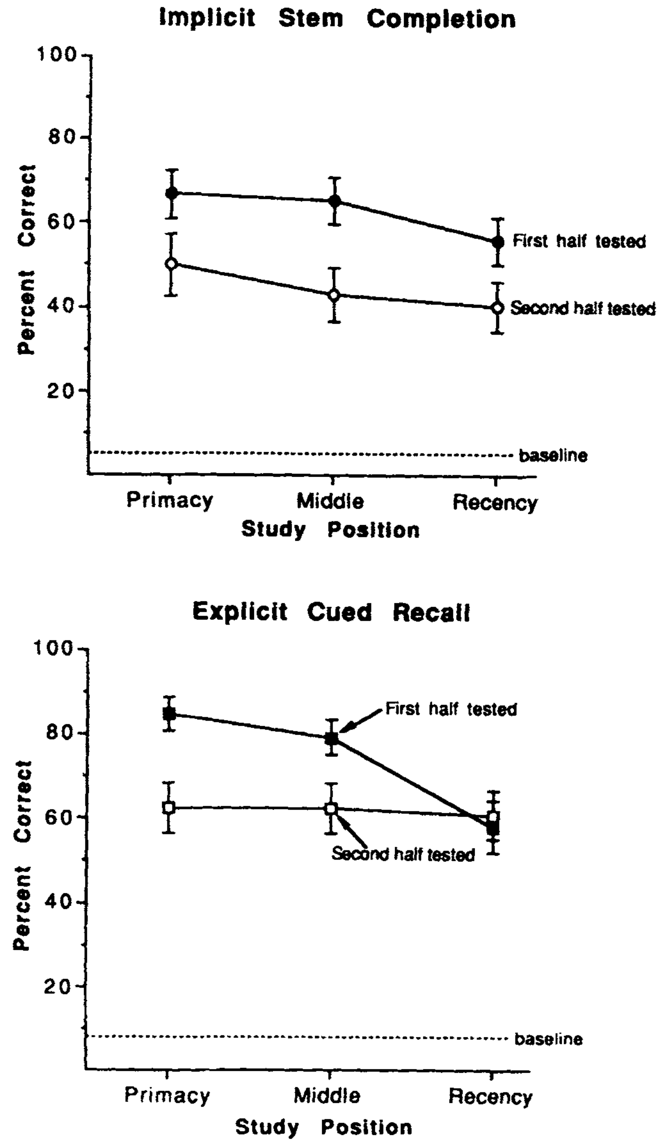

Figure 4. Experiment 2: Implicit stem completion and explicit cued-recall performance for a 12-item list of words as a function of study position and test half. Testing followed a 1-min, filled delay. Error bars indicate standard error of the mean.

Experiment 3

In Experiment 3, an attempt was made to replicate the serial position effects observed in the implicit test with immediate testing (Experiment 1). Moreover, the procedures used in Experiment 3 were expected to bring performance in the explicit cued-recall condition down from ceiling levels so that serial position effects in that condition could be evaluated with greater confidence. In Experiment 3, the length of the study lists was increased from 12 to 24 items, and the presentation rate was increased from 2 s per word to 1 s per word. Otherwise, the procedures used in Experiment 3 paralleled those used in Experiment 1.

Method

Subjects. Ninety-three subjects were recruited at the University of California at Berkeley and were paid for participating in the experiment. Eighteen subjects were assigned to the free-recall condition, 39 subjects were assigned to the implicit word-stem completion condition, and 36 subjects were assigned to the explicit cued-recall condition. All of the subjects were native speakers of English with no reading disabilities. None of the subjects had participated in either of the previous experiments.

Materials and design. The materials used in Experiment 3 were the same as those used in Experiment 1 except that the length of the study list was doubled by adding 12 filler words (i.e., words that would not be tested in the stem completion and cued-recall conditions). These words were of the same average frequency of occurrence as the other list words and contained the same proportion of living and nonliving things. For each study list, 6 filler words were inserted between the first 4 words and the middle 4 words, and 6 more filler words were inserted between the middle 4 words and the last 4 words. This arrangement allowed the use of the same test orders and avoided the problem of diluting serial position effects either by averaging over more study positions or by increasing the length of the test sequence.

Procedure. The procedure for Experiment 3 was the same as for Experiment 1 except that the words were presented at a rate of 1 s per word instead of 2 s per word. Because of the speeded presentation, subjects were not asked to read each word aloud before giving their answer to the living/nonliving orienting question. Rather, subjects read the words to themselves and said only yes or no for each word. As in Experiment 1, test instructions were given immediately following presentation of the last study item. In the implicit stem completion and explicit cued-recall test conditions, the words studied in the first four, middle four, and last four positions in the list were the only items tested.

As in the previous experiments, subjects were eliminated if they did not follow instructions. In this experiment, the data from 3 subjects tested in the implicit stem completion condition were discarded because those subjects indicated that they had tried to avoid using studied words to complete stems. Thus, the data from 36 subjects were analyzed for the implicit stem completion condition.

Results and Discussion

Figure 5 displays free-recall performance as a function of serial position at study. Serial position effects were analyzed only for the first four, middle four, and last four words in the study lists. An ANOVA revealed no overall effect of study position, $F(5, 85) = 1.37, p = .25, MS_e = 1048.20$. However, recall of the first pair of items was significantly greater than recall of the second pair of items ($p < .05$), and recall of the first pair was also significantly greater than recall of all middle pairs (Items 3 and 4, 11 and 12, 13 and 14, and 21 and 22) combined, $F(1, 17) = 3.82, p = .05, MS_e = 1048.20$. Thus, for free recall of a 24-item list presented at a rate of 1 s per item, there was some evidence of a primacy effect but no recency effect. The primacy effect was weaker than that observed in Experiment 1, but this result conforms to findings of reduced recall of primacy items when list length and presentation rate are increased in intentional learning (Glanzer, 1972; Postman & Phillips, 1965a). There is no obvious explanation for the lack of a recency effect with immediate testing.

Performance in the implicit stem completion condition is shown in the upper panel of Figure 6. In comparison with a baseline guessing rate of 6.71% ($SE_M = 1.2\%$), significant priming was observed at all study positions. Importantly, this experiment provided a general replication of the serial position effects found in the implicit test condition in Experiment 1. The graph in Figure 6 suggests a primacy effect in the first half of testing and no effects of study position in the second half of testing. An ANOVA revealed a main effect of test position, $F(1, 35) = 6.76, p < .05, MS_e = 1157.41$, but no interaction of study position with test position. However, planned pairwise comparisons revealed that in the first half of testing, recall of primacy items was greater than recall of middle items ($p < .05$). In addition, there was significant forgetting of primacy items from the first half of testing to the second half ($p < .05$). Thus, the finding of a primacy effect early in testing with no serial position effects late in testing was replicated. As in the free-recall condition, the one anomaly was the failure to find a recency effect in the first half of testing.

Performance in the explicit cued-recall condition is shown in the lower panel of Figure 6. One aim of this experiment was to reduce performance in the first half of explicit testing. Indeed, in this experiment, recall in the first test half at all study positions was about 10% less than it was in Experiment 1. Thus, ceiling effects are less of a concern in this experiment. Examination of the results displayed in Figure 6 suggests primacy effects in both the first half and second half of testing, with forgetting of items at all study positions over the course of testing. An ANOVA confirmed both main effects of test position, $F(1, 35) = 16.08, p < .01, MS_e = 832.01$, and study position, $F(2, 70) = 3.03, p = .05, MS_e = 1380.62$, with no interaction, $F(2, 70) = 0.24, p = .79, MS_e = 922.29$. Planned pairwise comparisons showed that recall of primacy items was marginally greater than recall of middle items in the first half of testing ($p < .09$) and significantly greater in the second half of testing ($p < .05$). Forgetting from the first half of testing to the second half of testing was significant for primacy items ($p < .05$) and middle items ($p < .01$) and marginal for re-

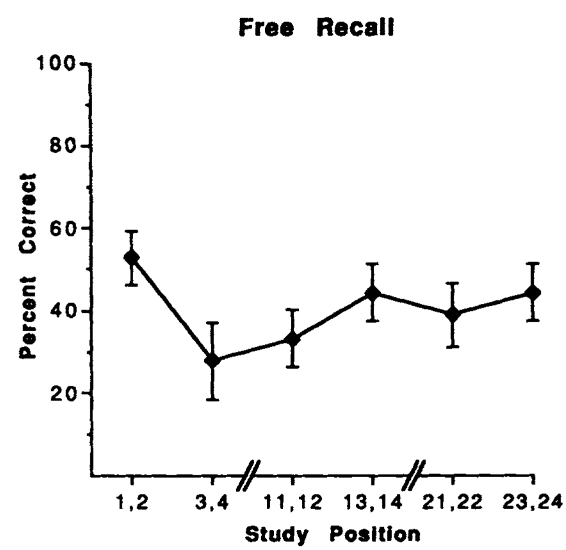

Figure 5. Experiment 3: Free recall of a 24-item list of words as a function of study position. Testing immediately followed incidental learning. Error bars indicate standard error of the mean.

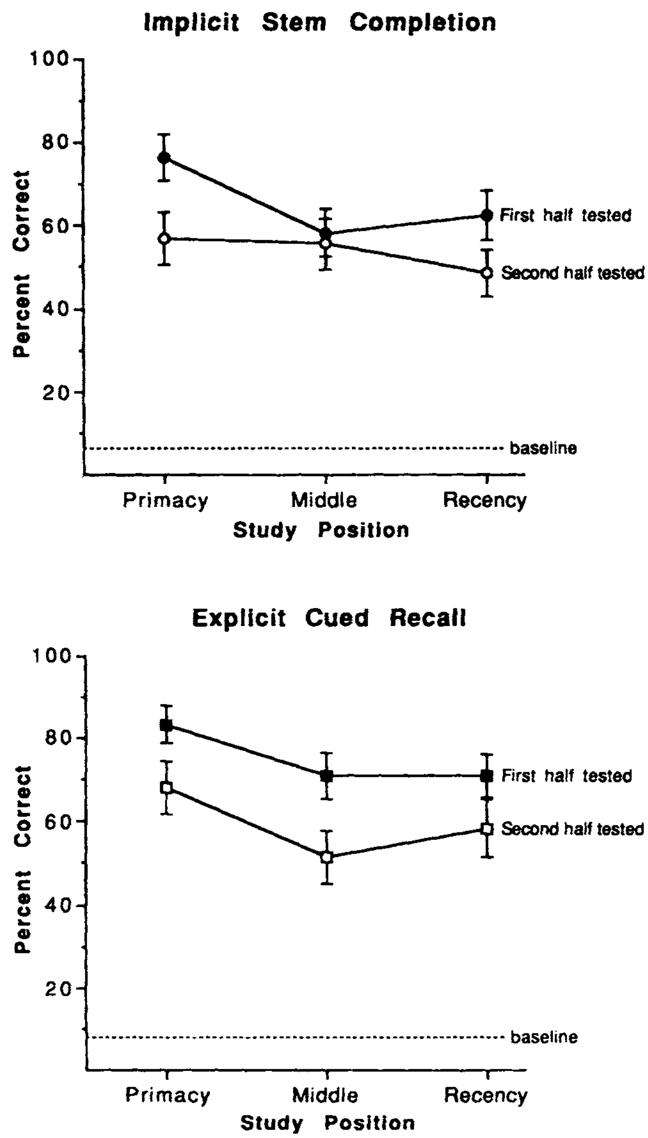

Figure 6. Experiment 3: Implicit stem completion and explicit cued-recall performance for a 24-item list of words as a function of study position and test half. Testing immediately followed incidental learning. Error bars indicate standard error of the mean.

cency items ($p < .09$). Thus, serial position effects for explicit cued recall in this experiment, in which ceiling effects were eliminated, were more consistent with past research (Tulving & Arbuckle, 1963). Most notably, in contrast with the implicit stem completion test, the primacy effect in the explicit cued-recall test persisted through the second half of testing.

General Discussion

In these experiments, both primacy and recency effects were observed in implicit tests of word-stem completion. These effects, however, were transient. No serial position effects were found in the second half of testing (Experiments 1 and 3) or when testing followed a 1-min, filled delay (Experiment 2). Serial position effects were also examined in explicit tests of cued recall. When performance on explicit cued recall was below ceiling levels, a primacy effect persisted throughout testing (Experiment 3). Similarly, in explicit tests of free recall, primacy effects were consistently observed, both with immediate testing (Experiments 1 and 3) and when testing following a filled delay (Experiment 2).

These findings are consistent with previous findings of recency effects in implicit tests of memory (McKenzie & Humphreys, 1991; Rybash & Osborne, 1991; Sloman et al., 1988). Furthermore, in this study, implicit stem completion performance for recency items declined substantially following a 1-min, filled delay (Experiment 1 vs. Experiment 2). In explicit cued-recall and free-recall tests, performance for recency items similarly declined following a filled delay. These effects of delay on memory for recency items are consistent with classic findings from studies of serial position effects in free recall (Glanzer & Cunitz, 1966). The similarity in the patterns of performance for recency items in the implicit and explicit tests suggests that these effects were mediated by a common process, such as short-term memory (Atkinson & Shiffrin, 1968) or implicit memory (Baddeley & Hitch, 1993).

Further comparisons of serial position effects in implicit and explicit tests indicated differences in both primacy and recency effects. These differences were revealed by analyses of test position effects—that is, by comparing stem completion performance in the first half of testing with performance in the second half of testing. The most striking finding was the transient nature of the primacy effect in the implicit word-stem completion test. That is, the primacy effect that was present in the first half of testing was eliminated in the second half of testing (Experiments 1 and 3). In contrast, in the explicit cued-recall test, when performance was below ceiling levels, a primacy effect persisted throughout testing (Experiment 3). Another difference between the implicit and explicit tests was the effect of test position on performance for recency items. Specifically, in all three experiments, performance on recency items declined from the first half to the second half of testing in the implicit stem completion tests. This decline in recency performance was not observed in the explicit cued-recall tests. This finding stands in contrast to the finding that a filled delay between study and test had similar effects on recency performance in implicit and explicit tests.

The present finding of a transient primacy effect in the implicit tests might appear to conflict with a previous finding of a long-lasting primacy effect in word-fragment completion (Sloman et al., 1988). In that study, serial position effects were examined in a test of word-fragment completion in which the test fragments were presented in the reverse of the order in which the words had been presented at study. Thus, the first item studied was the last item tested. In the present study, when primacy items were tested late in the implicit test, no primacy effect was found. In the Sloman et al. (1988) study, a primacy effect was observed in the form of better performance for the first-studied item than for subsequent items. The apparent conflict between these findings can be resolved by examining the instructions given to subjects in the fragment completion experiment. Subjects were told "to try to complete each fragment with a study–list word" (Sloman et al., 1988, p.

227). Because the instructions refer to the study episode, the fragment completion test given by Sloman et al. (1988) was an explicit test. Thus, their finding of a long-lasting primacy effect in fragment completion is consistent with the present finding of a stable primacy effect in the explicit cued-recall test in Experiment 3.

The present results suggest two questions. First, what is the basis for the serial position effects observed in the implicit tests? One possibility is that performance is better for primacy and recency items because they are encoded more strongly or more distinctively. That is, it may be that boundary items are preferentially activated over middle items because they have fewer neighboring items that may cause interference. By this view, the modulation of initial activation by interference effects gives rise to serial position effects in implicit tests. Interference theories have been proposed to explain serial position effects in explicit tests (e.g., Wright et al., 1985) as an alternative to traditional multistore theories (Atkinson & Shiffrin, 1968). Because interference effects are assumed to occur without the use of conscious or explicit retrieval processes, an interference view may be particularly suited to account for serial position effects in implicit tests. Although past studies have suggested that performance on implicit tests of memory is not vulnerable to interference (Graf & Schacter, 1987; Jacoby, 1983), those studies investigated extralist interference effects rather than intralist effects.

Second, what is the basis for the differences between the patterns of serial position effects in implicit and explicit tests? In particular, why were implicit serial position effects more disrupted over the course of testing than explicit effects? One possibility is that the act of performing stem completion during the test phase creates interference at the level of perceptual and lexical processing. By this view, implicit tests, which depend heavily on these aspects of processing (see Roediger & Srinivas, 1993; Schacter, Chiu, & Ochsner, 1993), would be highly susceptible to such interference effects. Because performance on explicit tests additionally draws on conceptual and elaborative processing, explicit serial position effects—particularly the primacy effect—may be less vulnerable to interference that occurs over the course of testing. Indeed, past studies have shown that interference can have selective effects. That is, interference at the conceptual level, such as that produced during AB–AC paired-associate learning, was shown to affect performance on explicit but not on implicit tests (Graf & Schacter, 1987).

The interference interpretation described above suggests a qualitative difference in the serial position effects for implicit and explicit tests. Alternatively, the findings may be attributed to quantitative differences. That is, implicit serial position effects may be more transient simply because memory is weaker. Distinguishing between qualitative and quantitative interpretations will require further investigations of serial position effects in implicit and explicit tests. According to the interference hypothesis, serial position effects in implicit and explicit tests are mediated by interference operating at different levels of processing. If this is the case, then variables that have dissociable effects on explicit and implicit test performance in general should also have dissociable influences on serial position effects. For example, manipulations of level of processing at study should disrupt serial position effects in explicit but not implicit tests. Conversely, changes in presentation modality between study and test should affect serial position effects in implicit tests more than in explicit tests. Furthermore, amnesic patients should show normal patterns of serial position effects on implicit tests, despite impaired performance on recall of primacy items in explicit tests (Baddeley & Warrington, 1970).

In conclusion, serial position effects in implicit tests of memory were observed in the form of both primacy and recency effects. These effects, however, were transient, disappearing over the course of testing. Comparisons of implicit and explicit tests revealed that, in both types of tests, performance on recency items declined following a filled delay. Yet, patterns of serial position effects changed differentially over the course of testing in the two types of tests. That is, implicit serial position effects were eliminated in the second half of testing, whereas explicit effects were more stable. Interference effects operating on different aspects of processing (e.g., perceptual, lexical, and conceptual) may mediate differences in the patterns of serial position effects observed in implicit and explicit tests. These findings provide a conceptual link between the relatively recent endeavor to characterize implicit and explicit memory and the older problem of characterizing serial position effects in memory.

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