Bulletin of the Psychonomic Society
1977, Vol. 9 (4), 265-268

Storage and retrieval processes in the serial position effect

BARRY SKOFF and RICHARD A. CHECHILE
Tufts University, Medford, Massachusetts 02155

A technique that separates storage from retrieval (Chechile & Butler, 1975; Chechile & Meyer, 1976) was used to study the role of these processes in the production of the serial position effect. Using a serial learning paradigm with paired associates, both the probability of storage and the probability of retrieval decreased for items in the middle of the list. While both storage and retrieval components contribute to the serial position effect, the storage and retrieval changes were found to be uncorrelated. It is suggested that the serial position effect is due to the cue distinctiveness of end items in a serial list producing a facilitation of initial discrimination and storage of these items and their subsequent organization and retrieval from memory.

The serial position effect has long been recognized as a robust phenomenon, where the items at the beginning and end of a list are learned quicker, and with fewer errors, than the items in the middle of a list (Ebbinghaus, 1913). Current theories of the serial position effect involve the concepts of distinctiveness and organization along some discriminable dimension (Ebenholtz, 1972). For example, in the standard serial learning paradigm, the temporal and ordinal position of the items can form a meaningful organizing dimension. Furthermore, list items may differ in regard to their distinctiveness on this dimension. Murdock (1960) defined and scaled distinctiveness as the extent to which a stimulus "stands out" from other contextual and background stimuli. He also showed that for a serial order dimension, the distinctiveness scores result in a bowed serial position curve. Additionally, a number of related experiments (Ebenholtz, 1965; Phillips, 1958) demonstrated that when responses in a standard paired-associate learning task were paired with stimuli that could be ordered along some discriminable dimension (e.g., different values of Munsell grays), a serial position effect emerged when mean errors or mean trials to criterion were plotted against the stimuli arranged in order. According to Murdock's schema, the differential distinctiveness of the stimuli could have resulted in the differential discriminability and learning of the items in a serial list. In fact, Ebenholtz (1972) theorized that a serial position effect would result whenever items in a list could be associated with, or organized along, a discriminable sensory or conceptual dimension.

While the concepts of distinctiveness and organizational dimension are now important concepts in our understanding of the mechanisms involved in the production of the serial position effect, we still do not know how the more fundamental memory processes of storage and retrieval are affected. Are the items at the middle and ends of the list differentially encoded and stored because of their differential discriminability? Or is there differential retrieval of information from the middle and ends of the list due to differences in the distinctiveness of dimensionally stored items in memory?

Recently a technique has been devised to separate storage and retrieval processes in memory (Chechile, 1973; Chechile & Meyer, 1976). The method involves interspersing recall trials with forced-choice recognition trials and requiring the subject to rate his or her answer on a 3-point confidence scale. It is assumed that both storage and retrieval are dichotomous. On any one trial, the subject has either sufficient or insufficient storage concerning the target item. Across many such trials, the proportion of times the subject sufficiently stores the target information is defined as θ_s, the probability of storage. Given that sufficient storage has occurred on a given trial, there can be either successful retrieval of all the stored information or unsuccessful retrieval. Across the trials where there is sufficient storage, the proportion of times the subject successfully retrieves the target information is defined as θ_r, the probability of retrieval. Thus, for example, the correct recall of a target item on any given trial requires both sufficient storage and successful retrieval of the target information. The probability of correct recall across many trials, designated θ_c, is defined as $\theta_s \cdot \theta_r$. A more thorough explanation of the separation can be found in Chechile and Meyer (1976).

A number of experiments successfully separating storage and retrieval processes using this procedure have also demonstrated the validity of these measures (Chechile, 1973; Chechile & Butler, 1975; Chechile & Meyer, 1976; Gerrein, 1976). One such test of validity is the fact that θ_s and θ_r in these experiments have been

Leonard C. Mead sponsors this paper and takes full editorial responsibility.

uncorrelated, indicating that they are independent and thus measures of different memory processes. In addition, Chechile and Meyer (1976) have also shown that varying the available response time (a variable that should a priori affect only retrieval) in fact only changes θ_r. In the present experiment, the storage-retrieval separation analysis will be employed in order to determine the role of storage and retrieval processes in the serial position effect.

METHOD

Subjects

Thirty undergraduate students at Tufts University participated in the experiment.

Materials and Apparatus

Twenty-four words were selected from the Kučera and Francis (1967) norms. The words chosen were all two-syllable nouns with a frequency range of 50 to 200. Each word was consecutively paired with the numbers 1 through 24, so that a list of 24 number-word pairs comprised the study list for the experiment. The tape-recorded trials were played on a Sony TC 366 stereo tape deck with Koss Pro-4AA headphones.

Design

Two random arrangements of the words and test trials were used, with the first 15 subjects receiving the first arrangement and the last 15 subjects receiving the second. A series of trials, consisting of alternating study and test phases, were repeated until the subject reached the criterion of three consecutively perfect test phases. The 24 number-word pairs were presented in order to the subject during the study phase of the experiment and the subject was tested on the list during the test phase. Each test phase was comprised of eight recall, eight old recognition, and eight distractor recognition test cues. For example, a recall test cue might be "5-recall," while an old recognition test cue might be "8-river" and a distractor recognition test cue might be "8-table," where river in fact was paired with 8 in the study phase but table was paired with some other number in the list. The test cues were constrained such that for every three test phases, one of each test cue appeared for each serial position. Apart from the above constraints, the recall and recognition test cues were randomly intermixed in the test phase.

Procedure

The presentation of the list was announced with the words "study phase." The list was read one word at a time, with each word preceded by the number representing its ordinal position within the list. The presentation of one number-word pair took 1.5 sec. The test cues were announced with the words "test phase," and immediately followed the study phase. Each test cue was preceded by its ordinal number, with the original serial order retained. If asked to recall, the subject had 2.5 sec to recall the correct item occurring at this serial position in the list before a buzzer signaled the presentation of the next test cue. The subject also had 2.5 sec in which to respond if the test cue was an old or distractor recognition item. In addition, the subjects were asked to rate their recognition responses on a 3-point confidence scale, with 3 being "most certain."

The experiment began after the subject was completely instructed on the procedure, including a short three-item two-trial practice session. The study and test phase were alternated without any break up to a maximum of 21 recorded study-test phases. The experimental session continued until the subject correctly responded to each test cue for three consecutive test phases. The subjects were also asked to recall the entire serial list at the conclusion of the session.

RESULTS

Fifteen of the subjects received one random arrangement of the number-word pairs and the order of presentation of the test cues, while the other 15 subjects received a second random arrangement of the list and test cues. A t test was performed on the proportion of the errors for each subject for the two groups in order to check for any effects due to the different arrangements. There was no significant difference between the proportion of the total errors for the two groups ($t = .02$, $df = 28$, $p > .49$), and thus the data from the two groups were combined for further analysis.

The group means for recognition and recall data are displayed in Table 1 in terms of proportions. In this table the serial positions are blocked in groups of three and the data are grouped over all subjects and all trials. As is clear from the table, a typical serial position effect resulted for the proportion correct recall. The items from the middle serial positions (Blocks 3 to 7) have a lower proportion correct recall than beginning items (Blocks 1 and 2; $t = 6.32$, $df = 29$, $p < .001$), end items (Block 8; $t = 4.96$, $df = 29$, $p < .001$), and beginning and end items combined ($t = 6.38$, $df = 29$, $p < .001$). The proportion of high-confidence hits

Table 1
Group Mean Recognition and Recall Data in Terms of Proportions as a Function of Blocks of Three Serial Positions

	Old Recognition						Distractor Recognition						
	Yes			No			Yes			No			
Serial Blocks	1	2	3	1	2	3	1	2	3	1	2	3	Correct Recall
1	.01	.07	.86	.01	.02	.03	.01	.02	.01	.01	.05	.91	.73
2	.02	.14	.66	.06	.07	.05	.03	.03	.02	.06	.09	.78	.54
3	.04	.17	.58	.07	.05	.08	.03	.06	.01	.07	.08	.74	.46
4	.01	.19	.60	.08	.07	.05	.03	.07	.01	.08	.13	.68	.45
5	.07	.17	.58	.10	.05	.03	.02	.04	.02	.04	.10	.79	.52
6	.07	.21	.54	.09	.05	.04	.03	.09	.02	.11	.13	.62	.37
7	.04	.24	.52	.09	.06	.04	.04	.12	.02	.09	.11	.62	.38
8	.05	.11	.71	.06	.03	.04	.01	.03	.01	.04	.06	.86	.63

(i.e., yes–three responses for old recognition) also shows a serial position effect suggestive of storage difficulties. However, the recognition data in Table 1 have not been corrected for guessing and rating factors.

The storage-retrieval separation analysis, in effect, corrects for guessing and rating factors on an individual subject basis. The resulting measures of storage (θ_s) and retrieval (θ_r) were determined by Equations 16-24 from Chechile and Meyer (1976). These measures were determined for each subject: first, by grouping across trials for blocks of three serial positions and, second, by grouping across blocks of six serial positions and three trials. The group averages for the resulting probability of storage (θ_s) and the probability of retrieval (θ_r) are displayed in Figure 1 as a function of blocks of three serial positions. The storage measure (θ_s) for middle items (Blocks 3 to 7) is lower than θ_s for the beginning items (Blocks 1 and 2; $t = 8.5$, $df = 29$, $p < .001$) or θ_s for the end items (Blocks 8; $t = 7.86$, $df = 29$, $p < .001$). Likewise, the probability of retrieval (θ_r) for middle items is lower than θ_r for the beginning items ($t = 2.46$, $df = 29$, $p < .025$) or θ_r for the end items ($t = 3.17$, $df = 29$, $p < .005$). The storage and retrieval measures are also smaller for the middle serial positions, Blocks 3 to 7, as compared to the combined ends, Blocks 1, 2, and 8 ($t = 10.15$, $df = 29$, $p < .001$ for θ_s and $t = 3.67$, $df = 92$, $p < .001$ for θ_r). Therefore, both storage and retrieval processes can be seen to play a role in producing the serial position effect.

Despite the fact that both storage and retrieval

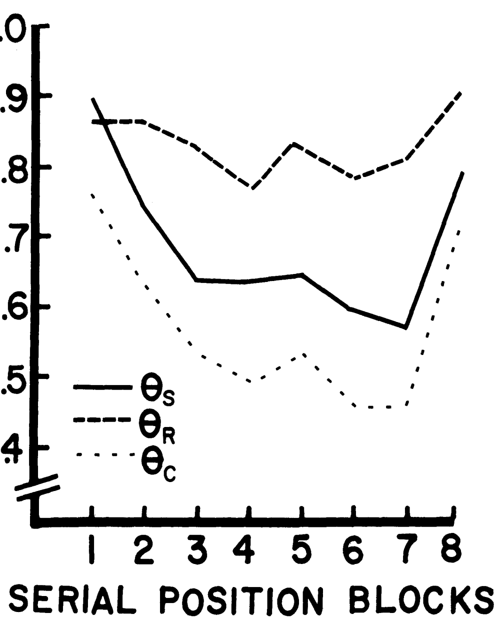

Figure 1. Mean probability across subjects for storage (θ_s), retrieval (θ_r), and correct recall (θ_c), plotted as a function of blocks of three consecutive serial positions.

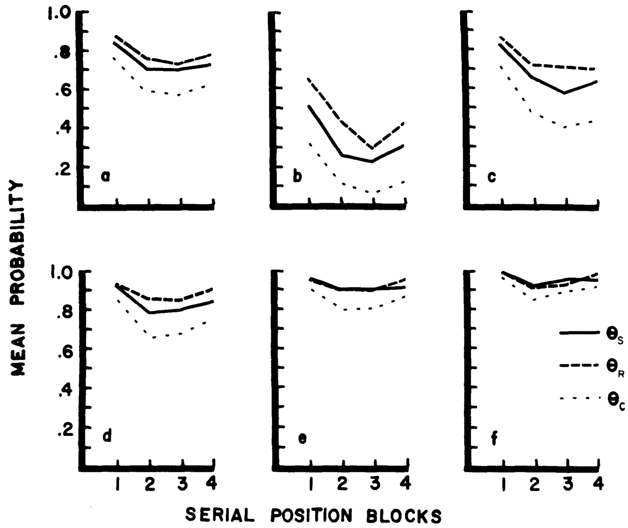

Figure 2. Mean probability across subjects for storage (θ_s), retrieval (θ_r), and correct recall (θ_c), plotted as a function of blocks of six consecutive serial positions for successive degrees of learning: (a) overall, Trials 1-15, (b) Trials 1-3, (c) Trials 4-6, (d) Trials 7-9, (e) Trials 10-12, and (f) Trials 13-15.

measures are changing in the same direction between the middle and end serial positions, the correlation between the storage change and the corresponding retrieval change is −.19 ($df = 29$, $p > .30$). This small and insignificant correlation strongly suggests that the storage and retrieval measures are independent constituent parts of correct recall (θ_c).

Figure 2a is a display of θ_s, θ_r, and θ_c as a function of serial position, in blocks of six, grouped over Trials 1 through 15. In order to get a better idea of how storage and retrieval processes in the serial position effect develop with the level of serial acquisition, these data were broken down further. Figures 2b-f show how storage and retrieval processes (as a function of serial position) change across successive blocks of three trials. The figures illustrate that, while storage and retrieval processes contribute to the serial position effect for correct recall, the retrieval contribution appears to diminish more rapidly with learning, as the serial position effect for θ_r is already approaching a ceiling effect by the second group of trials (Figure 2c). Storage, on the other hand, takes somewhat longer to reach its ceiling, but by the fourth block of trials (Figure 2e) both θ_s and θ_r have reached their limit. The serial position effect for θ_s, θ_r, and θ_c in these figures is less pronounced, especially for end items, because the data are blocked over six serial positions. As can be seen from Figure 1, the serial position effect, for the end of the list in particular, encompasses only the last block of three serial positions. When these data are combined into even larger groups, the serial position effect for items at the end of the list tends to disappear.

DISCUSSION

This experiment demonstrates that both storage and retrieval processes contribute to the serial position effect in serial learning in that both the probability of storage (θ_s) and the probability of retrieval (θ_r) are smaller for items in the middle of the list. The fact that the changes in the storage and retrieval measures from the middle to the ends of the list are not correlated further demonstrates that these are independent processes. The independence of storage and retrieval found here and in other studies using this separation technique (Chechile, 1973; Chechile & Butler, 1975; Chechile & Meyer, 1976; Gerrein, 1976) lends further support to the validity of θ_s and θ_r as independent constituent parts of correct recall.

Perhaps the simplest explanation for the serial position effect for storage is as a natural consequence of discrimination learning with stimuli that vary in distinctiveness. While learning the list, the subject is confronted with a complex discrimination task in which he or she is to form an association between the number, which serves as the stimulus, and the word paired with it. Both the ordinal position and the digit stimulus correspond to a coordinated underlying continuum with presumably more distinctive extremes. Both cues can thus make it easier for the subject to discriminate and store the end items of the list before storing the less distinctive middle items. For example, 1 and 2, being at the beginning of the list, are more distinctive, and thus more easily discriminable, than 12 and 13 in the middle of the list. Thus the items paired with 1 and 2 are apt to be encoded and stored earlier than the items paired with 12 and 13.

The serial position effect, however, is not due only to storage effects. Of the items that are sufficiently stored, there is a greater tendency for the subject to retrieve the end items than middle items, particularly early in learning. It is reasonable to assume that the sufficiently stored pairs are organized roughly in memory along a continuum, with clusters corresponding to beginning, middle, and end. Since there are fewer items in the beginning and end clusters than in the middle, this restricts the number of items the subject has to search through during retrieval. Shiffrin (1970) demonstrated that the probability of successful retrieval improves if the subject can restrict the number of items in the search set. During the early stages of acquisition, the end items comprise smaller search sets than do middle items; thus, one would expect, and finds, a retrieval advantage for these items (Figure 2b). As learning progresses, overlearned items reduce the effective size of the search sets throughout the entire list, and end items eventually lose their original retrieval advantage (Figures 2c-f). More specifically, the initial clusters of beginning, middle, and end become, themselves, more organized as learning progresses, so that the effect of smaller search sets is only a phenomenon related to early learning and organization. Consequently, the concept of cue distinctiveness of end items in a serial list can be used to explain the initial organization of stored items in memory, so as to make retrieval easier for end items. Furthermore, these two subprocesses independently function so as to contribute to the overall serial position effect.

REFERENCES

Chechile, R. *The relative storage and retrieval losses in short-term memory as a function of the similarity and amount of information processing in the interpolated task.* Unpublished doctoral dissertation, University of Pittsburgh, 1973.

Chechile, R., & Butler, K. Storage and retrieval changes that occur in the development and release of PI. *Journal of Verbal Learning and Verbal Behavior*, 1975, **14**, 430-437.

Chechile, R., & Meyer, D. A Bayesian procedure for separately estimating storage and retrieval components of forgetting. *Journal of Mathematical Psychology*, 1976, **13**, 269-295.

Ebbinghaus, H. *Memory: A contribution to experimental psychology.* New York: Teacher's College, Columbia University, 1913.

Ebenholtz, S. Positional cues as mediators in discrimination learning. *Journal of Experimental Psychology*, 1965, **70**, 176-181.

Ebenholtz, S. Serial learning and dimensional organization. In G. H. Bower (Ed.), *The psychology of learning and motivation* (Vol. 5). New York: Academic Press, 1972.

Gerrein, J. *Organization, storage, and retrieval factors in alcohol-induced forgetting.* Unpublished doctoral dissertation, Tufts University, 1976.

Kučera, H., & Francis, W. *Computational analysis of present-day American english.* Providence: Brown University Press, 1967.

Murdock, B. The distinctiveness of stimuli. *Psychological Review*, 1960, **67**, 16-31.

Phillips, L. Mediated verbal similarity as a determinant of the generalization of a conditioned GSR. *Journal of Experimental Psychology*, 1958, **55**, 56-62.

Shiffrin, R. Memory search. In D. A. Norman (Ed.), *Models of human memory.* New York: Academic Press, 1970.

(Received for publication November 1, 1976.)