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What Is Learned in Serial Learning?[1]

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Serial learning is usually conceived of psychologically as the acquisition of a chain of S-R units: each item in the series is the stimulus for each succeeding item. With sufficient repetition the learner's own verbal responses become the only stimuli necessary to elicit each successive response. This simple and appealing conception of serial learning (if we ignore the unessential complications added by Hull) has prevailed to the present time. The only trouble is that, empirically, serial learning has not yielded to this particular analysis. As a result, the chief preoccupation of present researchers in this field has been the search, thus far without much success, for the so-called "functional stimulus" in serial learning. The problem was first noted by Primoff (1938), who, in studying transfer from paired-associate to serial learning, came to the following conclusion: "A serial response seemed to be different from and less difficult to establish than a chained series of its component connections; a serial association differed from a series of S-R bonds" (1938, p. 394). Full recognition of this problem was given by Underwood (1963) in his review and discussion of the relevant research, the gist of which is that the sum of the experimental evidence shows the S-R chain formulation to be either totally incorrect or at best far from adequate.

This formulation fails most drastically in its power to make predictions concerning transfer between serial and paired-associate learning. While the usual interpretation of the S-R chain theory must lead to the prediction of a substantial amount of positive transfer from serial to paired-associate learning (and vice versa) when both lists have a number of S-R units in common, in actual fact, no appreciable transfer occurs under these conditions. Since much of this evidence has been previously summarized in Underwood's paper as well as in previous articles (Jensen, 1962; Keppel and Saufley, 1964), it need not be reiterated in detail. It all highlights the central question: If what is learned cannot be conceptualized adequately as a chain of S-R units, then just what does take place in serial learning? What would constitute a satisfactory psychological model of serial phenomena?

The S-R chain theory of serial learning has also been criticized on more purely theoretical grounds by psychologists who have been critical of S-R formulations in general. The most elaborate and far-reaching discussion of serial phenomena in non–S-R terms is the paper by Lashley (1951). Though Lashley pointed out many of the difficulties an S-R theory would have to encounter in dealing with serial learning, he did not propose any clear alternative theory. His emphasis, however, seemed to be on central integrative processes which organize sequential behavior and which are not highly dependent upon a sequential input of conditioned stimuli. A more explicitly Gestalt approach to serial learning has been advocated by Asch, Hay, and Diamond (1960), whose experiments in this field have emphasized the spatial and

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configurational properties of the serial list. Their suggestion that serial *position* may function as a "cue" can, of course, be quite divorced from Gestalt conceptions and can be comprehended within the S-R framework and subjected to experimental test.

This is precisely the concern of the present study: does serial *position* per se, or some symbolically mediated equivalent thereof, act as the functional stimulus in serial learning? Since there have also been previous attempts to answer this question, a review of the current situation is in order. The state of research on this topic has grown quite complicated, and it will be easier to summarize if we adopt a consistent terminology and organize the details by means of some simple schemata.

The Major Hypotheses

Sequential Hypothesis. There are three major S-R hypotheses concerning what is learned in serial (Ser) learning. The first will be labeled the *sequential* hypothesis. It states that each item in the list is the functional stimulus for each adjacently succeeding item; and it assumes that, as learning takes place, the learner's verbal responses themselves become the stimuli for successive responses.

This hypothesis, or an elaboration of it which will be called the *compound sequential* hypothesis, has been the prevailing conception of Ser learning. The *compound sequential* hypothesis states that two or more of the preceding items serve as the effective stimulus for each successive item in the series. It is usually assumed that the more remote one item is from another in the series, the weaker is its stimulus function. Backward associations are also assumed to occur and to result in some degree of response competition or interference with the forward associations.

Position Hypothesis. The second major conception will be labeled the *position* hypothesis. It states that what is learned are associations between the items and their ordinal positions. One difficulty with this conception which is seldom recognized is how *position* acts as the functional stimulus, since in the usual anticipation method of Ser learning, in which each item appears singly in one window of the memory drum, serial position per se has no objective stimulus characteristics. Therefore, if position is to be regarded as the functional stimulus, one of two assumptions must be made: either absolute temporal position acts directly as the stimulus, or the temporal order gives rise to some symbolically mediated representation of serial position. The first alternative seems highly improbable, since alteration of the pacing interval in the course of Ser learning has not been shown to produce large decremental effects on performance; under certain conditions it can even facilitate performance. The second alternative, therefore, seems more tenable. Exactly how temporal order might mediate serial position is an open question. Mediation could take the form of temporal position eliciting the ordinal numerals in the learner; the numerals then serve as the "stimuli" for the "paired-associate" learning of the items in the list. Something of this nature was proposed by Schulz (1955), who required *S*s, immediately after learning a serial list, to designate the ordinal number of the serial position occupied by each syllable when the syllables were presented in a random order. The *S*s were able to designate ordinal position, and their accuracy was a function of serial position, the middle positions being the most difficult. If what the *S* had actually learned was an S-R connection between ordinal position and syllable, Schulz's task would represent a test of the formation of backward associations, since the syllables were given as the stimuli for the responses of naming ordinal position. On the other hand, it is possible that such associations are not acquired during the course of Ser learning, but once the list is mastered the *S* may be able to mediate these connections through his "knowledge" of the list, whatever that may consist of psychologically.

Dual-Process Hypothesis. The third major formulation, which grew out of discouragement with the two previous ones and which is a combination of the two, is called the *dual-process* hypothesis. In its simplest form it states that both sequential *and* positional associations are acquired in Ser learning. As a result of certain empirical findings, which are apparently in conflict, however, there are now two versions of the dual-process hypothesis. The first, suggested by Young, Patterson, and Benson (1963), states that the extremes of the Ser list are learned predominantly by sequential associations while the middle items are learned predominantly by positional associations. The second version, suggested by Ebenholtz (1963b), states just the opposite, viz., that position learning occurs predominantly at the extremes and sequential learning occurs in the middle of the list. The associations assumed by either version of the dual-process hypothesis are not regarded in an all-or-none fashion. Both sequential and positional associations can be assumed to occur throughout the entire list; the disagreement concerns their relative strengths in various parts of the list.

Experimental Paradigms

The hypotheses outlined above have been subjected to a considerable number of experimental investigations, all of which, however, may be classified under three general transfer paradigms. We will describe each paradigm, along with the associated findings.

Transfer from Paired-Associate to Ser Learning. The evidence from this paradigm, based on the traditional procedures of paired-associate (PA) and Ser learning, is largely negative, though there have been instances of a moderate degree (35–55%) of positive transfer (Young, 1959; Jensen, 1962). It can be argued, however, with some empirical support (Jensen, 1962), that PA to Ser transfer depends upon *S*'s transferring his *set* for PA learning to the Ser task. When *S*'s tendency to regard the Ser list as a continuation of the PA task is experimentally hindered, transfer does not occur, even though *S* is fully informed of the relationship between the PA and Ser lists.

The latest evidence from the PA to Ser paradigm is an experiment by Young, Milaukas, and Bryan (1963) which provides some interesting new facts. Young *et al.* varied the degree of prior PA learning (15 trials versus 30 trials) and used both positive and negative Ser transfer tasks (Group P and Group N). For Group P all the adjacent items in the Ser list were previously practiced as PAs. For Group N there was no correspondence between the PA and Ser adjacencies. Control *S*s (Group C) practiced a PA list in which both S and R terms consisted of entirely different adjectives, and then learned the same Ser list as presented to Groups P and N. Generally, Group P showed no significant transfer, although the subgroup which had 30 prior PA trials showed significant ($p < .05$) transfer (28%), while the subgroup which had only 15 prior PA trials showed no significant transfer. It should be noted that the Control Group in this experiment received the Ser list without prior response learning. If the Ser items had been prefamiliarized in the Control Group, it is possible that no transfer at all would have materialized. The transfer found by Young *et al.* represents a savings of only 2 out of approximately 7 trials needed to attain criterion; at least one of these trials might be assumed to be needed for the response-acquisition phase of the rather difficult list of adjectives used in this experiment. It is advisable in this type of experiment that the Control Group either be prefamiliarized on the items in the transfer list or that the list be composed of items which involve very minimal response learning, such as high-frequency one-syllable words.

The other major finding of this study by Young *et al.* is that Group N (both the 15 and 30 trial conditions), as compared with the Control Groups, showed highly significant ($p < .001$) *negative* transfer (approximately —55%).

Ebenholtz (1963b) used the PA to Ser paradigm to investigate the positional hypothesis. The stimulus item of each pair consisted of a particular position in a vertical array of small "windows." The particular window to which *S* was to respond was indicated by the appearance of a red patch in the window; the response item (nonsense syllable) which followed after 3 sec would appear in the same "window." The ten items were presented in a more or less random order and *S* had to learn to associate each response item with a particular spatial position. One of three transfer tasks followed: (*a*) a Ser list in which the temporal serial order of the items corresponded to their spatial order in the PA task, (*b*) a Ser list in which the response terms had no systematic relationship to the spatial array, and (*c*) a Ser list in which the *sequence* of the items corresponded to the order of the items in the spatial array but the *positions* of the items in the Ser list did not correspond to their positions in the spatial array. Ebenholtz found that transfer condition *a* was superior to *b* and *c*, which did not differ significantly from each other. Since there was no proper control group, and since conditions *b* and *c* could be interpreted as negative transfer paradigms, it cannot be said for sure whether condition *a* produced any position transfer. Ebenholtz estimated the percentage of transfer by comparing performance on the same task by another group of *S*s which had received no previous warm-up task. We know that warm-up and generalized practice effects from first to second task are very great; for example, Young, Patterson, and Benson (1963) found that a second, unrelated Ser list took only about half as many trials for mastery as the first Ser list. Thus, the transfer reported by Ebenholtz (77% for condition *a* and 41% for condition *b*) is undoubtedly grossly overestimated. Since the relative degree of transfer was greatest at the ends of the list and least in the middle, Ebenholtz concluded in favor of a dual-process hypothesis in which the extremes of the series are learned predominantly by positional associations, and the middle items of the series, where discrimination of position is presumably more difficult, are learned predominantly by sequential association. Again, without the proper control groups, this conclusion cannot be very firm. At most, what the PA to Ser paradigm in the Ebenholtz experiment does show is that it is possible for spatial position to *mediate* transfer to a Ser list. Thus, spatial position might serve as a mediating link between temporal-order cues and responses in Ser learning.

Transfer from Ser to PA Learning. This paradigm overcomes the objection just pointed out in connection with PA to Ser transfer. If Ser learning transfers positively to derived PAs, it must mean either that specific sequential connections have been acquired in Ser learning or that *S*s can rapidly repeat the Ser list to themselves to "find" the required response term for each PA.

Ser to PA transfer has always produced less apparent transfer than PA to Ser. For example, the Ebenholtz procedure described above was reversed to form the Ser to PA transfer situation (1963b). Under the condition producing the highest transfer (i.e., perfect congruence between serial position and spatial position) there was only 46% transfer, as contrasted to 77% transfer in the corresponding condition of the PA to Ser paradigm. Again, there was no proper control group and 46% is almost certainly an overestimate of the amount of transfer, for the same reason mentioned previously.

In short, the literature contains no bona fide demonstrations of significant positive transfer in the Ser to PA situation. In one study by Young (1962), even 10 trials of overlearning of the Ser list produced no transfer. Young also tested the compound sequential hypothesis by using two adjacent items from the Ser list as the stimulus terms in the PA transfer task, but this only produced slight negative transfer. Young concluded that both in terms of trials to criterion and number of correct responses ". . . prior serial learning retards subsequent PA learning" (1962, p. 310).

Could it be that in going from a Ser to a PA list *S*s try to transfer their knowledge of the Ser list to the PA task by tacitly going through the Ser list until they get to the stimulus item of the PA and thence to the required response? The *S*s reported attempting this strategy (Erickson, Ingram, and Young, 1963) and attributed the failure of transfer to the fact that the PAs were presented at a rate too fast to permit consistently successful mental scanning of the Ser list. To determine the degree to which this strategy, if actually operative, might be facilitated by slowing the rate of presentation of the PAs, Erickson *et al.* had *S*s first learn a Ser list (14 adjectives) at a 1.5-sec rate and then learn the list of derived PAs at one of three rates: 1.5:1.5, 2:2, or 4:4. Comparisons with the appropriate controls for the three rates of presentation revealed neither significant over-all transfer nor a significant increase in transfer as a function of presentation rate. The serial-position data revealed transfer only on the items in the last two positions of the Ser list; there was zero transfer for the items at the beginning of the series and negative transfer for the middle items. These findings seem to contradict the implications of the strategy which *S*s purported to use in the Ser to PA situation. But there is an important detail of the procedure used by Erickson *et al.* which might well have stacked the cards against the success of the *S*s' purported strategy, viz., only half the items in the PA transfer list consisted of PAs derived from adjacent items in the prior Ser list; the other PAs in the list were entirely new. Under these conditions it seems not unlikely that the strategy reported by the *S*s proved to be too inefficient (at best it could mediate only half the PAs) and was therefore quickly abandoned.

Transfer to a Derived Serial List. In this paradigm the learning of the original Ser list is followed by the learning of a second Ser list which is different from, but in some way related to, the first list. Probably because it has the advantage of not forcing the *S* to change his set from a Ser to a PA procedure, it has been adopted in several of the most recent investigations, particularly those concerned with the role of serial position as the functional stimulus.

Ebenholtz (1963a) used variations of this paradigm in two experiments designed to test both the sequential and positional hypotheses. In one experiment a Ser list was presented to one group in the usual manner. Another group received the same list, but each trial always began at a different place in the series; thus the sequence of items remained the same from trial to trial, but the position of the items with respect to the intertrial interval varied from one trial to the next. Learning was significantly slower in the second condition, as would be predicted from the position hypothesis. The *Ss* in the second condition, being deprived of position cues, were *forced* to learn the series sequentially, and we know that such learning, of which PA learning is an instance, is generally more difficult than Ser learning. Others have used essentially the same procedure, with minor variations, and found the same result (Bowman and Thurlow, 1963; Winnick and Dornbush, 1963). So a point is scored in favor of the positional hypothesis. It would have been interesting in the Ebenholtz experiment to have had both groups finally learn a derived PA list; one would predict that the condition of Ser learning in which position was varied would produce markedly greater transfer to the PA list than the constant-position condition.

In another experiment, Ebenholtz (1963a) tested the positional hypothesis as follows: Group I learned Ser List 1 followed by Ser List 2, as indicated below (*K* represents new items).

List 1: A B C D E etc.

List 2: K_1 B K_2 D K_3 etc.

The old items retained the same positions in List 2 that they had held in List 1. Group II learned first a Ser list composed of the same items as List 1, above, but in a different order, and then learned List 2; the relationship between the lists was such that the old items in List 2 were four positions removed from the positions they held in the prior list. A control group learned first an equivalent but irrelevant list and then learned List 2. The results clearly showed faster learning only for those items in List 2 which retained the same position they held in List 1. [Essentially the same experiment was performed earlier by Young (1962, Exp. III), with results which lead to essentially the same conclusions.] These results, however, still do not rule out the sequential hypothesis. A good reason for this reservation concerning these findings which seem to favor the position hypothesis is that the results can also be explained in terms of the sequential hypothesis by assuming that every other response (i.e., the old items) in List 2 was mediated by the associations learned in List 1. The highly systematic and simple relationship between Lists 1 and 2 should not have made such mediation at all difficult.

An experiment intended to overcome this weakness was performed by Keppel and Saufley (1964). In the List 2 used by Keppel and Saufley some of the items retained the same positions they held in List 1, but not in any systematic pattern that could be readily transposed or mediated from List 1 to List 2. However, the results were essentially the same as Ebenholtz's; more items in constant positions were given correctly in 10 transfer trials than items in different positions. Most of the transfer was attributable to the items at the ends of the lists, which agrees with Ebenholtz' conclusion that position learning is more pronounced at the extremes and weakest in the middle of the list. Thus it seems probable that sequential mediation is not an adequate explanation of the positional transfer found in these experiments. It is interesting that, while constant position resulted in positive transfer, changed position did not result in more intrusion errors based on position. Overt errors were predominantly due to sequential associations, that is, they resulted largely from sequential transfer from List 1 and not from positional transfer. Sequential transfer means that stimulus n in the transfer list is followed by response $n + 1$ from the original list. It would appear that if sequential associations are formed in Ser learning, they are incidental and may create interference and intrusion errors in a negative transfer paradigm, without producing any appreciable positive transfer in a positive paradigm.

For reasons that are not at all clear, the positional hypothesis fared less well in a series of experiments by Battig, Brown, and Schild (1964). They used the Ser_1 to Ser_2 paradigm, with three variations of List 2: (*a*) 3 of the items (of a 12-item list) maintained the same positions and the same sequential adjacencies as in List 1, (*b*) 3 items maintained the same sequence but held different positions, and (*c*) 3 items maintained the same positions but the sequence was not maintained. Degree of List 1 learning and the location (beginning or middle of the list) of the crucial 3 items were also varied. While some aspects of these experiments are difficult to interpret, Battig *et al.* were able to conclude quite definitely that there was ". . . complete lack of support . . . for direct associations of individual items with their serial positions as a principal mechanism of serial learning." There was no facilitation of items appearing in the same serial position unless the items were also sequentially adjacent. Conditions *a* and *b* both resulted in greater transfer than condition *c*, a finding which is consistent with the sequential but not with the positional hypothesis. Other aspects of the findings suggest that different processes might play different roles at various stages of practice. A question which was not raised by Battig *et al.*, but which seems pertinent, is whether their results might easily be explained by the possibility that the cluster of 3 items retaining the same sequence creates a kind of von Restorff effect. The isolation effect would not be so great for the same three items appearing at separate positions in the list.

"Backward" Ser Learning. If Ser_2 consists of Ser_1 in reverse order, the sequential and positional hypotheses should have different implications regarding the amount of transfer as a function of serial position, or so it has been argued by Young, Patterson, and Benson (1963). Since the middle items would be changed least in position, the position hypothesis would predict relatively greater positive transfer in the middle of the list and possibly negative transfer at the extremes. Assuming the existence of backward associations, the sequential hypothesis would predict either approximately equal transfer throughout the series or greater transfer at the extremes due to relatively greater overlearning of the associations between items at the extremes. To test this hypothesis Young *et al.* performed the appropriate experiment and found the result predicted by the position hypothesis. Though the overall transfer was not statistically significant, the middle positions did show significant positive transfer. While these results are quite clearcut, they are nevertheless quite puzzling in view of the fact that other paradigms have suggested that positive transfer occurs at the extremes of the list.

Instructional Variables

In all but one of the transfer experiments we have reviewed (Jensen, 1962), *S*s were never informed of the nature of the transfer situation. An experiment by Winnick and Dornbush (1963), in which the starting point for a continuous serial list varied from trial to trial, showed that instructions to the *S* indicating the possibility of a shift in starting position was a significant variable in speed of learning. In a transfer situation instructions would seem even more crucial, and we believe it is a methodologically important point in research on this problem that all *S*s be made fully aware of the transfer aspect of the experiment. Otherwise the possibility exists that differences in the amount of transfer obtained by different paradigms and with different learning materials might be due to differential tendencies of various conditions to elicit self-instructions which may affect degree of transfer.

The present experiment, based on the Ser to PA paradigm, was designed to obtain further evidence concerning the relative and absolute amounts of transfer of sequential and positional cues in Ser learning.

METHOD

Design

The principal aim of the experiment was to measure the amount of transfer from a Ser list to a PA list under two different conditions of PA learning. In one condition of PA learning, *Pos.* (position learning), serial position alone served as the stimulus item of each pair. The *S*'s task was to learn to associate each response item with a particular serial position. The other condition, *seq.* (sequential learning), consisted of a derived double-function PA list in which each item of the prior Ser list served as the stimulus for its immediately succeeding item. Here the *S*'s task was to learn the derived PAs by the usual anticipation method.

The standard transfer design was used, with each condition of PA learning having an appropriate control group. Thus there were four groups in all: the Position Transfer group (Pos. T), the Position Control group (Pos. C), the Sequence Transfer group (Seq. T), and the Sequence Control group (Seq. C).

Materials

Since it seemed desirable to minimize the time spent in response learning in the present experiment, the 12-item Ser list (Task 1) for the transfer groups and the derived 12-item PA lists (Task 2) for both the transfer and control groups consisted of high frequency three-letter words with no initial letters duplicated: END, JOY, MAN, HAT, WIT, PIE, SUM, GAS, TIP, NET, ART, and BED. The 12-item Ser list (Task 1) for the control groups consisted of trigrams matched with the word list for trigram frequency (based on the table of trigram frequencies in Underwood and Schulz, 1960, pp. 326-369) and also having no duplicated initial letters: COM, REL, ZIN, VEN, EST, FAC, TIS, MUL, PIM, NOP, BOT, and DAL. The Ser lists were preceded by a set of three asterisks which also served as one of the stimulus items in the derived PA list of the Seq. conditions.

Procedure

All lists were presented on a memory drum. The Ser lists were presented at a 2-sec rate with a 2-sec intertrial interval. The PA lists were presented at a

2:2 rate; there were three different orders of presentation of the pairs. In all conditions *S*s were required to attain a criterion of one errorless trial. The time elapsing between successive tasks was about 2 min, which allowed *E* to change the tape in the memory drum and to read the instructions for the next task.

Task 1 (Ser List). The *S*s were instructed to learn by the anticipation method. On the first presentation of the list for all groups, *E* pronounced the items aloud. (The purpose of this procedure was to insure more or less uniform pronunciation of the trigrams.)

Task 2 (PA List), Group Pos. T. In this transfer condition the stimulus item of each pair consisted of a horizontal row of 12 frames ("boxes"), one of which contained a bright red dot. The particular position indicated by the dot in the set of 12 frames was considered the stimulus to which a particular word had to be associated. Following the 2-sec presentation of the set of frames containing the red dot, the frames were presented again for 2 sec, this time with the appropriate response printed in the previously designated frame.

Just before Trial 1 the *S* was shown a set of completely empty frames and *E* explained the relationship between Task 1 and Task 2: "Each of the words in the series you just learned has been paired with one of the 12 boxes arranged in a row like this. The first word in the series has been paired with the first box in the row [*E* points to the "box" on the *S*'s extreme left], the second word with the second box, the third word with the third box, and so on to the last word with the last box in the row [*E* points to the "box" at *S*'s extreme right]. Thus there are 12 pairs of boxes and words." This was followed by an explanation of the function of the red dot as the positional stimulus, along with the usual instructions for PA learning by the anticipation method. The *S*s began anticipating on the first presentation.

Task 2 (PA List), Group Pos. C. In this control condition the materials and procedure were identical to those of the transfer group, except, of course, that the instructions had to be modified as follows: "Each of the words in a series of 12 has been paired with one of 12 boxes arranged in a row like this. Thus there are 12 pairs of boxes and words." From here on all the instructions were the same as for the transfer group. The *S*s began anticipating on the trial following the first complete presentation of the PA list.

Task 2 (PA List), Group Seq. T. Here the PAs were presented in the traditional manner, with the stimulus item appearing in the left-hand window of the drum, followed by the pairing of both stimulus and response items. As in the Pos. T condition, *S*s were explicitly informed of the relationship between Task 1 and Task 2: "Each of the words in the series you have just learned has been paired with the word that immediately followed it in the series. The asterisks are included so that there is a set of 12 pairs." This was followed by the usual PA instructions. The *S*s began anticipating on the first presentation.

Task 2 (PA List), Group Seq. C. This control condition received the usual PA instructions without reference to the prior Ser list. The *S*s began anticipating after one complete presentation of the list. In all other respects the materials and procedure were the same as for the corresponding transfer group.

Subjects

There were 80 *S*s in all, 20 *S*s in each of the four groups. All *S*s were female and were volunteers from summer session courses in a Catholic girls college. Fifty-three of the *S*s were lay students and 27 were Catholic sisters. Their mean age was 23 years, 8 months; $SD = 6$ years, 8 months. Each *S* was assigned to one of the four groups cyclically in the order of their appearance at the laboratory.

RESULTS

Over-all Transfer

Ser to PA. Table 1 presents the mean trials to criterion for each of the conditions of the experiment. It is immediately clear that the transfer (T) and control (C) groups do not differ by many trials on the transfer task for either the Pos. or Seq. condition. The percentage of transfer was measured by the standard formula: % Transfer $= 100 \times (C - T)/C$. The Pos. condition resulted in 2.6% transfer; the Seq. condition produced negative transfer (— 10.9%). These amounts

TABLE 1
MEAN TRIALS FOR MASTERY OF SERIAL AND PAIRED-ASSOCIATE TASKS

	Task 1 (Ser)		Task 2 (PA)	
Group	*M*	*SD*	*M*	*SD*
Pos. T	14.10	7.45	14.85	9.37
Pos. C	15.90	6.82	15.25	7.46
Seq. T	13.05	6.31	23.25	9.32
Seq. C	15.30	7.87	20.95	9.33

of transfer are indeed minute, and analysis of covariance shows them to be totally lacking in significance. In the analysis of covariance the control variable was trials to criterion on Task 1, which were converted to *T* scores within the T and C groups separately, so that each group's mean was 50, with a *SD* of 10. (This *T* conversion was necessary, since Task 1 was different for the transfer and control groups.) The covariance analysis revealed a highly significant Methods (Pos. *vs.* Seq.) effect ($F = 16.38$, $df = 1/75$, $p < .001$), but no significance ($F < 1$) for Groups (T *vs.* C) or for Methods $\times$ Groups ($F < 1$). Since the Methods means differ, and since percentage transfer is based on relative savings in the transfer groups as compared with the control group, it could be that while the *absolute* differences between T and C within each Method are not significantly different, the methods might show a difference in the *proportion* of C/T. In other words, a distinction is made between *absolute* and *relative* amounts of transfer. The relative differences can be tested for significance by analysis of variance simply by transforming the data to $\log_{10}$, or, if the data include zeros, to $\log_{10}(x + 0.5)$. When the data are thus transformed to a log scale, differences may be interpreted as ratios. The $\log_{10}(x + 0.5)$ transformation was performed on the data used in the first analysis and the analysis of covariance was carried out on these transformed data. The results remained essentially unchanged; Groups and Methods $\times$ Groups were nonsignificant sources of variance ($F < 1$ in both cases).

Transfer on Trial 1. Since transfer effects might rapidly dissipate with successive learning trials, possibly due to an increase in interference tendencies, the methods of learning were compared for amount of transfer on just the first learning trial of Task 2. The percentage of transfer for the Pos. method was 28.5; for the Seq. method, 23.1. An analysis of variance applied to the Trial 1 data showed that there was significant transfer on Trial 1 for both the Pos. and Seq. methods, but the amounts of transfer in the two methods did not differ significantly. It should be pointed out that some, possibly all, of Trial 1 transfer might be attributable to response learning rather than to the associative aspect of the prior Ser learning.

Transfer as a Function of Stage of Learning

Since the Trial 1 data of Task 2 revealed significant Ser to PA transfer, it was decided to analyze amount of transfer as a function of stage of learning. For this purpose, the number of trials needed to attain successive criteria (from 1 to 12 correct anticipations) was obtained for every *S*. Since these data are constrained by the fact that the series must necessarily increase from Criterion 1 to Criterion 12, a condition which makes analysis of variance impermissible, the data were converted to difference scores, i.e., the number of trials needed to go from one criterial level to the next, rather than the number of trials needed to attain each criterion. To obtain greater stability, these scores were summed for each *S* over criteria 1-4, 5-8, and 9-12, thus yielding a point for each one-third of the total trials to criterion. The means of these points for the various groups were used to obtain the percentage of transfer $[(100 \times (C - T)/)]$ at each of the three stages of learning. The results are shown in the left half of Fig. 1.

The data from which the percentage transfer was determined were subjected to analysis of variance, first in raw scores form and then as transformed to $\log_{10}(x + 0.5)$, to test absolute and relative transfer for significance. The analysis shows that the amount of transfer differs significantly ($p < .01$) as a function of the stage of learning. As can be seen in Fig. 1, practically all the positive transfer occurs in the first stage of learning (i.e., in the first one-third of the trials needed to attain criterion). Both analyses agree in showing no significant differences between the Pos. and Seq. conditions in over-all amount of

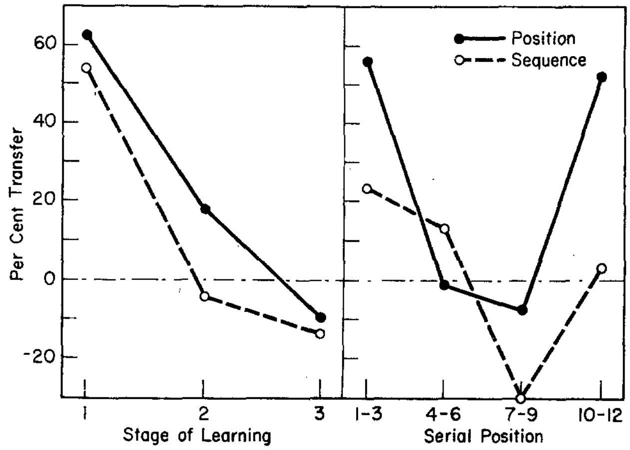

FIG. 1. Percentage transfer as a function of the stage of learning and of serial position (see text for full explanation).

transfer or in the amount of transfer as a function of stage of learning.

Transfer as a Function of Serial Position

Anticipation errors (overt errors + omissions) in Task 2 were analyzed as a function of their serial position in Task 1. To gain stability, the data were combined for positions 1-3, 4-6, 7-9, and 10-12. The percentage transfer as a function of position is shown in the right half of Fig. 1. Again, analysis of variance of these data showed no appreciable difference between the Seq. and Pos. methods in amount of transfer. The Positions × Groups interaction, being nonsignificant for the raw data and highly significant ($p < .01$) for the log-transformed data, indicates no difference between positions in absolute transfer but very significant differences in *relative* (percentage) transfer, as is indicated by Fig. 1. The Pos. and Seq. methods did not differ in the degree to which they show transfer as a function of serial position. The situation is quite clear in Fig. 1, and agrees perfectly with the stage analysis: items learned in the earlier trials are generally those in positions 1-3 and 10-12, and these are the positions showing the greatest transfer.

DISCUSSION

The present experiment was not intended to answer the question proposed in the title of this article, which, of course, is a theoretical problem and not an empirical one. Current hypotheses, however, do attempt to answer this question, and they lead to predictions which the present experiment was designed to test. The results indicate that the currently favored position hypothesis is hardly more adequate than the sequential hypothesis, which, as in many previous studies, again proved patently inadequate. And if the dual-process hypothesis is conceived of merely as the *summation* of positional and sequential learning, it, too, must be regarded as lacking, for the sum of two zeros is still zero.

Why is there no significant over-all transfer from Ser to PA learning for either the Sequential or Positional method, despite the fact that both methods clearly show positive transfer in the first few trials?

At least two essentially different types of explanation may be entertained.

(a) Any one or a combination of the above hypotheses is basically correct, but massive interference builds up in the second task which completely counteracts the associations that would make for positive transfer. It might even have to be assumed that, for some as yet unknown reason, these interference tendencies are greater in the transfer group than in the control group, since they must overcome the initial positive transfer. This hypothesis cannot be evaluated further until we know more about the variables of which interference in second-task learning is a function, particularly in the Ser to PA paradigm. Headway in solving this problem might be made by having Ser to PA transfer experiments in which the degree of associative interference is manipulated by the selection of list items, by varying the procedures of first-list learning, and by grouping *S*s on the basis of individual differences in susceptibility to interference effects as established by performance in prior learning tasks. Since the von Restorff effect might be due to the relative immunity of the isolated item to interference effects within the list, for example, it would be interesting to know to what degree the von Restorff effect would transfer from a Ser to a PA list.

(b) The class of alternative hypotheses would state that Ser learning cannot be explained adequately by any of the previously described S-R hypotheses, but that it consists of something sufficiently different from the processes involved in PA learning, of either the sequential or positional type, as to lead to the prediction of no transfer from Ser to PA learning. The ephemeral position transfer occurring in the first few learning trials would be attributed to the *S*'s attempt to maintain the *set* of the previous task or to the incidental learning of associations in the first task which the *S* tries to "use" in the second task. The maintenance of set or the intentional transfer of incidental learning, the argument continues, is so inappropriate to the second task, or so in conflict with the "natural" way of learning the second task, as to actually constitute an *interference* condition, which forces the *S* to abandon this approach and to learn the second task in the same manner as the control group. Thus the transfer group would show no overall advantage and might even show some negative transfer from having wasted time with an ineffectual strategy.

If the second alternative, which seems to be the most reasonable general conclusion to be drawn from all the available evidence, is favored, there remains the problem of how to conceptualize Ser learning. One possible approach, discussed in greater detail elsewhere (Jensen, 1962), would be to regard Ser learning as essentially a process of response integration rather than as the acquisition of specific S-R associations. (A similar notion was originally suggested by Lashley, 1951.) An integrated response in this sense, for example, would be the reproduction of a digit series comprehended by the memory span in a single trial. When the number of items in the series exceeds the memory span, more than one trial is needed to attain the integration of the series. But psychologically this would not be conceived of as the acquisition of specific S-R connections among the items in the series. So far this idea has not been sufficiently formalized or detailed to have much predictive power for specific experimental outcomes. Indeed, the further elaboration of this hypothesis must precede the development of an appropriate experimental program. It seems hardly necessary that we should continue to be abashed by repeated demonstrations of empirical outcomes which current theories are obviously unable to predict and for which they must intemperately strain to produce even *ad hoc* explanations.

Summary

A transfer experiment was performed under conditions that would permit *S*s who first had learned a serial list to a criterion of mastery to "use" either ***positional*** associations or *sequential* S-R associations in the subsequent learning of paired associates (PAs) formally comprised of the same S-R connections existing in the piror Ser list. The principal results were as follows: (a) There was no significant over-all transfer from Ser to PA learning, in terms of total trials to criterion, for either the Positional or Sequential conditions. (b)

There was significant Ser to PA transfer for both conditions only in the first third of the trials to criterion, after which transfer rapidly declined to zero. The Positional and Sequential conditions did not differ significantly in this respect. (c) The percentage of transfer is significantly related to serial position; those items at the beginning and end of the Ser list show positive transfer and those in the middle show zero or negative transfer.

The results were interpreted as supporting neither the position association nor the S-R "chain" association conceptions of Ser learning, and an alternative hypothesis was proposed for further consideration.

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