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Transfer between Paired-Associate and Serial Learning[1,2]

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The psychological differences between paired-associate and serial learning are probably far more profound than their formal differences would seem to suggest. Indeed, among S-R oriented psychologists the reaction to a number of studies which compare these two forms of rote learning has generally been one of surprise. The principal experimental investigations of the problem have been carried out by Young (1959, 1961a, 1962). Underwood (1961) recently reviewed the literature on the problem, including a number of unpublished studies, and has indicated their theoretical importance.

The traditional S-R conception of serial learning, which Young (1961a) refers to as the *specificity hypothesis,* represents serial learning as the acquisition of a chain of S-R associations. The stimulus for each successive response is assumed to be the item which immediately precedes it in the list. Thus, each item in the chain (except the first and last) is considered to have a *double function,* serving in turn as a response and as a stimulus.

This hypothesis that a serial list is learned essentially as a chain of paired associates (PA) implies that there should be a high degree of positive transfer from a previously learned serial list, A-B-C-D, etc., to learning a PA list, A-B, B-C, C-D, etc., even when the pairs are presented in a different order on each trial, as is usually done in PA learning. Conversely, a similarly high degree of transfer should be expected from a previously learned set of PAs, A-B, B-C, C-D, etc., to learning a serial list, A-B-C-D, etc. Now the main point of interest is the fact that the evidence clearly does not support these expectations. Briefly, as of now, the research presents the following points.

Transfer from a Serial to a PA List. Only a negligible amount of transfer has been found in going from a serial to a PA list in which the S-R elements are common to both tasks (Young, 1959, 1961a, 1962). For example, in Young's 1959 study, despite the fact that all the S-R elements were common to the serial and the PA tasks, there was only 8% transfer, a statistically nonsignificant amount. This is typical of Young's later findings. A significant amount of transfer appeared only in the first few learning trials, but the over-all transfer in these studies was practically nil. It was also found that 10 trials of overlearning of the serial list still did not result in significant transfer to the PA list (Young, 1962).

Transfer from PA to Serial List. Here the picture is quite different. There has generally been found a moderate degree of transfer from PA to serial learning when the S-R elements are common to both lists. Primoff (1938) found 35% transfer; Young (1959) found 55%. Since even this amount of transfer is less than one might expect, considering that the PA list was always learned to a criterion of mastery, Underwood (1961, p.

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18) has suggested that learning serial lists in the manner of a chain of PAs, though possible, may not be "natural" for the *S*. Transfer from the PA to the serial list is far less than perfect, perhaps, because in going through the serial list as if it were a chain of the previously learned PAs, the *S* must overcome some tendency to relearn the list in a different manner which is peculiar and "natural" to serial learning. The amount of transfer may reflect mainly the extent to which the *S* is successful in maintaining the *set* for responding to the serial task as if it were a PA task.

The present experiment is directly concerned with this problem. The main question is whether there is greater transfer from PA to serial learning when it is made relatively easy for the *S* to maintain the set for PA learning when going to the serial list than when it is made more difficult for the *S* to maintain his set for PA learning.

One other finding in the literature is quite relevant to the design of the present experiment. This concerns the difference between *double-function* and *single-function* PA lists. In a double-function list each item serves both as a stimulus and as a response, e.g., A-B, B-C, C-D, etc. In an single-function list the S and R terms are entirely separate, e.g., A-B, C-D, E-F, etc. Primoff (1938) was the first to note the great difference in difficulty of learning these two forms of PA task. The *S*s required two to three times as many trials to learn the double-function lists as they needed for the single-function lists. Young (1961b) performed an experiment which substantiated Primoff's findings and permitted a more generalized explanation of the phenomenon in terms of the known effects of intralist similarity on rate of learning: the rate of PA learning is inversely related to the degree of stimulus-response similarity. Primoff attributed the greater difficulty of learning the double-function than the single-function lists to the inhibitory effect of backward associations. This is also an empirically valid observation. In learning PAs such as A-B, B-C, etc., *S*s often give A rather than C as the response to B. These first-order backward associations rarely occur in serial learning, where the order of presentation is constant, probably because the *S* can remember the item one position back, since it has so recently been given as a response. Consequently, when *S* goes from a serial to a PA list of the double-function type, he is plagued by a source of errors—first-order backward associations—which he did not have to overcome during serial learning, with the result that positive transfer appears only on the first few trials of serial learning. Soon the errors of backward association overtake any initial transfer effect, and the total amount of transfer at the end of learning is practically zero.

That the inhibitory effect of backward associations in the double-function PA list is not the sole cause of poor transfer from serial to PA learning, however, is shown by an unpublished study by Young and Benson (cited in Underwood, 1961, p. 19), in which only a small amount of transfer occurred even when the PA task was a single-function list.

Findings such as these, which run counter to the expectations of the specificity hypothesis, have given rise to two alternative hypotheses: the *compound-stimulus hypothesis* and the *serial-position hypothesis*.

According to the compound-stimulus hypothesis, the functional stimulus in serial learning is not a single item but a compound of two or more items preceding the response term. Thus, the functional stimulus for D in the list A-B-C-D might be BC or ABC. Under investigation this hypothesis has fared no better than the specificity hypothesis. When *two* items in the learned serial list were used as the stimulus term in the PA transfer task, there was still no positive transfer (Young and Benson, unpublished, cited in Underwood, 1961, p. 19; Young, 1962). In the latter study there was even negative transfer!

According to the serial-position hypothesis, originally proposed by Woodworth and Poffenberger (1920, pp. 71-72), the functional stimulus in serial learning is the ordinal position, or some symbolic equivalent thereof, of each item in the list. The results of experimental investigations of this hypothesis seem to be conflicting [Rehula (Unpublished Ph.D. dissertation cited in Underwood, 1961, p. 21); Jensen and Blank, 1962; Young, 1962; Newman and Saltz, 1962]. Yet it appears from this evidence that whatever cue function serial position per se may possibly have, it is probably of minor importance, and Underwood's conclusion that the functional stimulus in serial learning has not as yet been identified still seems valid (Underwood, 1961, p. 22).

The purpose of the present experiment was to test the hypothesis that the "natural" way of learning a serial list is psychologically different from PA learning in that serial learning does not consist of chaining together successive pairs of S-R elements. According to this hypothesis, whatever transfer to serial learning results from the prior learning of a derived PA list (aside from generalized transfer effects such as warm-up, stimulus differentiation, and response integration) is due to the *S*'s tendency to carry over the "set" for PA learning to the serial list. Thus, there should be relatively less transfer from a PA list to a serial list when it is made difficult for *S* to maintain the "set" for PA learning. The *S* will then tend to learn the serial list in a manner peculiar to serial learning, resulting in less transfer from the prior PA learning than if the PA set were maintained.

METHOD

Design

Two experimental groups were compared for relative transfer from PA to serial (S) learning. Group PA(Odd)-S first learned a single-function list of PAs having the odd-numbered items of the derived 9-item serial list as the stimulus terms, thus: 1-2, 3-4, 5-6, 7-8. Group PA(Even)-S learned first the even pairs: 2-3, 4-5, 6-7, 8-9. The second task for both groups was, of course, the same serial list: 1 2 3 4 5 6 7 8 9. It was hypothesized that the Odd Group, for whom the serial list begins with a pair already learned (1-2), should find it easier to maintain the PA set than would the Even Group. Thus, if a different strategy exists for serial than for PA learning, the Even Group should be more prone than the Odd Group to lose the set for PA learning and to adopt the strategy of serial learning.

A Control Group learned the serial list first. In order to assess transfer from the serial to the PA list, some of these *S*s then learned the odd PA list.

Transfer due to response integration and acquisition per se was minimized by composing the serial and PA lists of colored forms, which in previous experiments have been shown to attain high response availability as soon as they have been described in the preliminary instructions to the *S*. Thus, practically all the learning that occurs with these stimuli involves only the associative phase of PA or serial learning. Since a preliminary study indicated that the PA task would have been too difficult for most *S*s if the pacing interval had been the same as in the serial learning (3 sec.), and since it was desired to have *S*s overlearn the first task to a rigorous criterion and yet not be unduly fatigued or suffer a motivational slump by the beginning of the second task, it was decided to use self-pacing in the PA task.

An aspect of procedure that is probably unique in PA-serial transfer experiments is that the *S*s here were clearly informed of the method by which the PA list was made up from the serial list (and vice versa), and in going from the first to the second task they were explicitly instructed to try to use the S-R connections they had acquired in the first task. The experiment was represented to the *S*s as a test to determine how well they could transfer what they learned in one situation to another. This procedure more or less insured that any failure of transfer to occur could not be attributed to the *S*'s failure to perceive the possibility for transfer from the first to the second task.

Subjects

The *S*s were 171 juniors and seniors (35 men and 136 women) recruited from an introductory course in educational psychology at the University of California. Three women were eliminated from the experiment for refusing to persist in the first task until they attained the criterion. Of the remaining 168 *S*s, all attained the criterion on both the first and second tasks. The number of *S*s in each treatment group was as follows: 25 in Group S—PA (Odd); 54 in Group PA(Odd)—S; 54 in Group PA(Even)—S. The serial learning data from a control group ($N = 35$) which learned only the serial list was combined with the serial data of Groups S—PA(Odd), and these combined data were used as the control (with $N = 60$) against which relative transfer was measured in the two groups (Odd and Even) going from PA to serial learning.

Procedure

The PA and serial lists were presented by two different apparatuses. The *S* sat a few feet in front of the apparatuses and could change from the apparatus used in the first task to that used in the second merely by turning 90 degrees in a swivel chair.

The stimulus items common to all tasks were colored forms—squares, triangles, and circles colored red, yellow, and blue. In the serial list from which the PAs were composed, each form appeared once in each of the three colors, and items of the same shape or the same color were never adjacent in the list. The color-forms appeared approximately 2 in. in size on the screen and the colors were vivid.

Instructions. All *S*s were told five things: (*a*) all the items to be learned would consist of color-forms (as described above) and items of the same shape or the same color would never be adjacent in the list; (*b*) the *S* was to learn by the anticipation method, by saying, for example, "red triangle," "blue square," etc., and guessing was encouraged from the first trial on; (*c*) *S* had to learn to a criterion of three consecutive errorless trials; (*d*) the serial task would be paced at a 3-sec. rate and the PA task would be unpaced (or self-paced); (*e*) the second task would be made up of the same S-R connections learned in the first task, for this was a test to see how well the *S* could transfer the first-task learning to the second task.

The procedure for PA learning or serial learning was exactly the same whether it was the first task or the second.

PA Task. The paired stimuli, first one and then the two together, appeared in two side-by-side ground-glass windows about 2 in. apart. On each trial the stimulus item was first presented alone in the left-hand window until the *S* made his anticipation and then the response term appeared in the right-hand window; the two items were displayed simultaneously for approximately 2 sec. and then the screen went blank for approximately 2 sec. before the next stimulus item appeared. The interval between the S and R terms was governed by each *S*'s own rate of responding. The order of presentation of the four PAs was different for every *S* and was random on every trial, with two exceptions: (*a*) the same pair was never repeated in immediate succession; and (*b*) every pair was presented once within each set of four presentations. The *S*s learned to a criterion of three successive errorless trials, each trial consisting of all four PAs.

When the PA task came first, immediately on attaining the criterion the *S* was told to turn to the other display panel and was reminded to try to transfer the PAs he had just acquired to the serial list about to be presented. The *S* began anticipating the serial list on its first presentation.

Serial Task. The 9-item serial list was always preceded by a green light as the signal for the first anticipation. The items were presented at a 3-sec. rate, with a 6-sec. intertrial interval. The *S*s learned to a criterion of three successive errorless trials.

When the serial task came first, immediately upon attaining the criterion, the *S* was told to turn to the other display panel and to try to transfer the S-R connections he had just acquired to the PA list.

Results

Since the primary concern was the *relative* amounts of transfer in the two experimental conditions [PA(Odd)—S and PA(Even)—S], no attempt was made to equate the experimental and control groups for generalized transfer effects such as warm-up and learning-to-learn, as would be necessary in order to establish the absolute amount of specific transfer. Since the two experimental groups did not differ in the first-task learning (PA), it can be safely assumed the generalized practice effects were the same for both groups.

Two measures of performance were used: number of trials to criterion (of three successive errorless trials) and the percentage of errors (100 $\times$ the ratio of errors to all opportunities for error).

The principal results of the experiment are summarized in Tables 1 and 2.

Transfer of Serial-Position Effect to Paired-Associate Learning

As shown in the lower half of Table 1, Group S-PA(Odd) learned faster than the corresponding control group (PA Odd); the differences both for trials to criterion and for percent errors are significant beyond the .001 level ($t = 3.34$ and 5.74, respectively).

TABLE 1

SUMMARY OF DATA ON LEARNING UNDER THE DIFFERENT CONDITIONS

Group	Trial 1 errors		Trials to criterion		Per cent errors	
	M	*SD*	*M*	*SD*	*M*	*SD*
			Serial Learning			
Control	7.83	1.10	24.98	7.73	43.49	7.31
PA(Odd)—S	5.70	1.49	16.50	6.91	36.69	9.90
PA(Even)—S	7.02	1.48	22.48	8.40	42.87	9.01
			PA Learning			
PA(Even)			17.48	5.97	43.99	12.80
PA(Odd)			18.54	7.28	48.02	12.21
S—PA(Odd)			12.24	7.83	30.97	12.02

The relative amounts of transfer to PA learning for the individual pairs is a function of the serial position held by the items during serial learning, as shown in Fig. 1. Note how perfectly the serial-position curve emerges in the transfer to the PA learning, even though the pairs were always presented in a different order. The control group pairs would form a practically straight horizontal line in Fig. 1. Analysis of variance yielded a Groups × Positions interaction significant beyond the .001 level. Apparently by the end of serial learning the items differ in associative strength according to serial-position, with the earliest learned items being the most overlearned and consequently having the greatest associative strength.

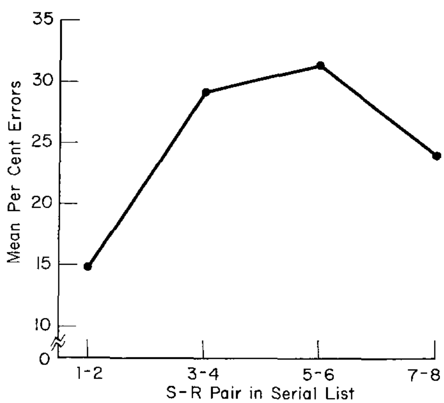

FIG. 1. Mean percentage of errors made on each of the pairs in the PA transfer task. The numbers on the abscissa indicate the serial positions occupied by the S and R members of the pair during the serial learning which preceded the PA task, in which the S-R pairs were presented in a random order.

It seems clear that *S*s, after learning (or overlearning) a serial list, are to some extent able to respond to the appropriately derived paired-associates as if the serial list had been learned in accordance with the specificity hypothesis. The basic question, however, is whether the acquisition of a chain of S-R associations is *essential* to serial learning or is merely *incidental* learning.

Transfer from Paired-Associate to Serial Learning

PA Learning. As shown in Table 1, the means and standard deviations of the two transfer groups, PA(Odd)—S and PA(Even)—S, do not differ significantly on either of the measures in the first-task PA learning. The Odd and Even pairs are quite equivalent. For trials and for percent errors the *t*'s are 1.00 and 1.66, respectively.

Serial Learning. Group PA(Odd)—S showed significantly faster learning of the serial list than Group PA(Even)—S. For trials to criterion, $t = 4.01$, for percent errors $t = 3.36$; for both, $P < .001$. The Odd Group differs significantly from the Control Group at the .001 level ($t = 6.11$ and 4.10 for trials and percent errors, respectively), while the Even Group does not differ significantly from the Control Group ($t = 1.63$ and < 1.00 for trials and percent errors, respectively).

TABLE 2
RESULTS FOR ITEMS PREVIOUSLY LEARNED AND ITEMS NOT PREVIOUSLY LEARNED IN TRANSFER FROM PA TO SERIAL LIST

Group	Trial 1 errors		Errors		Per cent errors	
	M	*SD*	*M*	*SD*	*M*	*SD*
			Previously Learned Items			
Control (Odd)	3.41	0.71	41.12	15.53	46.80	11.43
Control (Even)	3.56	0.64	42.32	16.85	47.90	8.61
PA(Odd)—S	1.50	1.17	17.02	12.07	29.30	13.54
PA(Even)—S	2.33	1.17	34.72	19.50	43.63	12.67
			Not Previously Learned Items			
Control (Odd)	4.42	0.74	45.48	17.50	41.45	7.42
Control (Even)	4.27	0.93	43.83	16.26	39.97	8.04
PA(Odd)—S	4.20	0.83	28.22	16.31	42.14	11.19
PA(Even)—S	4.69	0.57	41.57	18.14	44.12	6.02

As shown in Table 2, transfer is considerably greater for the associations specifically learned in the PA task than for those that were not a part of the PA task, and this is true for both the Odd and Even Groups. The Odd Group showed significantly faster learning than the Even Group both for items previously learned and for items not previously learned (in terms of number of errors to criterion, $t = 5.62$, $P < .001$, for previously learned items, and $t = 3.98$, $P < .001$, for not previously learned items).

First-Trial Data. Is the transfer from PA to serial learning an immediate effect or is it more a "savings" effect which shows up only later in the course of serial learning? Comparison of the first-trial data of the transfer and control groups, shown in Table 1, provides the answer. (The first-trial responses of the Control Group were pure guessing, since *S*s were required to begin anticipating on the very first presentation of the list.) The amount of transfer on the first trial is comparable to that for the entire course of learning. Again, the Odd Group shows significantly more transfer than the Even Group ($t = 4.57$, $P < .001$). Note, however, that on the first trial the Even Group is also significantly better than the Control Group, but this advantage is mostly lost in later trials. As one would expect, the only significant transfer on the first trial occurs on the associations previously learned in the PA task.

Failures to Respond. Did the Odd Group tend to carry over the PA "strategy" into serial learning to a greater extent than did the Even Group? That is, did the Odd Group tend more than the Even Group to regard the serial list as a chain of S-R pairs? If so, it would seem reasonable to expect a relatively greater percentage of failures to respond for the Odd Group on those items which were stimulus terms in the PA task. The items that *preceded* each of these in the serial list, having been response terms in the PA list, had thus never functioned as stimuli. Some change in the *S*'s "set" would seem necessary for these terms to elicit anticipations, as required by the serial task. The question, then, is, does the Odd Group change "set" less readily than the Even Group?

Since the Odd and Even Groups differ in total error rate, it is necessary, to examine this point properly, first to determine the percentage of all errors that are failures to respond. This was done separately for each position in the serial list, except for the items that never appeared in the PA list, i.e., the last item of the serial list for the Odd Group and the first item for the Even Group (these items were omitted from this analysis). From these data, on which the Odd and Even Groups were now, in effect, equated for total errors at each serial position, it was possible to compare the percentage of *failures* on the items that had been *stimulus* terms and on those that had been *response* terms in the PA list. The PA stimulus terms (Positions 1, 3, 5, 7) for the Odd Group account for 60% of the failures to respond in serial learning; the response terms account for 40%. The PA stimulus terms (Positions 2, 4, 6, 8) for the Even Group account for 48 per cent of the failures in serial learning; the response terms account for 52 per cent. (When the percentage of failures is not corrected for total error rate, the PA stimulus terms for the Odd and Even Groups account for 68% and 53% of the total failures, respectively.)

These results are highly consistent with the notion that the Odd Group tends to regard the serial list as a chain of PAs and therefore experiences relatively greater difficulty in making responses to the *response* terms carried over from the PA task. The *S*s tended simply to *wait* for the next stimulus item, as they had done in the PA learning, rather than to anticipate the next item, as required by the serial task. The Even Group, on the other hand, showed practically no difference in failure rate between the PA stimulus and response terms in serial learning.

Serial-Position Effects. The serial-position curves show the differences between the Odd and Even Groups most strikingly. The curves in Fig. 2 plotted in terms of mean errors at each position, clearly show the effects of the prior PA learning for the Odd Group, while the Even Group produced an almost typical serial-position curve. (Since the curve for the Control Group was quite typical, it was not entered in this graph.) It appears that the Even Group tended to lose its paired associations in going to the serial list, while the Odd Group was able to some extent to transfer the PA connections to the serial learning. In order to get a closer look at this phenomenon, it was decided to plot the serial-position curves in terms of each one-fourth of the trials to criterion. Figures 3, 4, and 5 show the serial-position curves of the Control, Odd, and Even Groups, respectively, when the curves are plotted in terms of the mean errors made in each quarter.

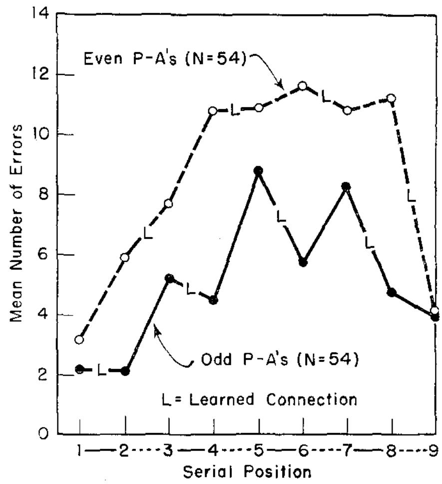

FIG. 2. Serial-position curves showing mean errors at each position for the serial transfer groups PA (Odd)—S and PA(Even)—S. The S-R connections that had been learned in the prior PA task are indicated by the letter *L*, and by the solid (Odd) and dotted (Even) lines connecting the numbers on the abscissa.

It is evident in Fig. 4 that the serial-position curves of the Odd Group continue to reflect the marked transfer effects of the previously learned items through at least the first half of the trials-to-criterion. In the Even Group (Fig. 5), on the other hand, the effects of the PA learning are reflected only in the first fourth of the trials, after which the serial-position curve begins to assume a more or less typical appearance. By the last fourth of learning, the curves of both groups are fairly typical serial-position curves and resemble closely that of the Control Group (Fig. 3). These results seem to suggest that the Odd Group may show greater transfer mainly because they were better

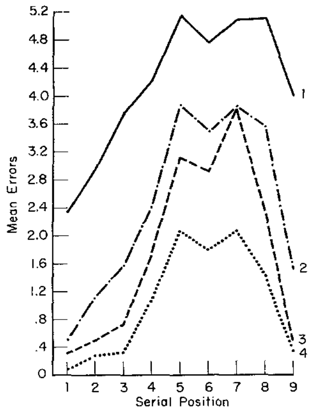

FIG. 3.

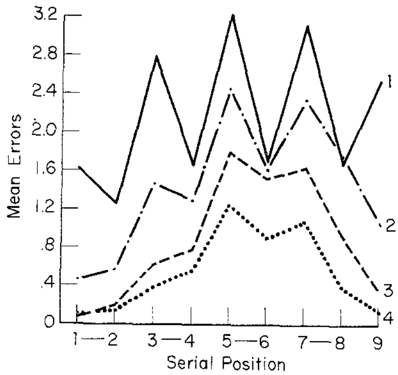

FIG. 4.

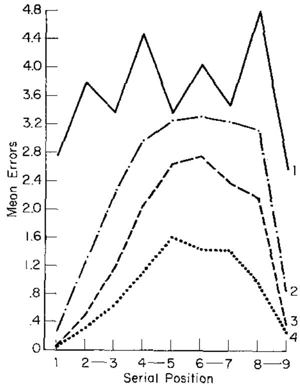

FIG. 5.

FIG. 3. The serial-position curves, in terms of mean errors, for the Control Group, plotted for each one-fourth of the trials to the criterion of three successive errorless trials.

FIG. 4. The serial-position curves, in terms of mean errors, for the PA(Odd)—S group, plotted for each one-fourth of the trials to the criterion of three successive errorless trials. The lines connecting the numbers on the abscissa indicate the S-R connections learned in the PA task.

FIG. 5. The serial-position curves, in terms of mean errors, for the PA(Even)—S group, plotted for each one-fourth of the trials to the criterion of three successive errorless trials. The lines connecting the numbers on the abscissa indicate the S-R connections learned in the PA task.

able to retain the PA set in the serial learning. The fact that they were not completely successful in this is shown by the less than perfect transfer even on the previously learned items and by the emergence of rather typical serial-position curves in the last half of learning.

The "Fate" of a Single, Learned Paired Associate. Was the Even Group more or less forced into abandoning the PA associations in order to be able to learn the list in accordance with some different strategy peculiar and "natural" to serial learning? To get at this, learning curves were plotted for single items. Figure 6 shows a typical set of such curves. It shows the percentage of errors (or the percentage of *S*s who fail to give the correct response) made on each of the first 11 trials (which is approximately half the mean number of trials to criterion) on the item nearest the middle position in the list which had been learned as a response in the PA task. Thus, for the Odd Group is shown the learning curve for Position 6 (which had been learned as the response term of the

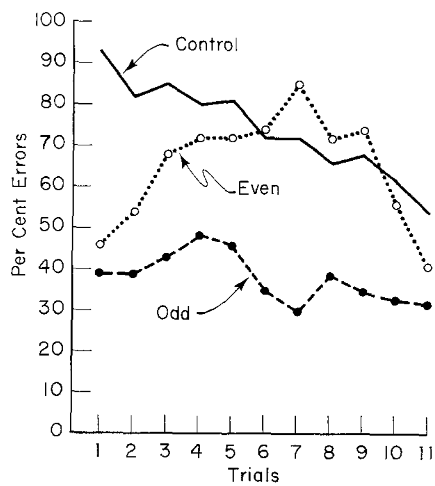

FIG. 6. Learning curves, in terms of percentage of errors (or percentage of *S*s making errors) on each of the first 11 trials of serial learning, for the item nearest the middle of the list which had been acquired in the PA task. The Control Group curve represents the mean percentage of errors on each trial for Positions 5 and 6 in the serial learning. The curve for the PA(Odd)—S group is for Position 6, which had been learned in the PA task as the response to the item in Position 5. The curve for the PA(Even)—S group is for Position 5, which had been learned in the PA task as the response to the item in Position 4.

pair 5-6 in the PA task). The curve of the Even Group is for Position 5 (the response term of the paired-associate 4-5). The curve of the Control Group is the mean of Positions 5 and 6. The results for the Control Group, of course, reveal a typical learning curve, with a fairly regular decrease in errors as a function of trials. The Odd Group shows an advantage from the very first trial, but there is practically no improvement in performance on this item through approximately the first half of learning. (This is reflected, too, in Fig. 4.) The Even Group shows an initial advantage, but it quickly fades, and by Trial 6 they perform no better than the Control Group.

These results are clearly in accord with the hypothesis that the PA strategy breaks down for the Even Group, which then abandons the previously learned PA connections and learns the list in a fashion peculiar to serial learning.

Correlations Between Serial and Paired-Associate Learning

If serial and paired-associate learning involve essentially the same kind of learning process, one should expect a fairly high correlation between individual differences in the two forms of learning, especially when the learning materials are the same in both modes of presentation. Table 3 presents the correlations between PA and serial learning for the various groups and conditions in this study. None of the correlations is significantly greater than zero at the .05 level, although all are positive, which suggests that there might be some true correlation, albeit slight. The variance the two tasks share in common, however, seems surprisingly small, considering their formal similarity. Scores based on the previously learned items show no higher correlations than items not previously learned.

TABLE 3

CORRELATIONS (PEARSON r) BETWEEN PAIRED-ASSOCIATE AND SERIAL LEARNING, BASED ON TOTAL ERRORS TO CRITERION[a]

Tasks	r
(*a*) S—PA(Odd)	.295
(*b*) PA(Odd)—S (Total List)	.035
(*c*) PA(Odd)—S (Learned Items)	.035
(*d*) PA(Odd)—S (Not-learned Items)	.034
(*e*) PA(Even)—S (Total List)	.207
(*f*) PA(Even)—S (Learned Items)	.129
(*g*) PA(Even)—S (Not-learned Items)	.265

[a] *Note*: for *a* (23 *df*) a correlation of .396 would be significant at the .05 level; for *b* through *g* (52 *df*) the required value is .268.

It is unlikely that these low correlations are due to low reliability of the learning measures. Some idea of the reliability of the serial learning measures is suggested by the correlations between error scores on the odd and even items in the serial list. These "split-half" reliabilities for the Odd, Even, and Control Groups were .88, .89, and .92, respectively. The "split-half" reliabilities of the paired-associate learning was obtained for the Odd Group and Control Group by correlating the errors made on pairs 1-2 and 3-4 with errors on 5-6 and 7-8; for the Even Group the errors on pairs 2-3 and 4-5 were correlated with pairs 6-7 and 8-9. The reliabilities thus obtained for paired-associate learning in the Odd, Even, and Control Groups were .90, .84, and .89, respectively.

DISCUSSION

These findings, along with those reviewed from the literature, invite the following generalizations and speculations. (*a*) Serial and paired-associate learning depend upon different processes or strategies of learning which psychologically have little in common, if paired-associate learning is viewed as the formation of S-R associations. (*b*) A serial list is not normally learned as a chain of S-R associations. (*c*) The slight transfer that occurs from serial to PA learning, when they formally have S-R elements in common, may be due to incidental learning of the PA connections in the serial list rather than to a fundamental similarity between serial and PA learning. In the present experiment there is no way of evaluating the degree of transfer attributable to generalized transfer effects, but even if there were a good deal of such transfer, the remarkable thing, considering the conditions of the experiment, is the relatively small degree (about 50%) of over-all transfer from the serial to the PA list. The conditions for producing specific transfer seemed close to maximal: *S*s were told they were supposed to transfer; only four single-function PAs were derived from the serial list; the serial list was overlearned to a criterion of three successive correct trials; and the PA presentation was unpaced, so that the *S* could have run through the serial list in his memory to find the terms that followed each stimulus item in the PA list. Under these conditions, if what is learned in serial and PA learning is essentially the same, it seems surprising that transfer was not close to 100 per cent. (*d*) In transfer from PA to serial learning, *S*s who are enabled to carry over their *set* for PA responding into the serial task learn the serial list faster than do *S*s for whom the congruence, or lack of it, between the PA and serial list is not such as to facilitate continuance of the PA response set.

Other evidence that different processes are involved in PA and serial learning are the negligible correlations between individual differences in the two forms of learning and the difference in difficulty of learning the PA and serial lists. The latter point can only be surmised from the present data, since the number of items in the PA and serial lists differed as well as the pacing of their presentation. But consider the following facts, based on first-task (control group) data: On a 9-item *serial* list presented at a 3-sec. rate, *S*s required on the average approximately 25 trials to attain criterion, while on a 4-pair *paired-associate* list (which involved learning only four-ninths as many connections as in the serial list) presented at a self-paced rate, *S*s required approximately 19 trials to attain the same criterion. [In a previous experiment (Jensen, 1962b) in which *S*s learned the same kind of 9-item color-form test with an unpaced rate of presentation, the average number of trials needed to attain one errorless trial was between 3 and 4.] Since the PA task was the single-function type, there was not the added interference which would have resulted had a double-function PA list been composed from these color-form materials. It is doubtful if the majority of *S*s could have mastered a double-function list in any reasonable amount of time. If the same kind of learning were going on in the two forms, why should they differ so greatly in difficulty?

But the really central question is exactly how serial learning differs from PA learning. To use Underwood's term (1961, p. 18), what is the "natural" manner in which a serial list is learned? One possible answer is suggested in the writer's tentatively formulated theory of serial learning (Jensen, 1962a). The hypothesis is not essentially an S-R conception of serial learning; it even suggests that a search for the "functional stimulus" in serial learning may be a vain pursuit. The theory holds that the "natural" process of learning a serial list consists of "attaching" responses to an anchor point (the first item, the intertrial blank space, or the signal preceding the first list-item) in both a forward and backward direction. What the *S* is doing is not linking up a chain of S-R associations, with each item acting as the stimulus for the next, but is *integrating* a number of responses. All that is meant by the term *integrated responses* is that the response elements (e.g., words or nonsense syllables) can be emitted by the *S* in a particular sequence without their being individually dependent upon specific eliciting stimuli or cues. This applies to either external stimuli or to response-produced stimuli. An example in the motor realm is a pianist's execution of a rapid passage of notes. There is a definite sequence of finger movements, but it is known that these movements can take place so rapidly as to make it impossible that they could be guided by external stimuli such as the printed score or the preceding sounds, or by proprioceptive feedback from the finger muscles. This complex response apparently issues from some centrally integrated process, and its sequential elements are not dependent upon eliciting stimuli for their execution. Another example of centrally integrated response elements is the immediate memory span; an *S* can make a series of responses, such as repeating a sequence of digits, after a single presentation of the series. There seems to be no specific stimulus for each digit. The units of a serial list can be thought of as being integrated in the same sense that a shorter series, comprehended by the memory span, is integrated. Through repeated trials the *S* can integrate a longer series of response elements than can be comprehended by his memory span. The items of a serial list might be conceived of as serving not essentially as the stimuli for anticipations, but as *reinforcers* of the *S*'s responses. Of course, the items also provide the *S*'s repertoire of responses that become integrated as the serial list. Thus, psychologically, the list is not composed of S-R connections; the items never really take on functional stimulus properties in the sense that they must do in PA learning. In PA learning the largest unit of integrated response is only two items, and thus each S-term is crucial to performance. In serial learning, on the other hand, the *S*, after a certain number of trials, is able on request to recite the serial list without being given any formal stimulus whatsoever. The list has become an integrated response without the need for specific stimulus cues along the way. An heuristic analogy might be to consider the groove in a phonograph record, which for its initial formation depends upon a sequential "stimulus" input, but which on later playings, once the stylus has been set in the groove, gives off the sequence of tones without any sequence of "stimuli" being involved at all. Certainly each successive tone is not the "stimulus" for the next. A similar sort of thing may be true for human sequential acts, such as playing a piece on the piano, assembling an apparatus, or learning a list of nonsense syllables. A pattern for an integrated response is laid down in the nervous system, likened to the groove on the phonograph record, rather than a sequence of discrete S-R associations, which might be likened to the chain reaction in a row of dominoes when the first one is tipped over. This conception of serial learning should suggest many experiments capable of further testing its validity.

Summary

It was hypothesized that serial learning takes place by a different process or strategy than PA learning and does not normally consist of the chaining together of S-R connections. It was also hypothesized that specific transfer of S-R pairs from PA to serial learning would be facilitated under conditions that make it relatively easy for the *S* to carry over his *set* for PA learning into the serial task as compared with conditions that make it relatively difficult to maintain the PA set. To test this hypothesis two experimental groups learned a PA list followed by a serial list with common S-R elements. A control group learned only the serial list. The two experimental groups, labeled Odd and Even, learned different pairs of items derived from the serial list. The Odd Group learned pairs 1-2, 3-4, 5-6, 7-8; the Even Group learned pairs 2-3, 4-5, 6-7, 8-9. The second task consisted of learning the serial list 1 2 3 4 5 6 7 8 9. The Odd Group, for whom the set for paired-associate responding in serial learning was facilitated by the fact that the first items in the serial list had already been learned as a paired associate, learned the serial list significantly faster than the Control Group. Though the Even Group showed some advantage over the Control Group in the first few trials of serial learning, this advantage disappeared completely by the sixth or seventh trial. This was true even of the adjacent serial items that had been pre-

viously learned as paired associates. This result was interpreted as being due to a loss of the PA set and the adoption of a strategy peculiar to serial learning. Other evidence that quite different processes are involved in serial and PA learning was the lack of a significant correlation between individual differences in the two forms of learning.

It appears that a serial list is not learned as a chain of S-R connections and that what the *S* learns in the serial task is somehow quite different from what he learns in the PA task, even though both tasks formally have the same associative elements in common. An hypothesis was suggested to account for these findings, viz., that in PA learning the S-terms serve primarily a cue or stimulus function, while in serial learning the subject integrates a number of responses (supplied by the items in the list) and the items serve primarily as reinforcers without acquiring a cue function, except possibly by incidental learning when the list is overlearned.

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