CONFUSION ERRORS IN SERIAL LEARNING

by

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Abstract

Two experiments examined the relative ability of different probes in eliciting items occupying various positions in a serial list, the shape of the serial position curve, and the distribution of errors in serial learning. In Experiment I, position, sequential, and backward probes were employed after one presentation of a serial list. The results indicated that all three probes had equal eliciting strengths and that all three probes produced similar serial position curves. Analysis of errors revealed a gradient of generalization around the target word. In Experiment II error distribution and the serial position curve were examined in a learned serial list using the missing scan as a probe. Analysis of correct responding showed flat serial position curves, and the distribution of errors around the target word seemed essentially random. The results were discussed in terms of current theoretical representations of serial learning.
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Introduction

Recent work in serial learning has been concerned with the problem of the effective stimulus. Operationally defined, the effective stimulus would appear to be the best elicitor of an item occupying a given position in a serial list. The search for the effective stimulus in serial learning has generally tested two hypotheses, the chaining hypothesis and the position hypothesis. The chaining hypothesis states that the effective stimulus for each item in a serial list is the preceding item; i.e. a network of item-to-item associations is formed in serial list learning. The position hypothesis states that the effective stimulus for each item in a serial list is the position the item holds in the list; the position hypothesis ignores item-to-item associations.

Recent tests of both hypotheses have involved transfer from a serial task to a paired-associate task. The paired-associate list used to test the chaining hypothesis is a double-function list (Young, 1959, 1961) in which the stimulus-response pairs are successive couplets taken from the serial list. Evidence for the chaining hypothesis is said to be found when performance by Ss in the transfer task is superior to performance by Ss in an appropriate control group. The paired-associate task used to test the position hypothesis is a spatial discrimination task (Ebenholtz, 1963; Jensen & Rowher, 1965) in which the stimuli consist of a vertical or horizontal array of boxes. For each stimulus, a dot appears in one of the boxes; the appropriate response to the dot is the word in the serial list holding the same position among other
words in the list that the dotted box holds among other boxes. Evidence for the position hypothesis is said to be found when positive transfer, as compared to an appropriate control, is obtained.

The current state of affairs concerning both hypotheses (summarized by Young, 1968) is that neither a double-function nor a spatial discrimination paired-associate task is an adequate description of serial learning. In testing a chaining hypothesis, Young (1959, 1961) observed no positive transfer. In testing a position hypothesis, Ebenholtz (1963) found what he termed positive transfer effects at the extremes of the serial list, but he failed to include a control group in which the words in the serial list were unrelated to the words in the paired-associate list. Jensen and Rowher (1965) included this appropriate control and found no positive transfer. They concluded that an ordinal position description of serial learning fared no better than a chaining description.

Because paired-associate analogies of serial learning have been unsuccessful in identifying the effective stimulus, it was felt that a different approach to serial learning was necessary. The approach chosen for the present study was a direct attack, without transfer to a paired-associate task or derived serial list. The advantage of a direct attack is that the original serial learning, rather than a relearning task, supplies the data of testing theories of serial learning. Thus, problems of difficulty of learning in the transfer task, difficulty in comparing different transfer tasks, etc. are circumvented.
In the present study, a probe technique was used to examine three phenomena of serial learning. The probe technique was chosen because, unlike a paired-associate task, a probe is not a learning task. The three phenomena studied were: (1) the relative ability of different probes to elicit items occupying various positions in the serial list. In this sense, each type of probe employed can be considered a different type of eliciting stimulus; (2) the shape of the resulting serial position curve; and (3) the distributions of errors around the target words, i.e. the shape of the generalization gradients.

Murdock's (1968) study of one-trial serial learning gives some indication of the relative eliciting ability of two types of probes, the sequential and position probes. Using the sum of d' values across serial position, Murdock found near equality of the d' values for sequential and position probes. In addition he found similarly shaped serial position curves for both sequential and position probes.

Two other studies give indirect evidence about relative strength of eliciting stimuli. Young, Patterson, and Benson (1963), in a test of the position hypothesis, found that Ss who had learned a serial list and were then transferred to the same serial list presented backward exhibited no positive transfer as measured in terms of trials-to-criterion. This finding is in accord with the double-function description of serial learning; Battig and Kopenaal (1965) have found that after ten study-test presentations of a double-function paired-associate list, response recall is superior to stimulus recall, i.e. forward associations are stronger than backward.
Studies by Bugelski (1950) and Murdock (1969) are relevant to the shape of generalization gradients. Bugelski plotted errors made by Ss in the course of serial anticipation learning. He found an inverse relationship between number of errors and the distance from the correct response and more errors in the forward direction than in the backward. However, Bugelski's conclusion that forward errors predominate may be an artifact of the anticipation task. It is unlikely that on a given trial Ss would respond with a word that had already been presented.

Murdock (1969) presented evidence that generalization does not exist in one-trial spatial learning. In a verbal learning task with stimuli composed of eight points in a circular array, the distribution of errors was rectangular; there was no spatial generalization. In Murdock's study, each S was tested on only one position after each list presentation.

The present study, then, was an extension and refinement of the studies by Murdock, Young et al., and Bugelski. First, the Murdock (1968) study was replicated and extended by the addition of a backward probe. Second, because Young et al.'s finding of greater availability of forward associates than backward associates applies only to learned serial lists, forward and backward associations were compared after one presentation trial. Third, the relationship of confusion errors to the target word was examined in one-trial serial learning. The differences in the Murdock (1969) and Bugelski findings shows there is some question as to error distribution in the present study.
Experiment 1

Method

**Design.** Each S was given one learning trial on each of 28 different serial lists. After the learning trial for a particular list, a forward, backward, or position probe was presented so that each S was tested with one probe on each list. There were 28 different probes used; a Latin square design, with randomly arranged rows and columns, insured that each S was tested with each probe. The 28 probes included ten position, nine sequential, and nine backward probes. For ten word lists, each word could be tested with a position probe; all but the first word could be tested with a sequential probe, and all but the last, with a backward probe.

**Materials.** Two hundred-eighty concrete and frequent nouns (C>5.50, F>20) were drawn from the Paivio-Yuille-Madigan (1968) list and were randomly rearranged to form 28 lists of ten words each. Words within each list were randomly rearranged to determine their serial position, and entire lists were rearranged to determine order of presentation. Individual slides were made of the 280 words; the words were presented with a standard carousel projector.

Twenty-eight test booklets of 29 pages each were made on 3x5 notecards. The first page of each booklet contained an identification number. The remaining 28 pages contained one each of the 28 probes in accordance with the Latin square design. Position probes read position followed by a number from one to ten. Sequential probes read after followed by the word preceding the target word in the serial list.
Backward probes read *before* followed by the word following the target word in the serial list. Answer sheets contained 28 lines for answers and were given identification numbers corresponding to the test booklets.

**Subjects.** Eighty-four volunteers from introductory psychology classes were used. Subjects were run in three sessions with 28 Ss participating in each session.

**Procedure.** Upon entering the experimental room, Ss were given a test booklet and an answer sheet. They were instructed as to the successive presentation of the serial lists and the nature of the three types of probes. They were also instructed not to turn the page of the test booklet until the entire list had been presented; upon completion of the presentation, Ss were instructed to turn the page and to use the provided stimulus to determine the answer. They were told to record the answer on the answer sheet and guessing was encouraged. Words were presented at a two second rate; the interval between successive lists was ten seconds, in which time the Ss had to record their responses. The number of the trial was announced before the presentation of each list so that Ss would know on which line they should record their answers.

**Results**

Serial position curves for the three probes are graphed in Figure 1. Figure 1 contains the percent correct at each position for the three probes.

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Insert Figure 1 about here

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Figure 1. Probability of recall for the three probes as a function of serial position.
All three probes produced similar curves with greater recency than primacy effects. Mean number correct per S for the eight positions shared by the position, sequential, and backward probes was 2.82, 3.01, and 2.80, respectively. An analysis of variance ($F(2,166)=0.605, p>.25$) showed no significant difference between the three probes. Extra-list intrusions and errors of omission occurred on less than 11% of all trials. These two types of errors will not be considered in further data analysis.

Murdock (1968) has shown that the exact shape of the serial position curve is dependent upon the method of scoring the data. Figures 2 and 3 show two methods of scoring other than probability correct. Both methods include corrections for guessing. Figure 2 contains the probability that a response is correct if that response came from a given serial position, a guessing correction referred to by Murdock (1968) as inverse probability.

![Insert Figure 2 about here](image)

As with Murdock's data, the graphs of inverse probability show a greater primacy than recency effect. Again, all three probes exhibit similarly shaped serial position curves. As inverse probability is a correction for response bias, the similar shape of the curves for the three probes shows that Ss make the same types of errors regardless of the type of probe. In fact, all three probes showed that Ss guessed items from the last positions of the serial list more frequently than items from the first positions. Figure 3 is also a graph of serial position curves.
Figure 2. Inverse probability of recall for the three probes as a function of serial position.
Figure 3 contains $d'$ values at each position for the three probes.

Again all three probes yielded similarly shaped serial position curves; these curves are more symmetrical than the curves in Figure 1 or Figure 2. The sum of $d'$ for the eight positions shared by the position, sequential, and backward probes was 8.10, 8.85, and 7.75, respectively.

Three methods to determine if errors occurred in the vicinity of the correct position were used. These three methods are graphed in Figures 4, 5, and 6. Figure 4 shows expected minus observed distance of errors from the target word divided by expected distance for the three probes. Distance, in this sense, means number of positions from the target word; expected distance is determined for each position by summing the distances from the target word of possible error cells, and dividing the sum by the number of possible error cells. As graphs in Figure 4 are plotted by serial position and different serial positions have different expected distances, division by expected distance is used to equate the values at each position.

Of the 28 points plotted, all but one shows greater expected distance than observed. Thus, the Ss guessed closer to the target position than would be expected by chance guessing.
Figure 3. $d'$ for the three probes as a function of serial position.
Figure 4. $(e-o)/e$ error generalization for the three probes as a function of serial position.
The method used in Figure 4 indicates that positions at the end of the list exhibited steeper generalization gradients than positions in the beginning of the list. To determine if this relationship was, in part, caused by the greater number of incorrect responses in later serial positions, another method of determining error distribution was used. This method involved a similar correction to the inverse probability correction and also used the (e-o)/e measure. An NxN intrusion matrix with rows as target positions and columns as output positions was drawn. Disregarding the correct responses found on the diagonal, each error cell was converted to a percentage with the numerator being the number in the cell and the denominator, the total number of false alarms in the column containing that cell. The observed distance was simply the row sum of the distances of errors from the correct response multiplied by the corrected cell scores. The expected distance was the expected distance used in Figure 4 multiplied by the percentage of false alarms in the appropriate row. These new 'generalization' scores are graphed in Figure 5.

As a result of this correction, the mean distance that errors occur from the target word does not vary systematically as a function of the serial position of the target word.

The two previous methods indicate that errors tend to occur in the vicinity of the target word but fail to describe the error
Figure 5. \((e-o)/e\) error generalization, corrected for guessing frequency, as a function of serial position.
gradients. To allow for the different number of items at different
distances for each serial position, relative distance (see Buschke &
Hinrichs, 1968) was used to describe these gradients. Relative distance
defines distance in terms of the two positions closest to the target
position, the two next closest, etc. This measure collapses over
serial position so that no position-differentiated values can be determined.
Figure 6 is a graph of relative distance for the three probes, graphed
in \((o-e)/e\) distance.

Insert Figure 6 about here

The \((o-e)/e\) correction was used to equate the values at each relative
distance. From Figure 6 it can be seen that frequency of guessing
decreases with distance from the target word. \(\chi^2\) was computed for the
three probes collapsed over \(S\)s and replications; values of 129.67,
78.73, and 55.67 were found for the position, sequential, and backward
probes, respectively. With 4df all values were significant at \(p<.001\).

**Discussion**

The fact that there were no significant differences between the
eliciting strength of position, sequential, and backward probes suggests
that all three probes are equally effective stimuli in one-trial serial
learning. The acceptance of the null hypothesis (equality of all three
probes) is supported by Murdock's (1968) finding that sequential and
position probes yield similar \(d'\) values. The present data conform
with Murdock's in other aspects. Graphs of percent correct showed
Figure 6. Relative distance of errors from target position for the three probes collapsed over serial position.
serial position curves with marked recency effects. The inverse percent correct produced curves with marked primacy effects. The sum of d' values by position for the position probe was 12.70, not unlike the value of 15 that Murdock found in serial lists of various lengths.

The equality of sequential and backward probes suggests equal availability of forward and backward associations after one trial of serial learning. This finding, in conjunction with the Young et al. finding, suggests a change in the relative strength of forward and backward associations as a function of degree of learning. This change is not necessarily contrary to a double-function description of serial learning. First, it may be the case that asymmetry develops as a function of practice. Second, it has been shown (e.g. Murdock, 1962) that stimulus and response recall may be symmetrical after one-trial paired-associate learning.

All three measures used lend evidence to the inverse relationship between number of errors and distance from the target word suggested by Bugelski (1950). The overwhelming dominance of forward errors found by Bugelski was not apparent although more forward errors were made than backward. The mean number of errors per S in the forward direction was 7.86 compared to 4.87 errors in the backward direction. However, even this difference may be an artifact of the task, as the number of errors coming from the end of the list was greater than the number from the beginning; therefore, this difference may be due to response bias.

Experiment I and the Young et al. study have provided data about
forward and backward associations early and late in serial learning and distribution of errors early in serial learning. Experiment II was designed to investigate error distribution late in serial learning, probing a completely learned serial list. For this purpose, the three probes of the first experiment appeared useless; it seemed unlikely that use of traditional probes would produce any errors in a learned serial list. The probe that was chosen was the missing scan. The missing scan has been found by Buschke and Hinrichs (1968) to produce an inverse relationship between number of errors and distance from the target item in the set of numbers 13-25; i.e. on error trials Ss guessed closer to the missing number than would be expected if they guessed randomly. Humphreys and Schwartz (in preparation) have found that the missing scan produced 'error generalization' in Bousfield categories and in learned categories; i.e. on error trials Ss guessed within the category of the missing item. In addition, the missing scan, like the probe and unlike paired-associate transfer paradigms, is a direct test of serial learning; the missing scan is not a learning paradigm.

Experiment II

Method

Design. The design was a missing scan probe of a learned serial list. In the serial learning, each S received 15 observation trials on a ten-word serial list; a test trial followed each set of three observation trials. Then each S on each trial was presented with nine of the ten words from the serial list followed by a subtraction
problem. After completing the subtraction problem the S was required to report which word had not been presented. In all there were 30 missing scan trials. The missing word was chosen at random with the restriction that each word must be missing once in each set of ten trials. The nine words presented on each trial were randomly arranged.

**Materials.** For the serial learning, ten unrelated one-syllable words were chosen from the lists used in Experiment I. The words were randomly arranged to determine serial position; the words were presented with a standard carousel projector.

Lists for the missing scan were tape recorded, using the serial learning words and three digit subtraction problems. The words were recorded at one word per second; recording time for each subtraction problem was three seconds.

**Subjects.** Fifty Ss were recruited from the subject pool used in Experiment I; there were two sessions of group testing.

**Procedure.** Upon entering the experimental room Ss were given answer booklets containing five pages for serial learning test trials and one page for missing scan trials. For the serial learning Ss were instructed as to the successive presentation of the serial list and the study-test design. On test trials Ss were instructed to write down the words in order; upon completing each test trial, Ss were instructed to turn the page of the answer booklet. After all Ss had turned the page, E announced that the observation trials would resume. Words were presented at a 2 second rate with a 5 second interval between successive observation trials.
At the completion of the five test trials, Ss were read missing scan instructions. The instructions informed the Ss that each time the tape recorder was turned on, nine of the words they had just learned would be read in a random order and that the nine words would be followed immediately by a subtraction problem. They were told to first answer the subtraction problem, then to write down the word that was missing. Both a subtraction and a word answer were recorded on every trial.

Results

Six Ss were eliminated from the data analysis; one was eliminated for failing to learn the serial list by the fifth test trial and five, for failing to respond with both a subtraction and a word answer on all missing scan trials. For the remaining 44 Ss, the mean number of correct serial learning trials was 3.95 out of a maximum possible of five. In the missing scan, data from the subtraction problems were not scored because the subtraction problem was included to partially eliminate the effects of immediate memory. The number of errors in reporting the missing word over Trials 1-10, 11-20, and 21-30 were 208, 222, and 226, respectively.

Figure 7 contains graphs of percent correct and inverse percent correct as a function of serial position. Both graphs show relatively flat serial position curves.
Figure 7. Probability correct and inverse probability correct as a function of serial position in the missing scan.
The three measures of error distribution used in Experiment I were also used to determine error distribution in Experiment II. None of the three measures showed any indication of anything but a random distribution of errors in relation to the target word. Relative distance collapsed over trials and serial position of the missing item is given here as an example. As there were two cells on each trial that were relative distances of 1, 2, 3, and 4 positions away from the target word and only one cell that was a relative distance of 5 away from the target word, relative distances of 5 were corrected by multiplication by two. With this correction, the expected relative distance with random guessing was 3.00 and the expected number of errors at each relative distance was 151.20. The observed relative distance was 3.12, and the number of errors at relative distances 1-5 were 148, 149, 125, 134, and 200, respectively. A chi-square statistic determined before the correction \( \chi^2(4) = 14.07 / p < .01 \) showed that guessing did vary from random. However, most of the value of this statistic can be attributed to the abundance of guessing at a relative distance of five positions. As the relative distance of five positions always involved the first or last word in the learned serial list, relative distance was redetermined ignoring outputs of the first and last positions and trials where first or last positions were target positions. This correction left four possible relative distances with the relative distance of four containing only one cell per trial. Multiplication by two of values at relative distance of four left the expected relative distance at 2.50 and the expected
number of errors at each relative distance at 108.00. The observed relative distance was 2.42 and the number of errors at distances 1-4 were 120, 112, 116, and 84, respectively. A chi-square determined before the correction for unequal number of cells at the relative positions showed that guessing did not vary significantly from random ($\chi^2(3)=4.01/p>.20$).

**General Discussion**

In Experiment II both measures of probability correct show flat serial position curves. This result suggests that all items in the learned serial list have equal strength as responses. The flatness of the serial position curve for the present study is similar to that found by Buschke and Hinrichs (1968) where twelve of the numbers 13-25 were presented, and Humphreys and Schwartz (in preparation) where nine of the numbers 0-9 were presented. The statement of equal response strength over items in a learned serial list can apply only to performance on the missing scan. It is uncertain whether or not a more sensitive measure, such as reaction time for a traditional probe, would yield a flat serial position curve.

Although the missing scan shows correspondence between serial position curves for a learned serial list and a set of consecutive numbers, no such correspondence exists for the distribution of errors. That is, a learned serial list, unlike a set of consecutive numbers, fails to exhibit clustering of errors around the target word. The lack of error generalization in a learned serial list shows that a
set of numbers cannot be representative of a learned serial list. This is an important finding because a set of numbers can be and has been (Buschke, 1966, 1967) described in the terminology of serial learning. Also, a number of investigators (Slamecka, 1964; Schwartz, 1970) have assumed that a set of numbers can represent a serial list.

The argument may be made that the difference between a learned serial list and a set of consecutive numbers is simply degree of learning. However, in the present study this explanation seems unlikely for two reasons. First, all but one of 50 Ss learned the serial list by the fifth recall trial, and of the remaining 49, 36 learned it by the second recall trial. This degree of learning is higher than the degree of learning Humphreys and Schwartz have found sufficient to produce error generalization in learned categories. Second, the serial position curves (Figure 7) showed equal response strength for all items in the serial list; this result emphasizes that the serial list was learned to the point where it no longer exhibited a serial position effect.

In terms of the purpose of the present paper, the combined results of Experiments I and II provide data on the eliciting ability of three probes, the shape of the serial position curve, and the distribution of errors in relationship to the target word. In Experiment I, it was found that position, sequential, and backward probes had equal eliciting strengths after one presentation trial. It was also found that all three probes yielded typical bow-shaped serial position curves. Error distribution was found to be inversely related to the target word. In Experiment II the missing scan was used to
probe a learned serial list. It was found that the missing scan produced a flat serial position curve and that errors were randomly distributed in relation to the target word. These results have been discussed as phenomena of serial learning. It is now appropriate to discuss these results in terms of the current hypotheses of serial learning.

The equality of the three probes used in Experiment I suggests either that all three probes are the effective stimulus or that none of the three probes is the effective stimulus. In either case, both chaining and position hypotheses would be unable to predict the three probes’ equality. The chaining hypothesis would predict that the sequential probe would be the most effective elicitor, and the position hypothesis would predict that the position probe would be the most effective elicitor. A dual process, with both chaining and position-learning involved in serial learning, might allow for the equality of the three probes.

The results of Experiment I also indicate that a spatial array is not representative of a serial list. Murdock (1969), using points in a circular array as stimuli and words as responses, found that errors were randomly distributed in relation to the target word when distance from the target word was measured in spatial units. In Experiment I it was found that errors were not randomly distributed, but that they decreased as a function of distance from the target word. Both Murdock’s study and Experiment I used one trial presentations. However, before concluding that serial learning is not spatial, it
must be pointed out that there are two differences between Murdock's paradigm and the spatial discrimination paradigm used by Jensen and Rowher (1965) and Ebenholtz (1963). In the Murdock task, the spatial array was circular and contained 8 positions. The arrays used in the Ebenholtz and Jensen and Rowher studies were linear and contained 10 and 12 positions, respectively. The importance of these differences can only be known with further experimentation.

The results of Experiment I and the Young et al. (1963) study seem to lend some support to the double-function description of serial learning. It seems that a serial list does act like a paired-associate list in that the asymmetry of associations develops as a function of learning. However, it also seems that a set of numbers would act as a perfect model of a chained serial list. A set of 10 or 12 consecutive numbers would appear to involve the network of item-to-item associations that the chaining hypothesis postulates. Furthermore, like the chaining description of a learned serial list, a set of numbers exhibits (to some degree) the concept of remote associations (e.g. Slamecka, 1964) in which the strength of an association is a negative function of the degree of remoteness. Using the missing scan to probe a set of consecutive numbers, Buschke and Hinrichs (1968) have found an inverse relationship between number of errors and relative distance from the target. In any case, the chaining hypothesis offers no means for explaining the different types of error distributions produced by a learned serial list (Experiment II) and a set of numbers.

In conclusion, it has been shown that current representations
of serial learning are inadequate to explain the present data. It is suggested that major reformulations of old approaches or the use of entirely new approaches are necessary for a successful theory of serial learning. In particular, it is suggested that the following five criteria be used in constructing or evaluating theories of serial learning. First, a theory of serial learning should allow for the eliciting ability of position, sequential, and backward stimuli. Second, it should provide for some relationship between items in a serial list, i.e. it must account for the error distribution found in Experiment I. Third, it must predict the development of asymmetrical associations within a serial list. Fourth, if the theory must involve the concept of serial position as a stimulus, it is preferable that the position stimulus is not spatially represented. And fifth, a theory should be able to differentiate between a learned serial list and a set of numbers.
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