A STUDY OF STRATEGIES IN SERIAL LEARNING

by

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Traditional approaches to serial learning stem from the pioneer experimentation of Ebbinghaus (1885-1964). The materials and methods used by him have provided the paradigm for most subsequent experimentation, and the development of the memory drum has allowed for standardization in the timing and methods of presentation of materials. Until very recently, most studies of serial verbal learning have been of the parametric type, concerned with the effects upon learning of variables such as the meaningfulness of materials (e.g., Noble, 1961), degree of familiarity with materials (e.g., Lindley, 1960; Noble, 1955), rates of presentation (e.g., Hovland, 1938), the length of lists (e.g., Hovland, 1940; Robinson & Brown, 1926), instructions (e.g., Sarason, 1957a, b; Sarason & Sarason, 1957) and methods of learning such as active-passive or massed-distributed (e.g., Hovland, 1939, 1940). Along similar lines, subject (S) variables such as sex and anxiety level have been examined in some recent experimentation (e.g., Sarason, 1957a; Sarason & Harmatz, 1965), and interest has been shown in the effects of stress (e.g., Kalish, Garmezy, Rodnick & Blake, 1958).

Implicit in most of these studies is a view of serial learning fostered in the writings of Ebbinghaus and strengthened by concepts from the work of Thorndike and Pavlov. This S-R connectionist view has explained serial phenomena using concepts such as stimulus generalization, stimulus-trace, response competition, inhibition of delay, and gradient of reinforcement. To express this view in general S-R terms, it is assumed that serial learning consists of the formation of connections between successive items in the list. Thus, each item in the serial list is considered to be the stimulus for the next item (which will provide the basis for the anticipatory response) so that a chain of direct associative links is formed. The stimulus for the response to each item in the serial list is the immediately preceding item, and a chain of S-R connections is the final outcome of the attainment of the learning criterion. Evidence for indirect associative connections was also presented by Ebbinghaus, and such remote associations have been analyzed using conditioned-response concepts such as trace-conditioning and inhibition of delay (e.g., Hull, 1935, 1940; Lepley, 1934).

Recent developments in experimental psychology in general and in serial learning in particular have effected a change in attitude toward the human subject in experimental situations. Such a change is expressed in an article by Orne (1962) which looks upon the human S in any experiment as a problem-solver, who attempts to figure out what the experiment is all about and to bring to bear the appropriate behavior. This view seems particularly pertinent in studies of verbal learning that use Ss of college age. Such Ss bring to the experiment structured attitudes toward experiments in general and probably rote memorization in particular. Basically, they are thinkers and problem solvers, and they actively approach serial learning by recognizing it as a problem situation, not unique, but similar to other learning in their past experience. Presumably, they search in the elements of the present situation for some solution--i.e., a means of achieving a rapid learning of the materials.

Experimental studies of serial rote learning undertaken in the 1960's are beginning to approach this viewpoint of the S. Such studies have undertaken fresh analyses of the serial learning process and have turned up results that seriously challenge traditional assumptions about serial learning. They constitute a drastic reconsideration of serial learning and a sharp departure from the viewpoints traditional to such studies. Generally, these experiments have asked a basic, but only recently formulated, question: what is the effective stimulus for serial learning? This question might be reworded: what strategy or technique does the S use to "tie together" a list so that he is finally able to recall all items in the correct order? Or alternatively, to use Orne's (1962) terminology, one might question the specific hypotheses that S has adopted about how learning might best be accomplished.

Of those participating in the recent resurgence of interest in serial learning, Underwood (1963) has made the distinction between the nominal stimulus and the functional stimulus. Both types of stimuli are discriminative stimuli that might be tied to the correct verbal response. The nominal stimulus is the one that the experimenter (E) presents to the S and which he believes will be used in the verbal learning task, while the functional stimulus is the one actually used, which is often something added to the learning task. It is possible that S, facing a serial learning task, says to himself (formulates a strategy or plan): "I will try to learn the list by concentrating on the beginning syllables first, then on the middle ones, etc.", or "I will try to learn the list by making up a sentence connecting the syllables." Underlying any such strategy will be the choice of a functional stimulus--the stimulus actually used to bring about learning, (or correct S-R relations).

While not traditionally viewed in this manner, it seems to this author that the theoretical formulations of Miller, Galanter, and Pribram (1960), and Restle (1962) are compatible with Underwood's nominal-functional stimulus distinction. Both of these treatments conceive of the learning process as composed of two basic stages--the selection of a plan or strategy for the solving of the problem and the execution of this plan. Both theoretical formulations also hypothesize some sort of feedback mechanism whereby the strategy may be altered if it is found to be incorrect. Restle's qualitative model (his quantitative model is a representation of the discrimination learning process and therefore does not apply to serial learning), since it is to apply to animals as well as humans, is considerably simpler than that proposed by Miller, et. al. (1960). In essence, Restle states that the problem that the organism faces gives rise to a set of strategies. Initially the organism chooses one of these strategies in a random manner and attempts to solve the problem by using it. If the strategy chosen is inappropriate or not helpful, the S then replaces it with another and this process continues until the task is successfully completed. Miller, et. al. (1960), since they are dealing only with human behavior, have formulated a more complex model which is divided into hierarchies of plans and subplans. A plan is defined as "any hierarchical process in the organism that can control the order in which a sequence of operations is to be performed" (p. 16). While their system follows the cybernetic model quite closely, it can be seen as basically similar to Restle's model in that the person facing a learning task initially forms an intention to learn; that is, he executes a plan to form a plan to help him learn. This is followed by the formation of a plan to learn which is in turn executed by the S learning the task. If the plan for learning initially formulated by the S is inadequate, he abandons it and formulates and subsequently executes another plan. This process is continued until the task is successfully completed.

The formulation of a plan could be viewed as S's choice of which functional stimulus to use as a basis for the required responses. In any verbal learning situation, as Underwood has suggested, many stimuli are present that might serve as discriminative stimuli keyed to a particular response. Since most college-age Ss are, in fact, quite sophisticated in typical laboratory-learning situations, they come to experiments with a large body of knowledge and possibly some learned habits having to do with the effective cues for learning. The plan, strategy, or effective stimulus used by any S may often be consciously chosen by him, may be suggested by the particular experimental conditions, or may be dictated by the instructions employed in the experiment.

In the serial learning situation an S would initially form an intention to learn--usually suggested by the E's instructions. Then he would form a plan or strategy of how to go about the learning task (in Underwood's terminology he decides which functional stimulus to use while learning the list). Perhaps his plan would be to learn the list by connecting the syllables to make a sentence. Then S executes his plan by attempting to learn the list according to whatever strategy he has decided to use. If this strategy (functional stimulus) does not help him learn the list, he will discard it and formulate and execute another plan. This process is continued until the list is learned.

A large amount of literature has accumulated on exactly what strategies the S executes (or what functional stimuli he concentrates on) while engaged in the serial learning task. Most of the literature has focused upon three possible functional stimuli. As initially stated by Young (1962), these are: (1) the immediately preceding stimulus in the list, (2) a combination of the preceding stimuli, and (3) the position the item occupies in the list. This first hypothesis, that each item in a serial list is the stimulus for the next word and the response to the preceding word has been called the specificity hypothesis by Young (1961). As mentioned earlier, this hypothesis was originally formulated by Ebbinghaus (1885-1964) and until recently has been the accepted view of the way that serial lists are learned. The second hypothesis--that the functional stimulus is a combination of the two preceding stimuli presented to the S--is an elaboration of the specificity hypothesis. It is called the compound-stimulus hypothesis.

Because of the way the serial list is constructed, it is also possible for the S to learn the serial list by associating the particular item with its spatial or temporal position on the serial list. That is, because the list is presented in a constant order--the first item is always first, the second always second, etc.--it is possible for S to learn when an item is coming by learning its position in the serial list. Although this source of cues has been recognized by experimenters in the past it has not been studied systematically until recently. This hypothesis is called the <u>position hypothesis</u>.

It must be recognized, of course, that there is a possibility that not one, but a combination of strategies can be used to learn the list and that strategies other than these may be employed. Perhaps <u>S</u> uses the associations between the items to learn the ends of the list and uses the serial position of the items in the middle of the list. Or strategies may be changed as experience in learning the list indicates the uselessness of one and the potential value of an alternative strategy.

The Specificity Hypothesis

The specificity hypothesis, as stated, is the view that serial learning progresses as the immediately preceding word or syllable becomes the functional stimulus for the response of naming the next item in the list. One experimental paradigm to test the specificity hypothesis is the serial to paired-associate (PA) transfer technique whereby <u>S</u> learns a serial list of words followed by a PA list in which the S-R pairs are composed of the adjacent items from the serial list. It is reasoned that if the specificity hypothesis has been at work in serial learning, positive transfer should result, since the associations between successive items on the serial list are maintained in the PA task. On the other hand, if some other strategy was used during serial learning, either zero or negative transfer would be expected. Similar reasoning underlies the studies using PA to serial and serial to serial transfer.

Serial to PA transfer.-- In Young's (1959) experiment, each of the items in the PA list was formed by making pairs out of adjacent items in the serial list with each item in the serial list serving both as a stimulus and a response in the PA task. This is called a double-function list. In the first part of the task the Ss were required to learn a serial list of adjectives and then they were transferred to a PA list in which each pair of items was in the same sequential relationship as in the serial list. For example, if the first four words in the serial list were "awkward, unwell, reported, better" in the PA list the first two pairs would be "awkward-unwell, unwell-reported, etc." If associations in a serial list are formed between adjacent items, then positive transfer should occur between such serial and PA lists. However, the results in terms of trials to successive criteria (comparing Melton curves for the experimental group and a control group which had had no previous learning) showed that although there was positive transfer occurring for the first half of the PA learning, no difference was obtained between the two groups in their total trials to one perfect recitation. Other experiments by Young have yielded similar findings when the degree of serial learning (Young 1961, 1962) in the task varied. Realizing that backward associations might interfere in the learning of a double-function list Young (1962) constructed a single function list in which each serial item appears only as a stimulus or a response, but not both, on the PA list. The single-function list produced a small but significant amount of positive transfer occurring early in learning, but disappearing as learning progressed.

A study by Jensen (1962) did produce a significant amount of positive transfer from serial to PA learning. The items were nine colored geometric forms on the serial list and four pairs of forms on the PA list. An important difference between the method used by Jensen and by Young might account for the differences found by these two experimenters. Jensen provided instruction about the relationship between the two lists. Perhaps just as important, in Jensen's task the serial list was learned to three perfect trials and the PA task was unpaced. This unpaced task could give the S time to go through the list and thus to anticipate the response correctly without necessarily using adjacent associations to learn the list as the specificity hypothesis stipulates. Arguing against this possibility, it has been found that differential positive transfer did not occur when the anticipation interval was varied from 1.5 to 4.0 seconds (Erickson, Ingram & Young, 1963).

Horowitz and Izawa (1963) have found that positive transfer between a serial and PA list occurs if the adjacent items have either high forward associative strength (with non-adjacent items having low associative strength), or if there is minimal associative strength between all the items on the list. This did not happen when the items have high backward associative strength or when there is high associative strength among remote associations. The implication of these findings is that associative interference (caused by associations among all the words in the list) leads to the use of some cue other than the utilization of the preceding item when learning the PA list. However, when there is no such interference (minimal associations among nonadjacent items in the list, but high association between adjacent items) the preceding item or combination of items will be used.

An experiment by Young and Casey (1964) has cast serious doubt on these findings. They criticized the findings of Horowitz and Izawa by pointing out that the control condition of their experiment did not control for any non-specific practice effects. Using the same adjectives that had shown the greatest positive transfer for Horowitz and Izawa but controlling for practice effects, Young and Casey found only a non-significant difference in favor of the experimental group. Thus it was concluded that the lack of positive transfer indicates that the inter-item associative strength might not be a significant cause for either the production or prevention of positive transfer.

A recent experiment by Brown and Rubin (1967) indicates that the mere fact that the Ss had had experience with a serial learning list interferes with PA learning. In their experiment Ss initially learned a 12-item serial list of either low meaningfulness or high meaningfulness by the serial method. After serial learning was completed the list was broken down into a single-function PA list: with the odd items the stimuli and the even items the responses. Slower PA learning was found after the serial-learning (SL) task. They concluded "...that previous failures to show significant positive transfer from SL to PA learning may not necessarily reflect... the absence of sequential associations in SL, but rather the cancellation of positive transfer by interference from paired adjacent-serial items. (Brown and Rubin, 1967, p. 555)."

Another recent experiment by Postman and Stark (1967) reopens the question of whether the specificity hypothesis may be partially adequate to explain the learning of a serial list. Three groups of Ss were used. For Group E, the PA list consisted of all the pairs of the adjacent items of the serial list. In Group E_R the paired associates were composed of nonadjacent members of the serial list. In addition one-half of the Ss were instructed about the relationship between the serial and PA lists while the other half were not. Finally, each of these six groups learned three different sets of serial and PA lists. Comparing the number of correct responses on the first transfer trial, it was found that

Group E significantly passed Group C while Group C and Group E_R were not different from each other. Also, instructions aided the Ss in Group E while they had no effect on the other two groups. That positive transfer from serial to PA learning is not a result of response familiarization can be concluded from the significant differences between Group E and E_R. If response familiarization were the cause of positive transfer these groups should not be different from each other since they had both learned the same serial lists. Thus, the positive transfer found in this experiment can be inferred to result from associative transfer. A similar analysis was performed on the total number of correct responses for 10 trials of PA learning. It was reasoned that whatever advantage Group E_R had from response familiarization would dissipate rapidly so that the effects of negative transfer would become apparent in later trials. This is indeed what occurred since in this analysis Group E was significantly superior to Group C which was significantly superior to Group E_R.

The main feature that distinguishes this work from previous experiments is the manipulation of the instructional variable and the method of evaluating transfer. It seems that if the scores of the earlier trials are considered alone in the analysis, then the serial to PA task can lead to positive transfer, and this effect can be further enhanced by instructing the Ss as to the relationship between the two lists. Instructing the control Group and Group E_R about the nature of the two lists does not aid them in learning the lists because it does not give them any cue as to how to learn the material. This experiment and one by Shuell and Keppel, (1967) which constitutes a replication of the above experiment, provides evidence that Ss can use the specificity hypothesis as a method of learning a serial list.

PA to serial transfer.-- If Ss are initially trained on a PA list and then transferred to a serial list made up of PA pairs, significant positive transfer would be expected by the specificity hypothesis. These results were found by Young (1959) Horowitz and Izawa (1963) and Young, Milaukas, and Bryan (1963). In the latter experiment the amount of positive transfer was small and only significant when a high degree of original PA learning was used. In summary, the use of this paradigm has demonstrated that the specific associations built up in PA learning can be utilized by Ss in serial learning. This is, at best, only supportive but not definitive evidence for the specificity hypothesis. Because Ss make use of a cue when it is available does not indicate that Ss will necessarily choose this cue when several are available.

Serial to serial transfer.-- Another typical method that has been used is to have selected items from the first serial list maintain their same positions while the remainder are varied. In aslight variation of this method, selected items from the first list shift in absolute position but maintain the same relative position. In former case, the specificity hypothesis would predict negative transfer since adjacent items have changed, and the specific associations between items must first be unlearned from the first list before new ones are formed in learning the second list. Although the same items are used in the two serial lists, their orders are changed, thus altering the specific associations between adjacent items. This is comparable to an A-B, A-B_r paradigm in PA learning, predictive of negative transfer.

Young (1962) had Ss learn two serial lists. On the second list alternate items were jumbled with respect to list-1 position, while the remaining items remained in the same serial position. The items which were in the same serial position were called S items while the jumbled ones were called D items. The specificity hypothesis predicts negative transfer for all items, since S-R sequences are not maintained. When the S and D items were compared by serial position, the S items were learned faster in the middle of the list with no differences at either end. Young concluded that the specificity hypothesis worked at the ends of the list, while the serial position hypothesis worked in the middle of the list.

A similar experiment by Ebenholtz (1963a) had one group of Ss transfer to a second list on which alternate items maintained the same positions (Group 1). A second group learned a second list in which half of the items were shifted a minimum of four positions from their position on the first list. Group 1 showed positive transfer as opposed to Group 2 and a control group who had learned lists of completely different items. Contrary to Young's results, the Ebenholtz results showed positive transfer at the middle and end of the list but not at the beginning. Thus, the specificity hypothesis was not supported.

Experiments dealing with transfer from specific sets of items within a serial list have presented a different picture. Battig, Brown and Schild (1964) compared the transfer of three bigrams located at either the beginning or the middle of a 12 item list. Three different conditions were used: (a) the three items remained in the same adjacent positions on the second list; (b) they were in a changed but adjacent position on the second list; and (c) they were in the same but non-adjacent positions on the second list. A consistent intra-cluster improvement was found for the items in the middle of the list but not for those in the beginning of the list, and there was greater positive transfer for those items in the middle of the list, but not for those in the beginning. These results favored the specificity hypothesis but not conclusively so, because of certain inconsistencies in the data.

Another method for testing serial to serial transfer is to maintain the sequential order of the original list in the second list but shift the original position of each item. The specificity hypothesis predicts little decrement in this instance. Young, Patterson and Benson (1963) performed an experiment in which the Ss learned one serial list followed by the same list in reversed order. The specificity hypothesis would predict negative transfer on all items. Since positive transfer did occur on items 4, 5, 6 and 10, the specificity hypothesis was rejected. Thus, it can be concluded that experiments using this method do not favor the specificity hypothesis.

Both Ebenholtz (1963b) and Winnick and Dornbush (1963) used a method of presenting a serial list which eliminates the possibility of associating an item to a constant serial position. Ebenholtz had Ss learn a list of 10-nonsense syllables which kept the same sequential relationship on each trial, but had each trial start with a different item on the list. The specificity hypothesis would predict no difference between this procedure and the standard procedure in which each item maintains the same serial position from one trial to the next since the same sequential arrangement is maintained on each trial. Since the experimental group took about 36 trials to learn while the control group learned the list in about 23 trials, it appeared that the loss of a known beginning position was a disadvantage and the specificity hypothesis gained no support.

Winnick and Dornbush (1963) used three different groups. One group had the same serial position from one trial to the next; the second group had the serial position changed by one in each trial; the third group had the starting serial position varied randomly from one trial to the next. The mean numbers of trials to criterion were about 12, 16, and 20 for the three groups respectively. These experiments, while showing that the lists are learned more slowly when the formation of sequential associations is the only possible method and favoring the position hypothesis, demonstrate at the same time that it is possible to learn the lists by using the specificity hypothesis alone.

In summary, the serial to PA transfer method has produced mixed evidence favorable to the specificity hypothesis while the PA to serial transfer paradigm has shown the facilitating effect of previously learned S-R associations in the learning of a serial list. Most of the evidence in serial to serial transfer methods has been unfavorable to the specificity hypothesis as an efficient serial learning strategy.

The Compound-Stimulus Hypothesis

It will be recalled that the compound-stimulus hypothesis states that it is possible that a combination of preceding items might serve as the cue for the succeeding item. Only a few experiments have been performed to test this hypothesis. An experiment by Young (1962) utilized the serial to PA learning paradigm in which the PA list stimuli were composed of <u>pairs</u> of preceding items from the serial list. These pairs were arranged one on top of the other for simultaneous presentation. This experiment found negative transfer from serial to PA learning and it was concluded that the compound-stimulus hypothesis was untenable. The procedure of this experiment was criticized by Horowitz and Izawa (1963) because the temporal order of serial presentation was not maintained when the two preceding stimuli appeared simultaneously. To remedy this criticism Young and Clark (1964) presented the two preceding stimuli sequentially in the PA task. Using this method significant positive transfer between the serial and PA lists was found. Thus, it seems that not only the preceding item but also the two preceding items can serve as cues in serial learning.

The Position Hypothesis

A great many experimental studies of the position hypothesis have been performed, and most of them seem to indicate that Ss can use the serial position of the item in the list as the basis for an effective strategy for learning a serial list.

Serial to PA transfer.-- An experiment by Jensen and Rohwer (1965) supports neither the specificity nor the position hypothesis. Two experimental conditions were used. In one condition of PA learning the serial position alone was the stimulus item of the pair. The Ss had to associate each response pair with a particular serial position. The other experimental group "...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 (Jensen & Rohwer, 1965, p.70)." The position hypothesis would predict positive transfer for Group 1 while the specificity hypothesis would hypothesize positive transfer for Group 2. Since there was no overall transfer for either group it was concluded that neither the specificity hypothesis nor the position hypothesis was tenable.

Young, Hakes, and Hicks (1967) tested the serial position hypothesis in the serial to PA-transfer model by using the ordinal position of the item in the serial task as the stimulus item in the PA task. In Experiment 1A the number-item pairings were consistent with those in the serial task while in Experiment 1B they were not. No overall transfer effect was found in either task but items at the end of the list tended to yield positive transfer and items in the middle of the list resulted in negative transfer in Experiment 1A. In Experiment 1B negative transfer resulted for items in the ends of the list. Some of the Ss in Experiment 2 were instructed about the relationship between serial and PA tasks. Such instruction increased the positive transfer from the ends of the serial list and increased negative transfer from the middle items when the serial position was the appropriate stimulus item on the PA list. The authors conclude that there are a number of cues functioning throughout the serial list, one of which is the absolute position of the item in the list.

In most of the other experiments, utilizing the serial to

PA transfer tasks in which no or negative transfer was found between the two tasks it was concluded that since the specificity hypothesis was not tenable, the Ss must have used the position of the words in the serial list as the cue for learning the serial list. However, Postman and Stark's (1967) demonstration that positive transfer can take place between serial and PA learning, if the measure used is the total number of items correct, makes doubtful the validity of this assumption.

Serial to Serial Transfer.-- A number of studies testing the position hypothesis have used the serial to serial transfer task. The experiments by Young (1962) and Ebenholtz (1963), which have already been discussed, are pertinent at this point. It will be recalled that Young's experiment supported the position hypothesis for items on the ends of the list, while Ebenholtz found slightly different results; namely that positive transfer occurred in the middle and end of the list but not at the beginning (thus not supporting the specificity hypothesis at all). It must be mentioned at this point that any kind of transfer in the beginning of the list is highly unlikely since very few (if any) errors occur in the beginning of a serial list.

Although the S items were learned significantly faster on the second serial list, it seems possible that they may have benefited from mediation between alternate items in the second list, with the previously learned intermediate item acting as the mediator. This is exactly the problem that Keppel and Saufley (1964) investigated. They replicated Young's basic conditions and included two other groups to study the effect of such mediation. In one group the alternate items shifted one position from that occupied in the first list. More rapid learning of S items would occur if mediation was involved. In the second group, one-third of the adjectives were chosen to remain in the same position while the remainder changed. Thus, there was a non-systematic arrangement of S items under this condition, which would make mediation improbable; hence, any beneficial effect of these S items could be attributed to their position. Since the S items were superior to the D items, one can conclude that the mediational chains did not occur and position was the cue involved.

Young, Patterson, and Benson (1963) had Ss learn two serial lists, the second of which was in the reverse order of the first. The position hypothesis would predict that those items in constant serial position would be learned faster than those changing their serial position. Thus, the items in the middle of the second list should be learned faster than those at the ends. The specificity hypothesis would predict negative transfer on all items. Using an 11-item list they found that items in position 4,5,6, and 10 were learned faster than control group adjectives which were completely changed from list 1 to list 2. This tends to support the position hypothesis.

In conclusion it can be said that experiments using the serial to serial transfer paradigm support the position hypothesis.

Different Methods of Serial Presentation.-- If the serial position is a cue for serial learning, then the identification of the ordinal position of the item in the list should make the list easier to learn. Jensen and Blank (1962) performed such an experiment using geometric forms as items identifying the original position for the S. Since learning was not made easier, they concluded that ordinal position was not a cue in their experiment.

If the ordinal position of the item is not a cue then it might be that the spatial position acts as a cue. Asch, Hay, and Diamond (1960) varied different aspects of the spatial array using nonsense syllables as stimuli, and found that when the syllables were presented in positions which followed the contour of a triangle, then there were fewer errors than when they were presented in the customary way. Thus, it was demonstrated that spatial array can act as a cue for serial learning, but can it be a sufficient source of cues for learning to occur? To answer this question Ebenholtz (1963a) presented one group with a list of nonsense syllables in varying temporal orders but in the same spatial position in a vertical arrangement. Since the items were presented in varied temporal orders, it would be difficult for one item to act as a stimulus for the next, so the S would have to depend upon position cues. Since it was possible for lists to be learned in this manner, spatial position was indicated to act as the functional stimulus.

As mentioned earlier the experiments of Ebenholtz (1963b) and Winnick and Dornbush (1963), which varied the starting position of the list, favored the serial position hypothesis. Saufley (1967) followed a similar procedure in which he varied the starting position for one group learning an 11-item list of adjectives, and kept the serial position constant for another group learning the same list. Once again, it was found that varying the serial position of the items retarded learning. While these experiments do not rule out the possibility that sequential associations may develop using standard serial learning procedures, they do demonstrate the fact that the difficulty in SL is substantially increased by eliminating position as a cue. Thus, it can be concluded that these experiments tend to show that the serial-position hypothesis is tenable.

The Present Study.-- The experiments reported here attempted to gain further insight into the relative effectiveness of the strategies that might be used. The first experiment explored the relative efficiency of the position and specificity strategies as induced by instructions for the learning of high and low association trigrams. Reaction time tests were used following learning to determine whether S had followed the instructions as well as to attempt to infer the strategies that the non-instructed control group utilized. It was predicted that the position instructions would lead to faster learning with low association trigrams, while the specificity instructions would be most efficient with high association trigrams.

The second experiment attempted to determine whether S could learn a serial list of 12 or 20 trigrams faster by forming two and four unit "chunks" than by learning one trigram at a time. Thus the list was presented to various groups of Ss one, two, or four trigrams at a time. It was hypothesized that, if grouping was an aid to learning, the chunking groups would learn the list faster than the group viewing one trigram at a time and that this would be especially true for the groups seeing the long list.

Experiment I

This experiment undertook to vary the strategies employed in serial rote learning through the experimental manipulation of instructions. Although a few studies have introduced variations in instructions (e.g., Jensen, 1962; Postman & Stark, 1967; Winnick & Dornbush, 1963; Young, Hakes & Hicks, 1967), this means of influencing the choice of strategy has been relatively neglected.

In this experiment, the instructions directed one group of Ss to learn by associating syllables with the position on the list and directed a second group to learn by trying to form associative links from one syllable to the next. The performance of these groups was compared with that of a control group, given standard serial learning instructions. The instructional stimulus is viewed, in the present study, as having a two-fold effect: it causes S, first of all, to initiate rehearsal of the materials and, secondly, to search for a strategy by which he can accomplish the learning of the materials as requested. The instructions, then, can both encourage rehearsal and make suggestions about learning strategies. On both counts, it was predicted that, if instructions were followed, these groups should learn more rapidly than controls.

In order to test whether the instructions were effective in influencing the strategies employed, associative reaction time (RT) measures were employed, following the serial learning. Subjects were asked: (1) to respond with the first syllable that came to mind when E pronounced a syllable from the list: (test of associational strategy) and (2) to respond with the appropriate syllable when E pronounced an ordinal position (test of positional strategy). It was reasoned that in the group given the position instructions the P-RTs should be faster, while with associational instructions, the A-RTs should be faster.

It was further hypothesized that the effectiveness of either strategy would be influenced by the materials to be learned; to wit, if the items themselves are suggestive of links (i.e., are high in associative value), instructions to carry out such linkage should be more effective than where the items are devoid of such potential. On the other hand, low association syllables, lacking the possibility of easy associational linkages, might be easier to learn by tying them to their numerical position on the list. To evaluate these hypotheses, the three instructional groups were subdivided into groups learning lists made up of either high association or low association items. A significant interaction effect was predicted between instructions and the association value of materials.

Method

Subjects.-- Ninety volunteer Ss from introductory psychology courses during the summer session at Queens College participated in the experiment. They were individually assigned to one of the six groups in the order of their appearance.

Experimental Design.-- Six independent groups of Ss were tested individually. One group was instructed to learn the list by associating each nonsense syllable with the following one (Group S). The second group was told to learn the list by associating each nonsense syllable with the number of its position in the list (Group P). The third control group was not given any strategy about the way to learn the list (Group C). Half of the Ss in each group were presented a list composed of high association nonsense syllables (HA), and half were presented a list of low association nonsense syllables (LA). Thus a 3x2 factorial design was employed, with three levels of instructions and two levels of associative value. The six groups were designated as S-HA, S-LA, P-HA, P-LA, C-HA, and C-LA.

Apparatus and Materials.-- The stimulus items consisted of two sets of 12 CVC trigrams selected from Archer's list (Archer, 1960). The LA syllables were between 9 and 41% association value, while the HA were between 73 and 95% association value. These items were arranged into six lists (three HA, three LA) according to the rules set forth by Hilgard (1951). To control for any possible effects due to item ordering within the list, three orders of these syllables at each level of association value were formed. The lists are shown in Table 1. The materials were typed in capital letters on standard memory drum tape and presented for learning on a Lafayette memory drum, at a two second presentation rate. The same interval was used between movements

TABLE 1

The Six Lists of Nonsense Syllables

Used in Experiment I

Low Association			High Association		
(1)	(2)	(3)	(1)	(2)	(3)
YIC	TEF	GEP	SUD	DUX	YEP
QOM	RIJ	ZIK	JAC	MOV	MOV
GEP	QOM	HUQ	YEP	YEP	JAC
SUV	SUV	XOL	MOV	GIR	SUD
RIJ	PAZ	PAZ	DUX	SUD	WIZ
PAZ	YIC	YIC	GIR	NAH	REK
XOL	VOB	TEF	LEN	BOT	HOF
HUQ	HUQ	QOM	BOT	LEN	DUX
TEF	GEP	SUV	NAH	WIZ	GIR
ZIK	ZIK	RIJ	WIZ	JAC	LEN
VOB	XOL	CAH	REK	HOF	BOT
CAH	CAH	VOB	HOF	REK	NAH

of the memory drum to pace recall.

<u>Procedure</u>.-- All <u>S</u>s served individually, learning the list by the serial-recall method in accord with a recent recommendation by Battig and Lawrence (1967). In this method, learning trials which exposed the items alternated with blank exposures during which <u>S</u>s were to attempt recall. Before the first learning trial, each <u>S</u> was given the following modified standard learning instructions: "This is a memory test. You are to learn the nonsense syllables that appear in the window of this machine in the right order as quickly as you can. When I start the machine the syllables will appear in the window one after another until 12 have been shown. Try to learn them as they appear."

Then after the 12th syllable was shown and before the first recall trial, the following instructions were given: "Now, right after an asterisk has appeared in the window you are to say what the first syllable is. Then a blank line will appear in the window. While that line is there, you are to say what the second syllable is; you are to continue in this manner until 12 lines have appeared in the window. Guess even if you are not sure."

After the first recall trial <u>S</u> was told: "Now the 12 syllables will be shown to you again for you to learn. This will again be followed by twelve blank lines. The procedure will continue in this way until you have learned all 12 syllables."

In addition Group S was told: "It has been shown that people learn this list faster if they form associations between the syllables. In other words they associate the first syllable with the second, the second with the third, and so on. For example, if the first syllable is ZOP, and the second KIP try to make an association between ZOP and KIP. If the third syllable is BUF also try to make an association between KIP and BUF. Remember, try to form associations between the syllables."

Group P was told: "It has been shown that people learn this list faster if they remember the number of the syllable on the list. In other words, if ZOP is the first syllable, KIP the second and BUF the third, say to yourself 'first is ZOP, second is KIP, third is BUF', and learn the entire list in this manner. Remember, learn the entire list by remembering the number of the position that the syllable occupies on the list."

The <u>S</u>s in Group C were given only the revision of the standard serial instructions. In addition, every few trials, during the inter-trial interval, the <u>S</u>s were reminded of the method that they were to use to learn the list.

After the list was learned, each experimental <u>S</u> was given two kinds of reaction time tests to determine whether he had followed the instructions while learning the list. Each control <u>S</u> was also given both reaction time tests in an attempt to infer the strategy that he used. The equipment used was a standard reaction time key attached to a Hunter clock counter. The reaction time for each trigram was measured to the nearest hundredth of a second. When E read the appropriate instructions, he depressed the key and held it down until S gave a response at which time he removed his finger and recorded the reaction time. The two sets of instructions that were given to each S were as follows:

A) "Now I am going to test you on how well you have learned the list. Would you please tell me which syllable is number _?"

These instructions were repeated for each serial position with three different orders of numbers randomly chosen.

B) "Now I am going to test you on how well you have learned the list. Would you please tell me which syllable comes after _?"

The instructions were repeated for each trigram. Three different orders of trigrams randomly chosen were used as stimuli. All Ss were given both sets of reaction time instructions. The order of presenting the instructions was alternated within each group to control for any order effect.

It would be expected that Ss given P instructions would make a stronger association between the number of the trigram on the list and the trigram than between successive trigrams. This stronger association should be manifested by a faster reaction time for the reaction time instructions A than for reaction time instructions B and Group P should therefore respond to instruction A more rapidly than to instruction B.

Conversely it would be expected that Group S would make stronger associations between successive trigrams than between the number of the trigram on the list and the trigram. This stronger association should result in more rapid responding to reaction time instructions B than to reaction time instructions A. The same reasoning should help infer which strategy the control Ss had used. The above should hold true for trigrams that are recalled correctly, when S answers incorrectly to either set of reaction time instructions there is no way of knowing how strong the association is. Therefore, only trigrams which were responded to correctly after both instructions A and B were used in this analysis.

Results

Reaction Times.-- The first step in the analysis of data was a comparison of the reaction times obtained from the six groups. It was reasoned that if the instructions were followed, strong associations would be built up between successive trigrams for the S-Groups and between the number denoting position of the trigram on the list and the trigrams for the P-Groups. Such strong associations should result in faster reaction times after learning when the "appropriate" reaction time instructions were given than with inappropriate instructions.

Table 2 shows the mean reaction times for the six groups for the preceding stimulus items and the position numerals. The data are broken down into type of learning instructions (specificity or position), the type of reaction times, and the order of recall for HA and LA trigrams. Of the HA experimental Ss, 23 out of 30 had faster reaction times when reaction time instructions were appropriate for the experimental instructions than when they were inappropriate. The probability of this occurring by chance according to the sign test is less than .004. When reaction time instructions were appropriate for the experimental instructions, 22 out of 30 LA experimental Ss had faster reaction times than when the reaction time instructions were inappropriate. The sign test indicated that the probability of this occurrence was less than .008. It would appear that experimental instructions were followed by most Ss.

It was also argued that it would be possible to infer the strategy that control Ss used by comparing their reaction times for position and specificity recall instructions. Ten of the 15 LA control Ss had faster reaction times when position reaction time instructions were used. The probability of this occurrence is equal to .15. Eight of the 15 HA control Ss had faster reaction times when specificity reaction times instructions were used. The probability of this occurrence is .50. Therefore, no assumptions regarding the preference of strategies for the control Ss are warrented.

Finally, it can be seen that the second time the Ss were asked to recall the syllables their reaction times were faster than the first time they were asked to recall the syllables.

TABLE 2

Mean reaction (in seconds) to position numeral and to preceding item for the six experimental groups in Experiment I. Numbers in parenthesis (1 or 2) indicate order of testing. Prop indicates Proportion of syllables correct.

	Low Association				High Association			
	Specificity		Position		Specificity		Position	
	Prop	RT	Prop	RT	Prop	RT	Prop	RT
Specificity	69/99	4.68(1)	69/99	3.89(2)	30/66	2.69(1)	30/66	2.98(2)
Instructions	37/66	3.11(2)	37/66	4.77(1)	66/99	2.59(2)	66/99	3.91(1)
Position	73/99	3.74(2)	73/99	4.13(1)	44/66	2.42(2)	44/66	2.80(1)
Instructions	47/66	3.58(1)	47/66	1.85(2)	68/99	3.04(1)	68/99	1.95(2)
Control	48/99	4.16(1)	48/99	2.91(2)	39/66	3.13(1)	39/66	4.25(2)
Instructions	42/66	3.50(2)	42/66	3.74(1)	61/99	3.78(2)	61/99	3.52(1)

It seems as if the Ss did not expect to be tested on their recall of the syllables and it took some time before they became adapted to the reaction time task. The finding that it takes S some time to adapt a set to respond rapidly is quite common in reaction time studies.

Since these data indicate that Ss followed instructions, the effect of differential instructions and association values may be evaluated by analyzing the trials to criterion, errors, and number of correct choices on the first quarter trials by separate 3 x 2 analyses of variance and Newman-Keuls tests. To determine whether there were any differences among lists, two one-way analyses of variance were undertaken, one for LA and one for HA syllables; no significant differences were found to exist among the lists.

Trials to Criterion.-- Mean trials to criterion and standard deviations for the six groups are shown in Table 3. A 3 x 2 analysis of variance, with three types of instructions and two association values found significance in the main effect of association value, $F\ (1,4) = 6.15$, $p < .025$. (See Table 1 of Appendix for detailed summary of analysis of variance). This indicates that, as expected, the HA trigrams were learned more rapidly ($\overline{X} = 8.24$ trials) than were the LA trigrams ($\overline{X} = 10.31$ trials). The main effect of instructions approached significance, $F\ (2,\ 84) = 2.54$, $p < .10 > .05$. This suggests that there is a tendency for P-instructions to induce the most effective learning strategy and the fastest learning ($\overline{X} = 8.10$ trials), while the control instructions, where the S must find his own strategy, resulted in the slowest learning ($\bar{X}$ = 10.40 trials).

In order to determine specifically which of the experimental groups were significantly different from each other, an internal comparison of the cell means was made by the Newman-Keuls studentized range test. (See Table 2 of Appendix). Group C-LA took significantly more trials to learn the list ($\bar{X}$ = 11.93 trials) than Group P-LA ($\bar{X}$ = 7.87 trials), $p < .05$. Thus the main reason for the borderline significance of instructions is the difference between groups C-LA and P-LA.

Errors.-- Errors (intrusions and omissions), mean errors and standard deviations for the three types of instructions and two association levels are presented in Table 4. The results of the 3 x 2 analysis of variance of the error data with instructions as one variable and association value, as the second (see Table 3 of the Appendix), found significance in the main effect of instructions, F (2, 84) = 3.80, $p < .05$, the main effect of association value, F (1, 84) = 6.10, $p < .025$, and the interaction between instructions and association value F (2, 84) = 3.65, $p < .05$. The significant main effect of association value indicates that, as expected, more errors were made while learning LA trigrams ($\bar{X}$ = 55.82 errors) than while learning HA trigrams ($\bar{X}$ = 44.00 errors). That the main effect of instructions is significant indicates that the P-Groups made the fewest errors ($\bar{X}$ = 41.60 errors),

TABLE 3

Mean trials to criterion (and standard deviations) for the six experimental groups of Experiment 1.

	INSTRUCTIONS		
	Specificity	Position	Control
Low Association	11.13	7.87	11.93
	(4.12)	(2.05)	(5.80)
High Association	7.53	8.33	8.87
	(3.62)	(3.56)	(2.67)

TABLE 4

Mean errors (and standard deviations) for the six experimental groups of Experiment 1.

	INSTRUCTIONS		
	Specificity	Position	Control
Low Association	63.20	38.87	65.40
	(22.25)	(12.32)	(30.44)
High Association	37.60	44.33	50.07
	(18.43)	(23.82)	(20.14)

while the C-Groups made the most ($\overline{X}$ = 57.74 errors). Again S-Groups are intermediate ($\overline{X}$ = 50.40 errors) between P-and C-Groups. Overall, the P-instructions have induced the most efficient strategy (in terms of errors) while the control instructions, leaving S to search for a strategy by himself were least efficient. The significant instructions by association value interaction indicates that this was especially true for the LA trigrams, whereas for the HA trigrams the S-instructions induced a more effective strategy resulting in fewer errors than either of the other instructions. A Newman-Keuls studentized range test was performed to determine the exact locus of the experimental effects (See Table 4 of the Appendix). This analysis indicates that the significant instructions by association value interaction was due to the fact that in the LA-Groups the P-instructions resulted in fewer errors ($\overline{X}$ = 38.87 errors) than either S-instructions ($\overline{X}$ = 63.20 errors) or C-instructions ($\overline{X}$ = 65.40 errors) $p < .05$, while in the HA-Groups there were no differential effects due to instructions. Thus, it seems that for LA trigrams the P-instructions induced the most efficient strategy while for HA trigrams the type of instructions had no effect.

Number correct on first quarter trials.-- An analysis of the number of correct responses on trials during the first quarter of learning was suggested by results of an experiment by Postman and Stark (1967) in which evidence supporting the specificity hypothesis was found when the first few trials were analyzed, but not when the number of correct responses on the entire list were analyzed. Mean number of trigrams correct and standard deviations for the first quarter of learning are found in Table 5. The results of an analysis of variance (see Table 5 of Appendix) found no significant differences among any of the means. The most probable reason for the discrepancy between these results and those found by Postman and Stark (1967) lies in the different procedures used. Postman and Stark utilized a PA to serial learning transfer procedure while this experiment used a procedure which induced various learning strategies by means of different instructions. Apparently any strategy induced by a PA task can be tapped early in serial learning whereas the differential effectiveness of various instructional strategies does not appear until later in learning.

Melton curves.-- Melton curves were formed by converting data into trials taken to reach successive criteria (three learned, six learned, etc). This permits a comparison of the learning curves of groups differing in numbers of trials to reach criterion; these curves, shown in Figure 1, indicate that the group learning LA trigrams by position instructions was constantly ahead of all other groups throughout the course of learning except for the group learning the HA list by specificity instructions. In all other cases HA-Groups learned the list more rapidly than LA-Groups.

Serial position curves.-- Serial position curves for HA-

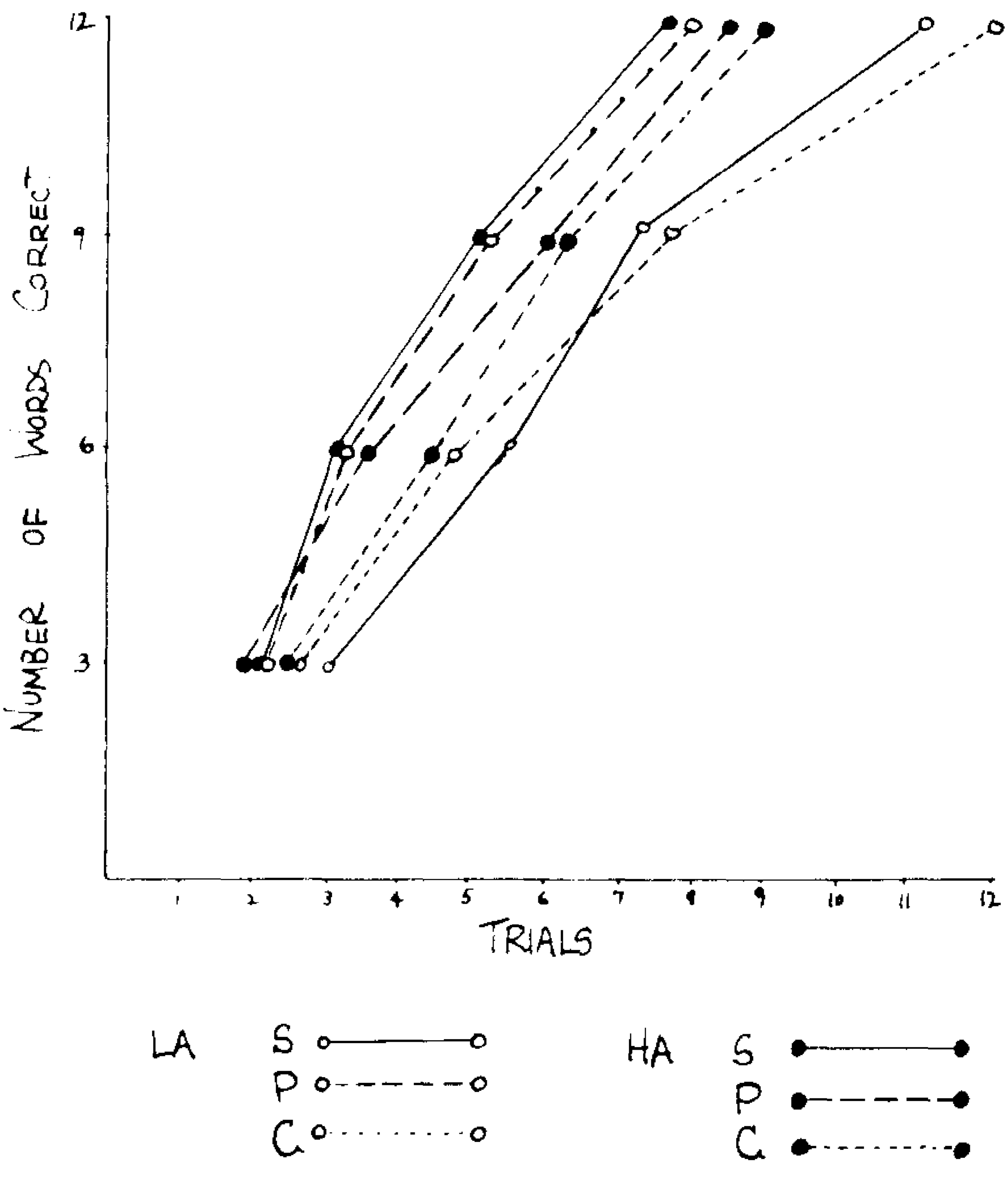
TABLE 5

Mean number correct (and standard deviations) on the first quarter trials for the six experimental groups of Experiment 1.

	INSTRUCTIONS		
	Specificity	Position	Control
Low Association	2.02	2.89	2.83
	(1.15)	(1.37)	(0.91)
High Association	3.14	2.78	2.70
	(1.18)	(1.06)	(1.52)

Fig. 1.-- Melton curves, showing trials to reach successive criteria of learning, for the six groups of Experiment 1.

FIGURE 1



NUMBER OF WORDS CORRECT
12
9
6
3
1
2
3
4
5
6
7
8
9
10
11
12
TRIALS
LA
S
P
C
HA
S
P
C

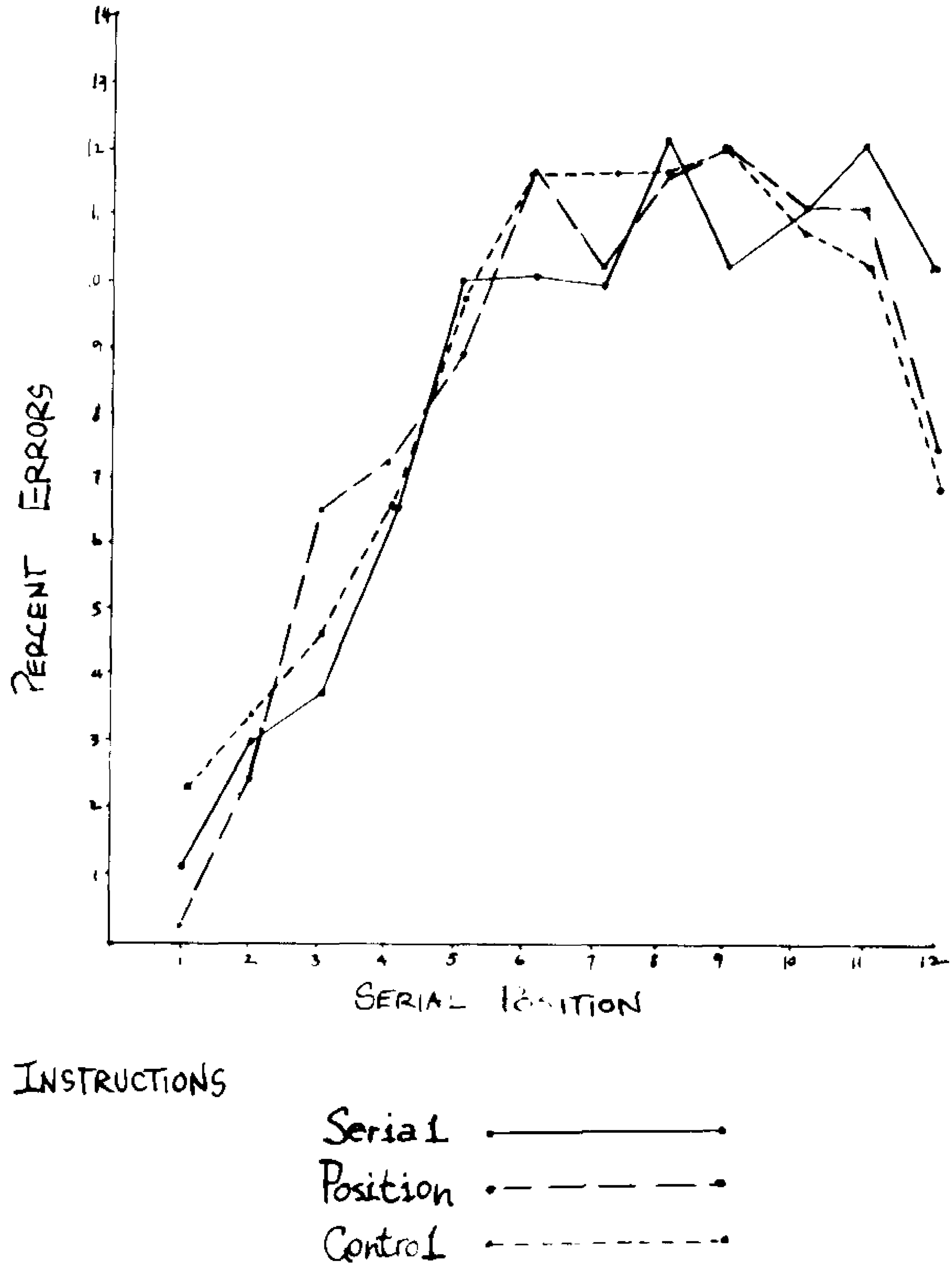
and LA-Groups are shown in Figures 2 and 3 respectively. It can be seen from Figure 2 that the shape of the curve for Group S-HA is somewhat different from that normally encountered in that, there is no major drop in the percentage of errors at the end of the curve. While this is a rather sharp departure from the typical serial position curve it is exactly what would be expected if the Ss learned the list by the specificity instructions; that is, if each S made a connection between each pair of syllables one would expect the beginning of the list to be learned most rapidly with more and more difficulty occurring as the S gets further and further into the list. The serial position curves for all low association syllables, on the other hand, are more like the typical inverted U shaped S P curves the ends showing fewer errors, the most errors occurring in the middle of the list.

Discussion

Two findings from this experiment seem worthy of further note. First is the effectiveness of instructions in influencing S's learning strategy. Most of the experimentation performed up to the present has been concerned with determining the strategy that Ss prefer to use rather than comparing the relative efficiency of various strategies (e.g., Brown & Rubin, 1967; Keppel & Saufley, 1964; Young, 1961). The present experiment, on the other hand, is an attempt to compare the effectiveness of the specificity and position hypo-

Fig. 2.-- Serial position curves showing the percentage of errors for each serial position, for the three HA-Groups of Experiment 1.

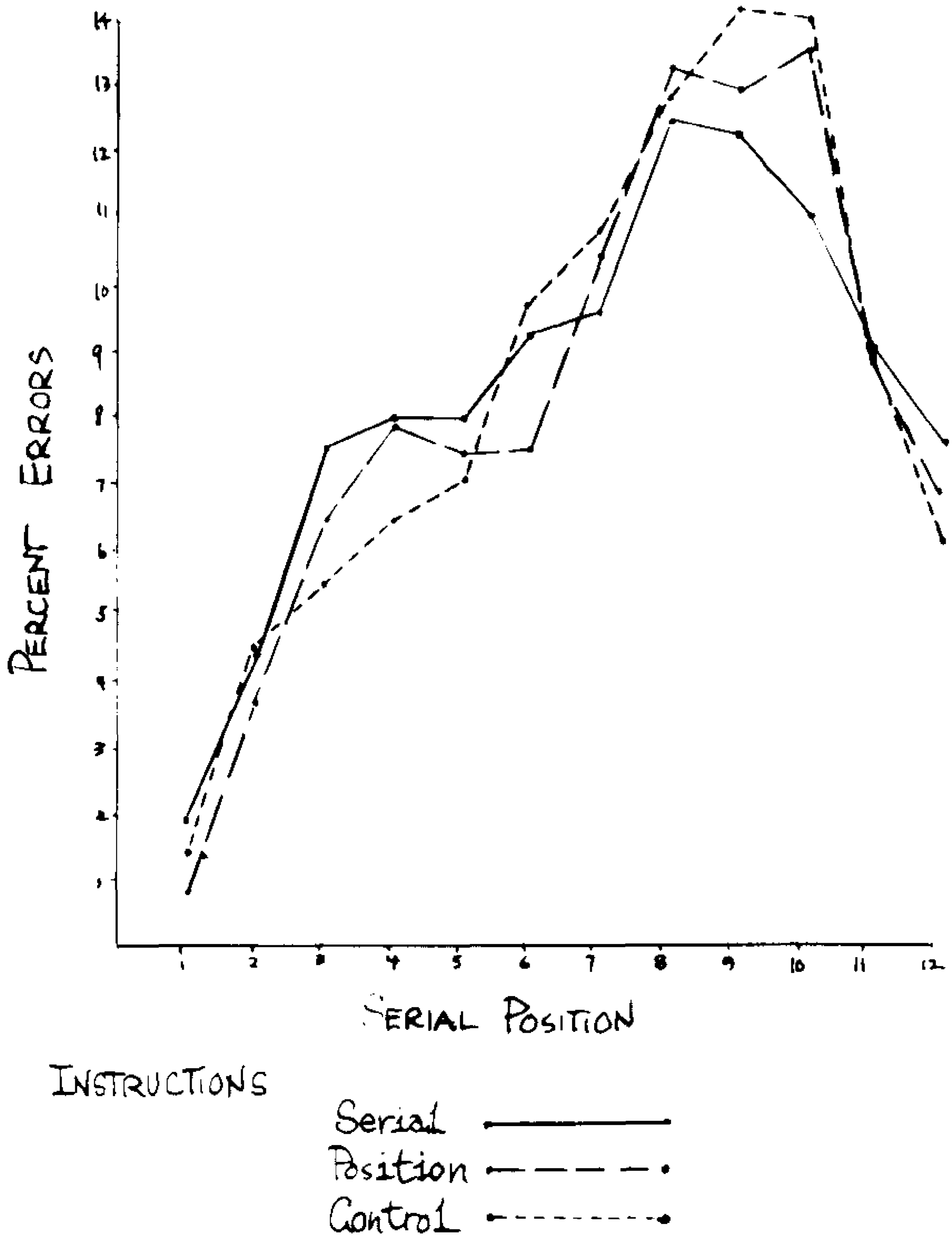
FIGURE 2



PERCENT ERRORS
SERIAL POSITION
INSTRUCTIONS
Serial
Position
Control

Fig. 3.-- Serial position curves showing the percentage of errors for each serial position for the three LA-Groups of Experiment 1.

FIGURE 3



14
13
12
11
10
9
8
7
6
5
4
3
2
1
PERCENT ERRORS
1
2
3
4
5
6
7
8
9
10
11
12
SERIAL POSITION
INSTRUCTIONS
Serial
Position
Control

theses as induced by instructions. Although previous experiments have employed variations in instructions as an experimental variable, most have done so for other purposes--e.g., to contrast intentional (i.e., instructed) and incidental (non-instructed) learning (e.g., Dornbush & Winnick, 1967; Eagle & Leiter, 1964; McLaughlin, 1965; Mechanic & D'andrea, 1966; Somners, 1967; Winnick & Lerner, 1963) to provide a basis for differences in motivation (e.g. Baron, 1967) to provide information or misinformation about the learning situation (e.g. Holden & Rotter, 1962; Miller & Lakso, 1964; Taylor, 1966). The present experiment, by contrast, has provided instructions about specific procedures that are to be used to accomplish learning. That the instructions were acted upon by Ss in this experiment is indicated by the reaction time data, which showed that groups given specificity instructions built up stronger associations between one trigram and the next one on the list and that P-Groups built up stronger associations between the number of the trigram on the list and the trigram than between successive trigrams. Furthermore, the significance of the instructional effect in the error data as well as the borderline significance of the overall instructional effect on trials to criterion indicates that the specific suggestion of a strategy provides these Ss with something of an advantage over the control Ss.

One possible explanation for these findings is that giving S instructions about how to learn the list allows him to start learning the list without having to search for a strategy. He would then learn the list more rapidly than if he had searched for a strategy, as long as the instructed strategy is not one which would hinder learning. Thus, both instructed groups in this experiment learned the list equally as well and more rapidly, with fewer errors, than the C-Groups. On the other hand, if either of the induced strategies is more efficient than the other in this situation, this would become evident by differences between P-and S-Groups.

The Newman-Keuls analyses do not give evidence unequivocally supporting either view. Group P-LA made significantly fewer errors than either Group S-LA or Group C-LA. The latter two groups did not significantly differ from each other indicating superiority of position instructions for the LA list. The first interpretation, on the other hand, is supported by the Newman-Keuls analysis of the trials to criterion data which show that Group C-LA took significantly more trials to learn the list than Group P-LA. However, there was no significant difference between Group P-LA and Group S-LA.

The second finding of note is that the effectiveness of a learning strategy (as induced by instructions) is functionally related to the characteristics of the materials to be learned. That this was the case in the present experiment is indicated by the significant interaction between instructions and materials for the error data. This significant interaction revealed first that position instructions were more effective than specificity instructions with low association trigrams. Secondly, neither strategy was found to be more effective for high association trigrams. This finding is quite understandable. Low association trigrams, by their very nature, provide little basis for the inter-item linkages demanded by the specificity strategy. The existence of numerical position in the list is therefore a feasible aid. As trigrams increase in association value, it should become easier to form inter-item linkages so that when high association trigrams are used the advantage of the position strategy is lost and the strategies are of equal efficiency. It seems reasonable to predict that inter-item linkages would be easier to form with words than trigrams and therefore the position strategy should have no advantage when words are used.

Experiment II

The second experiment explored a potential strategy that has not as yet been accorded much recognition. This is the possibility that, although he is instructed to anticipate individual items, S may group them together into larger perceptual units such as have been found in experimental studies of free recall. (e.g., Tulring, 1962).

Based on the experiments of Miller (e.g., 1956), it seems possible that if, in learning a serial list, S is able to combine a number of items into one "chunk", his learning of the list will be enhanced. Other experiments (Weingartner, 1963; Wright & Bernstein, 1965) have come close to this idea by showing that when associated items are inserted in a serial list as a cluster, these items are learned more rapidly than unassociated items. A recent experiment by Diethorn and Voss (1967) inserted a four-unit chain of normative associations (e.g., cottage, cheese, bread, eat; ocean, blue, white, dark) into various positions of a serial list. It was found that learning was facilitated at those positions where the chain was inserted. More directly relevant to the proposed study is an experiment by Kaufmann (1967) which studied learning of temporal groupings of three, four and six items. Based upon his results, Kaufmann suggests a possible strategy in which "...S divides the list into groupings, attempts to memorize their order, but organizes the groupings themselves into subjectively meaningful units (p. 699)". The second experiment examined this strategy for spatial groupings of items by the procedure of presenting the experimental lists in item-groupings rather than one by one. It was expected that the Ss who are presented trigrams two or four at a time might have an advantage over those being presented one at a time. In addition this advantage should be greater with long lists than with short lists.

Method

Subjects.-- Ninety volunteer Ss from introductory courses during the summer session at Queens College participated in the experiment. They were naive as to serial rote learning and were individually assigned to one of the six groups in the order of their appearance.

Experimental Design.-- Six independent groups of Ss were tested individually. Three sizes of group cluster were used. In Group I, the trigrams were presented one at a time; in Group II, the trigrams were presented in twos, in Group IV the trigrams were presented four at a time. Half of the Ss in each group were presented a short list composed of 12 trigrams (Group S) and half were presented a long list composed of 20 trigrams (Group L). Thus, a 3 x 2 factorial design was employed, with grouping as one dimension and size of list as the second. The six groups were designated as I-S, I-L, II-S, II-L, IV-S, and IV-L.

Apparatus and Materials.-- The stimulus items and lists were prepared as in the first experiment, except that syllables of medium associative value (between 45 and 65%) were used. Three lists of each size were formed to control for any possible effects due to list order. The lists are shown in Table 6. The materials were typed in capital letters on standard memory drum tape and presented on a Lafayette memory drum. The syllables for the control groups (Groups I-S and I-L) were presented at an interstimulus interval of two seconds for both learning and recall trials. For Groups II-S and II-L each cluster was presented for four seconds and for Groups IV-S and IV-L each cluster was presented for eight seconds and there was a total exposure time of 24 seconds for the short list and 40 seconds for the long list, hereby controlling the amount of time each syllable was presented (2 seconds).

Procedure.-- The procedure was the same as in the first experiment except that all groups were given the modification of the standard serial learning instructions. When the syllables were presented two or four at a time this was indicated to them in the instructions: "This is a memory test. You are to learn the nonsense syllables that appear in the window of this machine in the right order as quickly as you can. When I start the machine the syllables will appear in the window one after another (two at a time, four at a time) until 12 (20) have been shown. Try to learn them as they appear."

Before the first recall trial the instructions were also

TABLE 6

The three short and three long lists used

in Experiment II.

Short Lists

(1)	(2)	(3)
GEY	DAK	QIC
TUD	ZIN	PAJ
ZIN	LER	LER
FAW	TUD	TUD
LER	PAJ	ZIN
NUP	QIC	FAW
JIS	GEY	HEB
DAK	NUP	VUL
HEB	FAW	JIS
VUL	JIS	DAK
QIC	HEB	GEY
PAJ	VUL	NUP

Long Lists

(1)	(2)	(3)
CEP	TUD	JIS
GOZ	WOB	HEB
VUL	JIS	FAW
DAK	CEP	TOF
JIS	YAT	VID
WOB	JOH	GEY
LER	ZIN	PAJ
FAW	VUL	WUS
ZIN	GEY	QIC
TUD	DAK	GOZ
GEY	TOF	LER
JOH	NUP	NUP
QIC	LER	YAT
YAT	FAW	JOH
NUP	VID	ZIN
HEB	GOZ	VUL
VID	WUS	DAK
TOF	PAJ	CEP
PAJ	QIC	WOB
WUS	HEB	TUD

somewhat modified: "Now, right after an asterisk has appeared in the window you are to say what the first syllable is. Then a blank line will appear in the window. While that line is there you are to say what the second syllable is before a second line appears. You are to continue in this manner saying the syllables one by one until lines have appeared for all 12 (20) syllables. Guess even if you are not sure."

Results

The effect of the three different sized chunks and list length on trials to criterion, errors, the probability of an error and the number correct on the first quarter trials was analysed by separate 3 x 2 analyses of variance and Newman-Keuls studentized range tests. To further analyze the data Melton curves and serial position curves were drawn.

Trials to criterion.-- Table 7 shows the mean trials to criterion of the six groups, where only small differences as a function of chunk size can be observed. The analysis of variance and Newman-Keuls tests (see Table 6 and 7 of Appendix) found only list length to be significant.

Errors.-- Mean errors and standard deviations for the three chunk sizes and two list lengths can be found in Table 8. The 3 x 2 analysis of variance of these data (see Table 8 of Appendix) indicates that the main effect of the list length is significant F (1,84) = 161.28, $p <$ .005, the long list showing more ($\bar{X}$ = 142.22) errors than the short list ($\bar{X}$ = 38.71) errors. In addition the main effect of chunk size approached

TABLE 7

Mean trials to criterion (and standard deviations) for the six groups of Experiment II.

		Chunk Size		
		(1)	(2)	(4)
List	Short	8.00	7.23	7.45
Length		(2.59)	(1.47)	(2.85)
	Long	15.33	14.00	15.60
		(4.82)	(4.43)	(4.29)

significance, F (2, 84) = 2.72, $p < .10 > .05$. A Newman-Keuls studentized range test was performed to determine specifically which of the six groups were significantly different from each other (see Table 9 of Appendix). It can be seen from this table that each of the short lists resulted in fewer errors, $p < .01$, than each of the long lists. In addition it appears that Group II-L made fewer errors ($\bar{X}$ = 119.53 errors) than Group IV-L ($\bar{X}$ = 161.87 errors) $p < .05$. Thus, it appears that the borderline significance of chunk size in the analysis of variance was caused by a more efficient strategy being induced when S saw two syllables at a time than when he saw four syllables at a time.

Probability of error.-- Since a large proportion of the total variance in the analysis of errors was attributable to the main effect of list length it was believed that if the effect was controlled, a more sensitive test might result. It is possible to control for the number of syllables on the list by calculating the probability of S making an error with the following formula:

$$P = \frac{\text{Total number of errors}}{\text{Total number of Trigrams}}$$

The total number of trigrams is found for each S by multiplying the number of trigrams on the list (12 or 20) by the trials to criterion for that S. The mean probability of an error

TABLE 8

Mean errors (and standard deviations)

for the six groups in

Experiment II.

		Chunk Size		
		(1)	(2)	(4)
List	Short	41.20	35.87	39.07
Length		(15.81)	(10.68)	(18.34)
	Long	145.27	119.53	161.87
		(47.25)	(49.79)	(54.38)

and standard deviation for each of the six groups can be found in Table 9. The 3 x 2 analysis of variance of these data (Table 10 of Appendix) found the main effect of list length to be significant F (1, 84) = 6.78, $p < .025$. This indicates that more errors are made per syllable on long lists than on short lists (mean probability of an error is .464 and .422 for the long and short lists respectively). The main effect of chunk size again approached significance, F (2, 84) = 2.60, $p < .10 > .05$. As can be seen from the Newman-Keuls analysis (see Table 11 of Appendix) this is once again attributable to the significant difference between Group IV-L ($\bar{X}$ = .500) and Group II-L ($\bar{X}$ = .417), $p < .05$.

<u>Number correct on first quarter trials</u>.-- Mean number correct on the first quarter trials and standard deviations for each of the six groups are found in Table 10. Analysis of variance of these data can be found in Table 12 of the Appendix. From this table it can be seen, once again, that the main effect of list length is significant, F(1, 84) = 7.7099, $p < .01$. Thus, it can be concluded that by the first quarter trials the long list already results in significantly more correct responses ($\bar{X}$ = 3.52 correct) than the short list ($\bar{X}$ = 2.62 correct).

Another consistent result is the main effect for chunk size, which again approaches significance F (2, 84) = 2.8833, $p < .10 > .05$. The consistency of this result across the various measures strongly suggests that future research be

TABLE 9

Mean probability of error (and standard deviations) for the six groups in Experiment II.

		Chunk Size		
		(1)	(2)	(4)
List	Short	0.423	0.419	0.423
Length		(0.068)	(0.074)	(0.084)
	Long	0.473	0.417	0.500
		(0.057)	(0.075)	(0.075)

TABLE 10

Mean number correct (and standard deviations) on the first quarter trials for the six groups of Experiment II.

		Chunk Size		
		(1)	(2)	(4)
List Length	Short	2.90	2.27	2.68
		(1.64)	(1.26)	(1.43)
	Long	3.85	4.34	2.36
		(1.39)	(1.88)	(1.19)

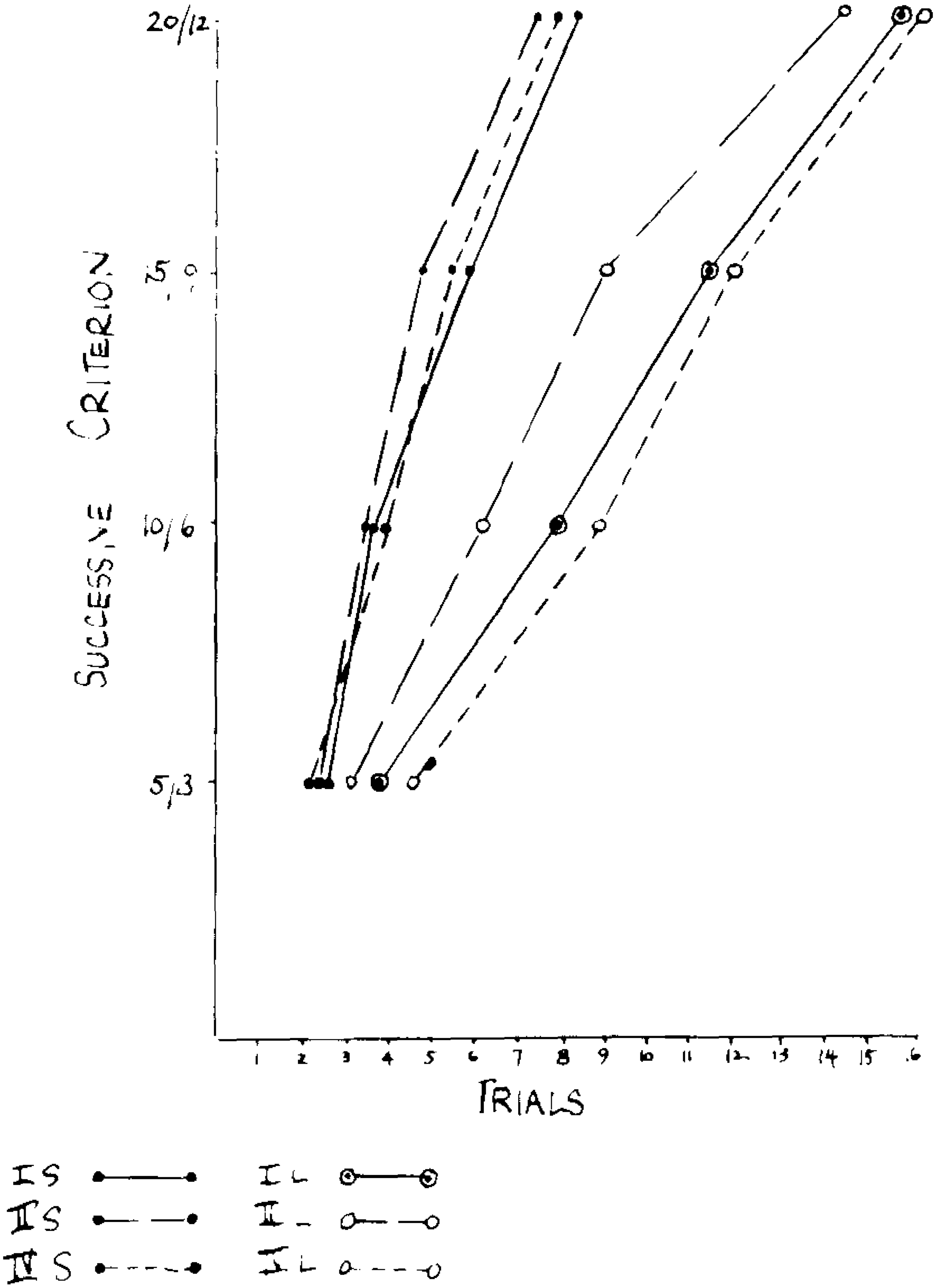
performed analyzing and controlling additional sources of variance. From Table 10 it can be seen that those groups who saw one trigram at a time had the most correct on the first quarter trials ($\bar{X}$ = 3.37 correct) while those who saw four at a time had the fewest correct ($\bar{X}$ = 2.52 correct). For the first time a significant interaction occurred, F (2, 84) = 4.6047, $p < .025$. That this results from Group II-S getting the fewest trigrams correct ($\bar{X}$ = 2.27 correct) and Group II-L getting the most correct ($\bar{X}$ = 4.34 correct) can be seen from Tables 12 and 13 of the Appendix. The latter Table shows the Newman-Keuls analysis of the means found on Table 12.

Melton curves.-- Melton curves plotting trials to successive criteria for each of the six groups are shown in Figure 4. It can be seen that as early as the first criterion (trials to get 1/4 of the trigrams correct) there is a separation between the two list lengths and that the L-list takes more trials to achieve each succeeding criterion than the S-list. It can also be seen that Group II-L is initially superior to the other L-groups and that this superiority was maintained (although not to a significant degree) throughout the learning task. It appears that showing the S two trigrams at a time allowed him to use the strategy of chunking the L-list trigrams into two-syllable trigrams, which functionally reduced the size of the list. Why this did not occur in the S-list is not known.

Serial position curves.-- Curves showing the percentage of errors at each serial position for each of the six groups

Fig. 4.-- Trials to successive criteria for the six groups of Experiment II.

FIGURE 4



20/12
15/9
10/6
5/3
SUCCESSIVE CRITERION
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
TRIALS
I S
II S
IV S
I L

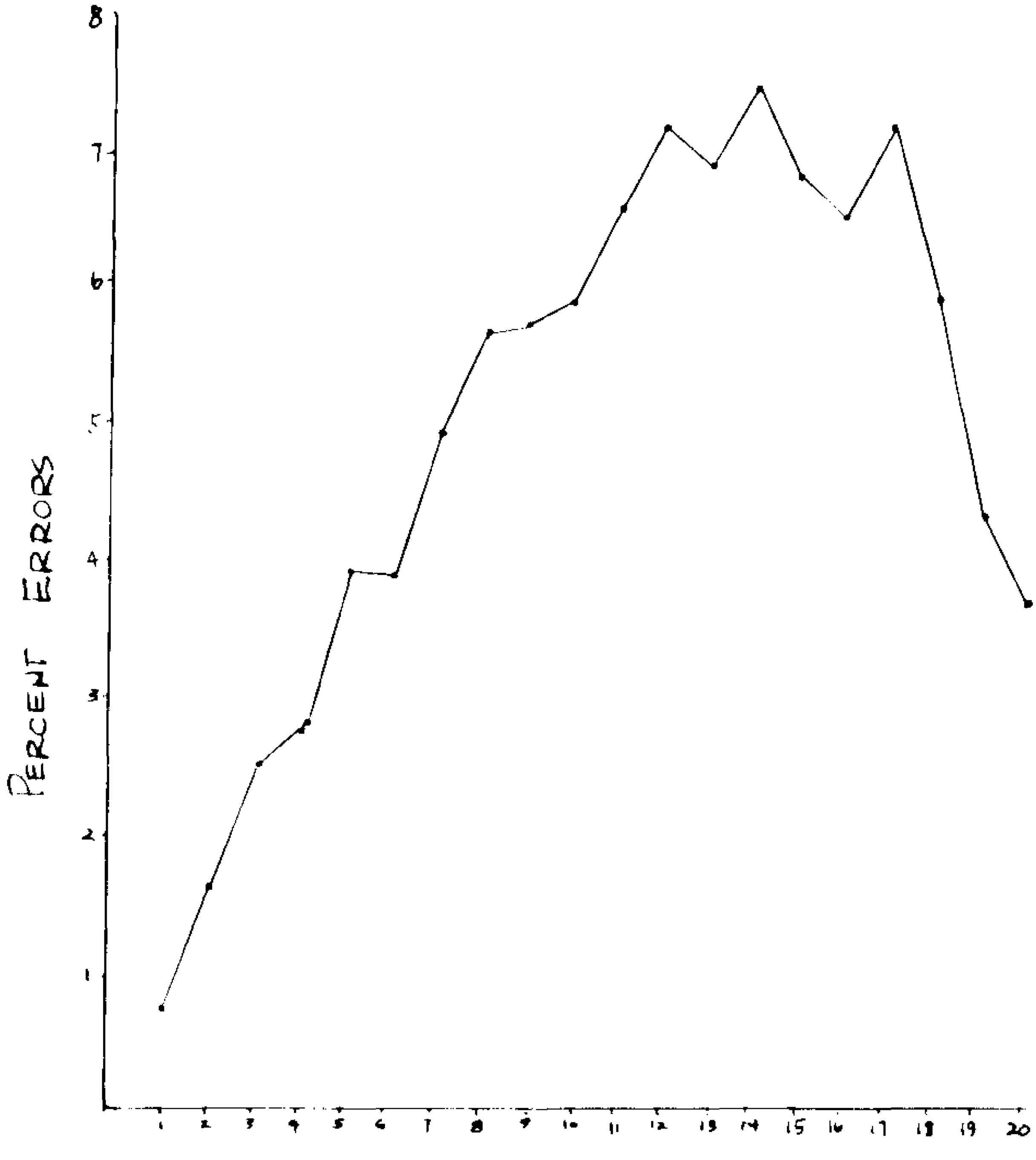
are shown for the L-list and the S-list in Figures 5 and 6 respectively. It will be noticed that for Groups II and IV the curves are drawn in such a way as to indicate the number of trigrams that were presented to S at one time. The serial position curves for Groups I-S and I-L appear to be typical curves which have the area of greatest difficulty in the middle of the list. While this is still basically true for the other groups, in Groups IV-L and IV-S smaller four-unit serial position curves have occurred within the larger serial position curves. That is, for almost every four-syllable perceptual unit, the first and last trigrams are learned more rapidly than the second and third trigrams. The result of this is a rather irregular overall curve with low points corresponding to the end syllables of the smaller curves and high points corresponding to the middle of the smaller curves.

Discussion

The objective of this experiment was to determine whether chunking syllables into two-or four-unit aggregates would be more efficient than learning them individually, and whether the chunking advantage would be greater for lists of 20 syllables than lists of 12 syllables. The chunking strategy was induced by the particular method of presentation rather than by instructions, as was the case in Experiment I. The technique of presenting groups of syllables appears to have been effective in inducing Ss to group items and to attempt to learn by chunking. This is indicated by the serial position

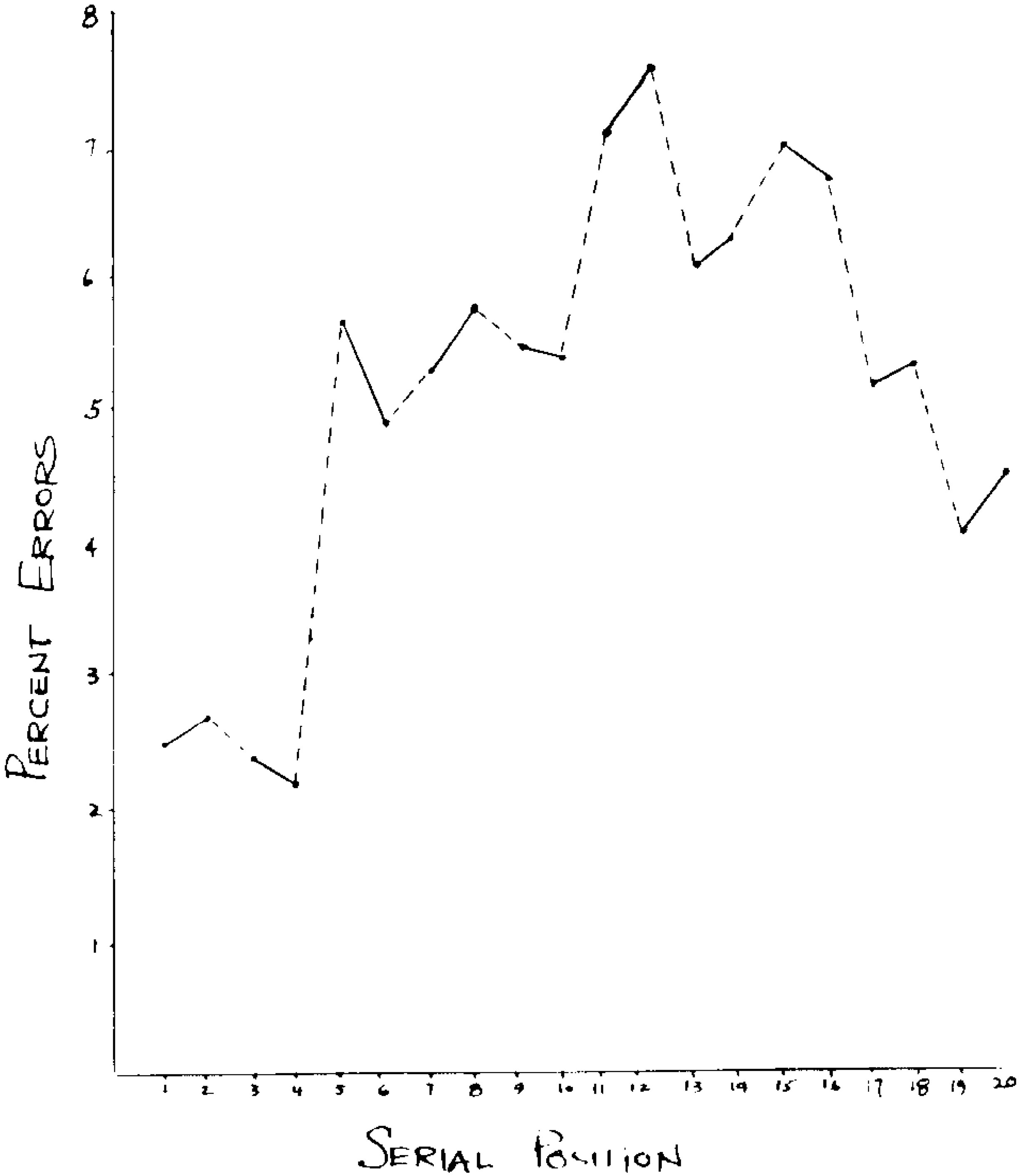
Fig. 5.-- Serial position curves for the long lists of Experiment II.

FIGURE 5A



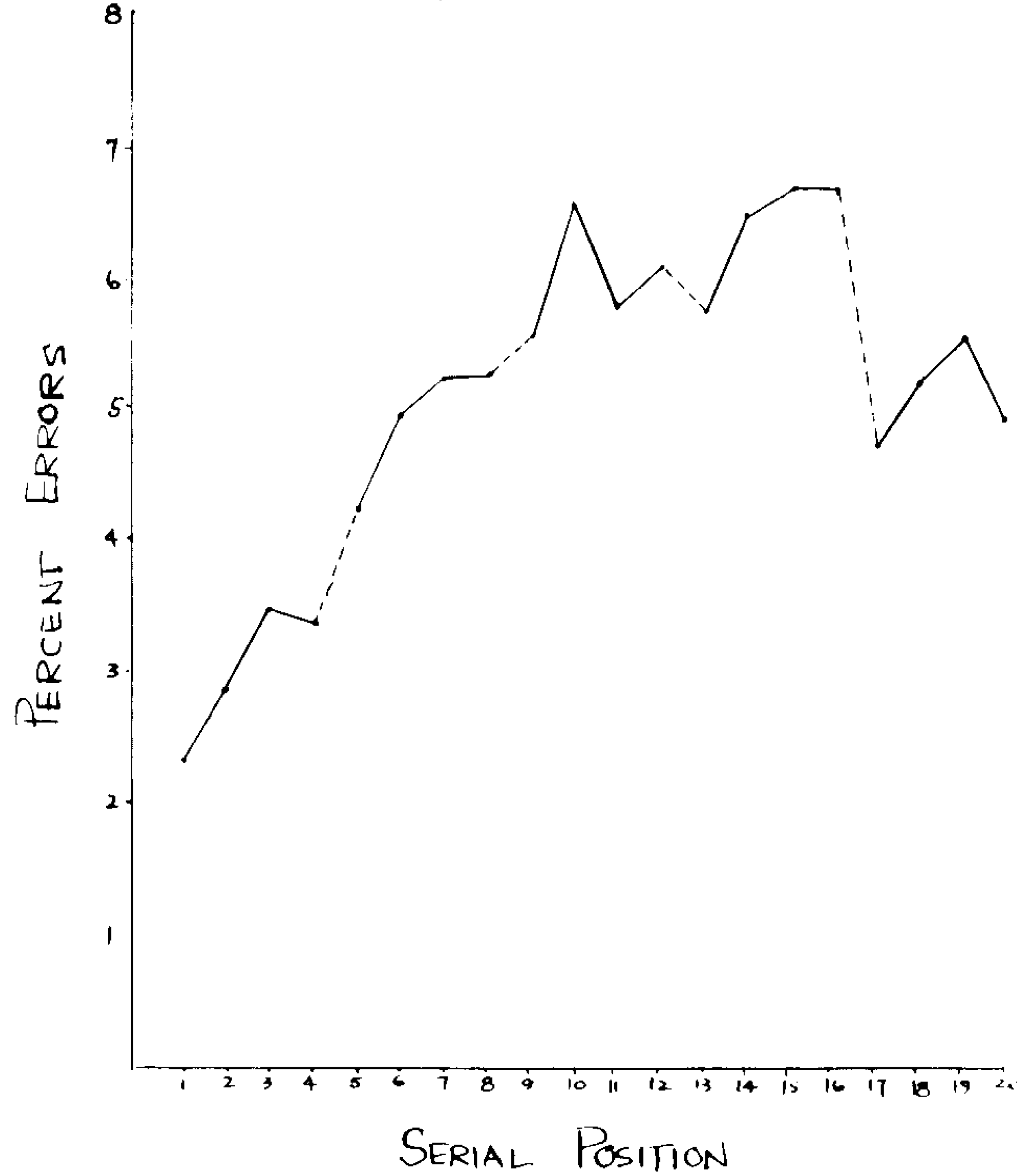
CHUNK SIZE: 1

FIGURE 5B



CHUNK SIZE: 2

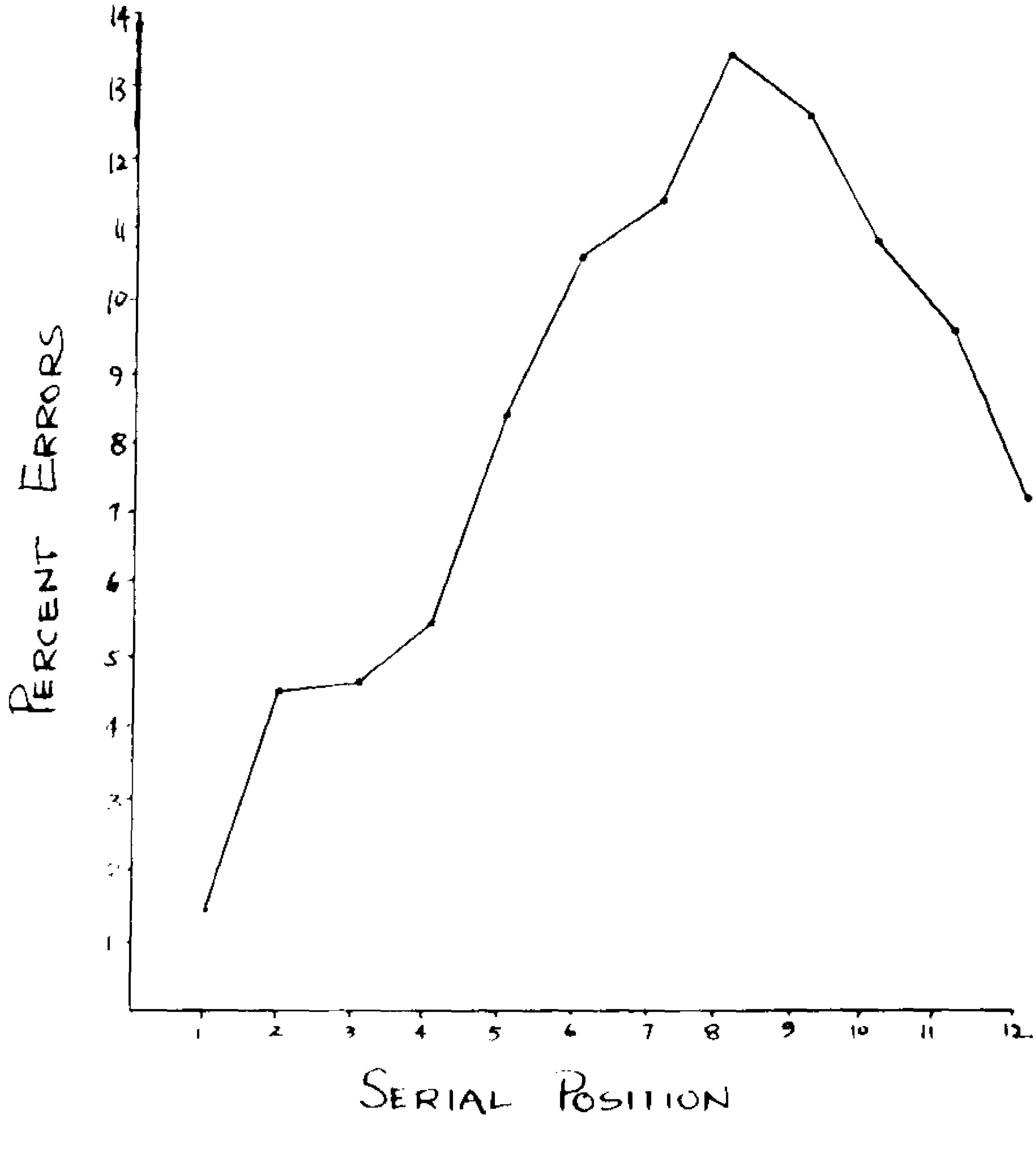
FIGURE 5C



CHUNK SIZE: 4

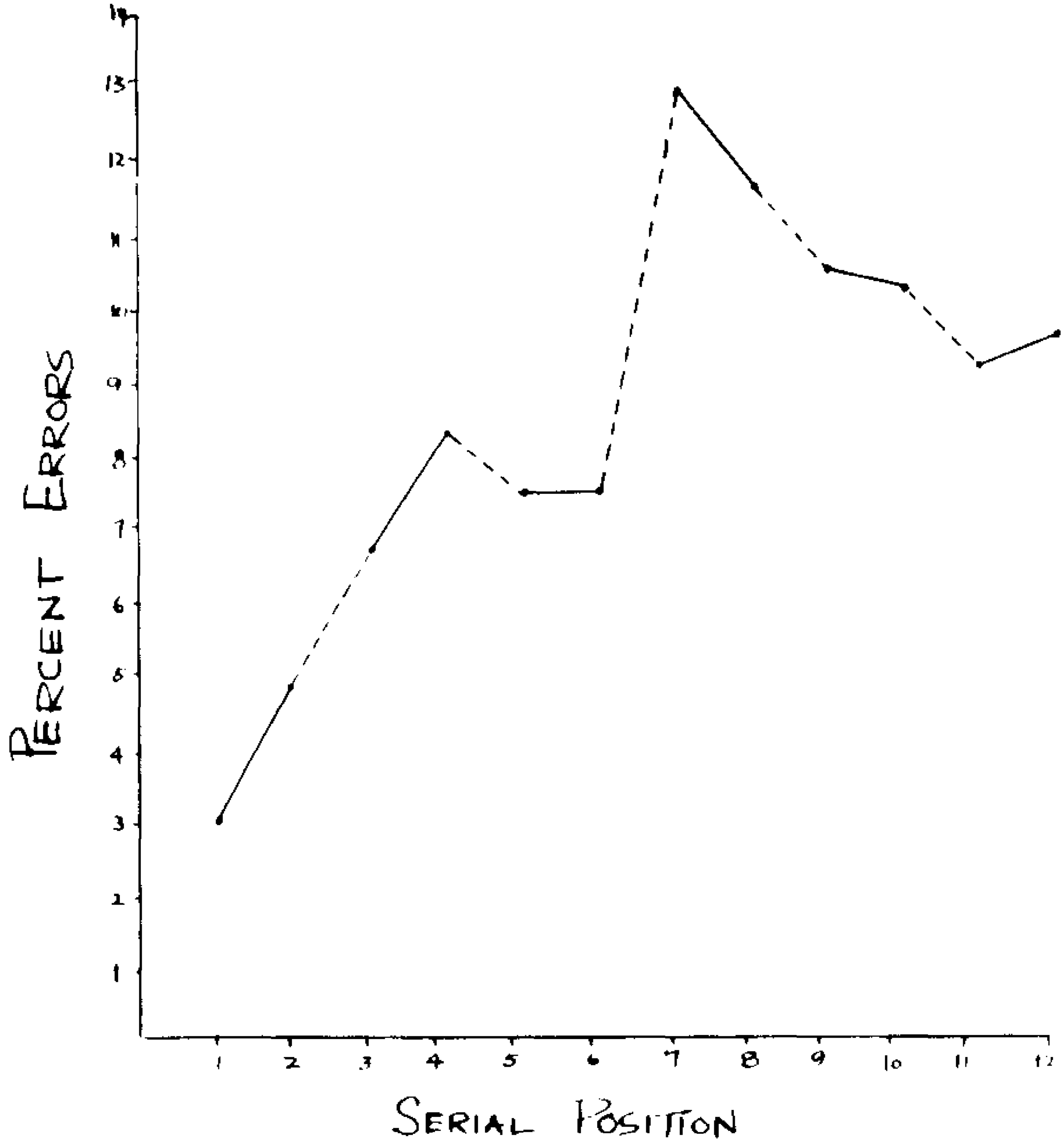
Fig. 6.-- Serial position curves for the short lists of Experiment II.

FIGURE 6A



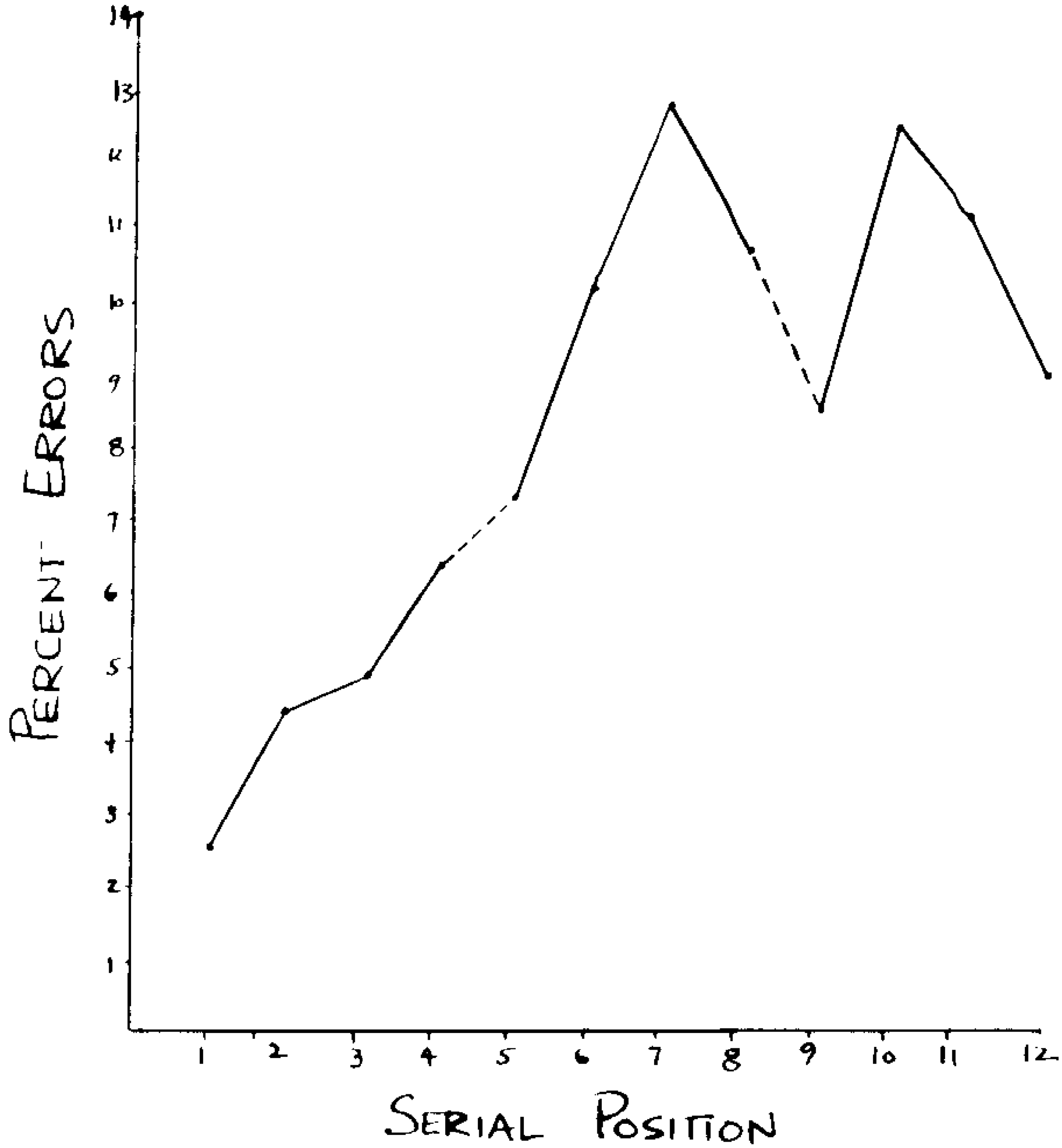
CHUNK SIZE: 1

FIGURE 6B



CHUNK SIZE: 2

FIGURE 6C



CHUNK SIZE: 4

curves. However, although chunking was attempted, it did not prove to be an effective aid to learning.

Although the main effect of chunk size never reached an acceptable level of significance, the consistency of the findings necessitates that it be discussed. Grouping trigrams into two-syllable chunks was the most efficient method in terms of errors and probability of error especially for the long list. This was expected on the basis of previous research which found that highly associated items inserted into a serial list are learned more rapidly than unassociated items (e.g. Diethorn & Voss, 1967; Weingartner, 1963; Wright & Bernstein, 1965). On the other hand, grouping the syllables into four unit-chunks resulted in the most errors with the greatest probability of error. Both the significant interaction occurring in the analysis of the number correct on the first quarter trials and the Melton curves indicate that this was especially evident for Ss learning the long list. Why should a chunk size of four cause the most errors and the greatest probability of error? Since a search of literature failed to reveal any explanation for this phenomenon, experimenter observations and introspective remarks of various Ss are the only source of information available. It seems that Ss shown four trigrams at a time became very confused about what they were supposed to do. E had to repeat the instructions more often to these Ss than to Ss in other groups, and even then many Ss still appeared to be confused about what the task required. It is proposed that future research be performed to help clarify the source of confusion. An experiment including groups learning three-syllable chunks of varying association value would help clarify the situation. There may be a functional relationship between the ability of Ss to learn lists by forming chunks of various sizes and the type of list presented to them. Findings from Experiment I suggest that chunking (which is what Ss instructed to learn the list by the specificity method may be doing) may be more effective for HA than for LA trigrams. Future research having Ss learn lists of varying association levels and various chunk sizes would help to clarify this relationship.

The lack of effectiveness of the chunking strategy may be related to findings from part-whole learning comparisons. The chunking strategy may in fact be considered to be a variant of part learning and possibly subject to some of its disadvantages. In part learning the entire list is divided into smaller sections and S learns one section before proceeding to learn the next section and so on until the entire list is learned. This is quite similar to what is required of Ss learning by the chunking method.

One disadvantage of the part method is the difficulty in connecting the separate parts (McGeoch & Irion, 1952). If this were a factor in the present experiment, the beginning trigrams of the chunks for Group IV should have a greater proportion of errors than the middle trigrams. Since the beginning trigrams were, in fact, generally easier to learn than the middle trigrams, this cannot be the reason for the lack of effectiveness of the chunking strategy. The present experiment is in agreement with the results of Postman and Goggin (1966) who found no differences between part and whole methods with P-A lists. It is, however, in disagreement with recent part-whole experiments using serial lists which have found a small but consistent difference favoring the pure-part method over the whole method with low and high meaningful lists (Goggin & Stokes, 1969; Postman & Goggin, 1964).

An experiment which paralleled the present one even more closely was performed by McLean and Gregg (1967) in which Ss had to learn 24 letter lists in serial order. Experimental Ss were presented with either 3, 4, 6, or 8 letter chunks while control Ss saw one letter at a time. All experimental groups learned the list faster than the control group. The major difference between McLean and Gregg's experiment and the present one is that they presented the stimuli in a horizontal array while this experiment presented the stimuli in a vertical array. It is believed that presenting S the stimuli in a vertical array is somewhat confusing to him since this is not the customary way that he learns materials and thus chunking material presented in this way becomes more difficult. This extra difficulty in chunking, it is proposed, compensates for the advantage that usually accrues to learning a serial list by the part-method so that in the experiment no major differences occurred between the experimental groups.

General Discussion

The general assumption underlying this research is that an S, when required to learn a serial list will attempt to complete the task as rapidly as possible and hence will search for a method or strategy which will extricate him from the situation with the minimum passage of time and energy. If the initial strategy attempted is not efficient in meeting this condition, he will discard it and formulate and test out a new strategy. This process will continue until an efficient strategy is found and S completes the task. This information is in agreement with the general theories of Miller, Galanter, and Pribram (1960), and Restle (1962) although it may not agree with these formulations on specific points.

In line with the above, the strategy formulation stage was short-circuited for the experimental groups in the two experiments reported here in an attempt to determine the efficiency of various strategies on the learning of a serial list. In the first experiment, strategies were initiated by the learning instructions, while in the second the arrangement of materials encouraged the use of a "chunking" strategy.

Comparison of the two experiments, to the extent that such is possible, suggests that the positional and associational strategies may be more appropriate (at least with most materials) than is the clustering strategy. Instructions were found to be effective in inducing the first two strategies, and the instructed groups learned somewhat more rapidly than did the control groups. Whether, in Experiment II, instructions to learn the items in groups or chunks could have had any effect was not determined; rather, the experimental manipulation of presenting the items in groups was used as a more certain way of inducing chunking. Induced by this means, little advantage was apparent in the learning of groups using two-item and four-item chunks on long and short lists over the learning of appropriate controls. The only observed trend was some tendency for the groups exposed to two-trigram chunks to learn the list with fewer errors and a lower probability of error than did the four-trigram chunking group.

It remains to be determined, however, whether a three-trigram group might be even more effective and whether the chunking strategy may be functionally related to characteristics of the material. The few previous studies of chunking in serial rote learning have introduced associated materials (e.g. Diethorn & Voss, 1967; Weingartner, 1963; Wright & Bernstein, 1965) into a list composed of otherwise unrelated items and found more rapid learning for these more easily grouped items than for the rest of the list. This suggests that the chunking strategy may be dictated by the characteristics of the materials and may be impervious to the kind of perceptual grouping introduced in this study. It may, therefore, be a specialized strategy called up by unusual circumstances of list construction, but one not likely to be used where the arrangement of items on the list follows the usual standardized rules, such as those laid down by Hilgard (1951).

If, on the other hand, the lack of effectiveness of the clustering technique is in part due to the unfortunate choice of cluster size used here, then future experiments varying the size of the spatial grouping might find the clustering of items into three-unit chunks to be a more effective technique than chunk sizes of two or four. Another possibility is that the most efficient chunk size is one which is subjectively imposed on the list and that any E imposed technique might only retard the learning of a serial list.

It seems likely that the spatial grouping of items is related to the specificity hypothesis investigated in the first experiment. If this is so, the relative ineffectiveness of grouping the syllables into two-or four-unit aggregates is somewhat understandable, since the formation of inter-item linkages on the medium association level syllables used here would be rather difficult. Future research varying the association level of the spatial grouping would aid in a further understanding of this problem.

This possibility, that it may be the materials themselves that induce the chunking strategy, is given credence by the finding from the first experiment of a significant interaction between the instructional variable and the association value of the nonsense syllables in the lists. Such an outcome suggests that an important consideration, as S attempts to formulate a learning strategy for himself, may be the attributes of the materials to be learned. Subjects, such as those comprising the control group in Experiment I, may spend the first few trials examining the materials to determine what might be an effective plan of attack. Where the items are high association syllables or meaningful terms, the associational strategy may suggest itself or may come into play even without S's awareness. A list composed of low association syllables may require more scrutiny and some, but not necessarily all, Ss may seize upon the positional strategy as a possible aid. Where the list has a group of items implanted together that are interrelated in some manner (e.g., being associated where words are used, as "barn", "farm", "cow", "milk"; or rhyming in nonsense syllables, as "VAR", "LAH", "DAR") the clustering strategy, so common in free recall, will come into play.

This finding is reasonable since LA trigrams, by their very nature, provide little basis for inter-item linkages, as demanded by the specificity instructions. On the other hand, as the trigrams increase in association level, the formation of inter-item linkages should become easier. When HA syllables are used, the advantage of the position strategy is lost and the strategies become equally efficient. It seems a reasonable extension to predict that inter-item associations are easier to form with words and therefore, the specificity strategy should have an advantage with words. It is possible that some of the discrepancies in the literature may be explained by this interpretation. Some experiments finding evidence for the specificity hypothesis have used words (e.g., Postman & Stark, 1967; Shuell & Keppel, 1967; Young, Milaukas & Bryan, 1963). Others using HA trigrams have not found evidence unequivocally supporting this view (e.g., Ebenholtz, 1963). Strangely enough very few, if any, of the studies investigating this problem have used low association value nonsense syllables. That this cannot be the entire reason for the reported discrepancies is demonstrated by experiments using words that find evidence for neither hypothesis (e.g., Jensen & Rohwer, 1965; Young, 1962) or the position hypothesis (e.g., Keppel & Saufley, 1964; Young, Patterson & Benson, 1963). It is possible that certain procedures necessitate the use of a particular strategy to facilitate efficient learning, regardless of the stimuli used.

In the first experiment Ss were given specific experimental instructions about how to learn the list. While a few other studies have manipulated the instructional variable (e.g., Jensen, 1962; Winnick & Dornbush, 1963) this variable has been relatively neglected. The reaction time data demonstrate that it is possible to influence Ss learning strategy by instructions. That this was so for the S-Groups is not at all surprising since most people have had practice learning serially presented material (e.g., poems) by connecting each item with the subsequent one. Therefore, it seemed natural to S-Group Ss that they should be instructed to learn a nonsense syllable list this way. That P-Groups followed instructions is more surprising, since the technique of remembering the ordinal position of the syllable on the list is different from the way Ss have previously learned serially presented material. The novelty of this technique was further shown by the reaction of P-Group Ss when instructions were given. Many were surprised when they were told that they would learn the list more rapidly if they learned the numbers of the syllables on the list. A few even remarked, during the course of learning, that they were abandoning the instructed strategy and learning the list by some other technique. Since the effectiveness of instructionally induced strategies has been demonstrated, this technique could prove valuable in future research dealing with strategies not only in serial learning but other areas of human learning such as paired associate learning, concept formation, free recall, etc.

APPENDIX

TABLE 1

Analysis of variance of the mean trials to

criterion of Experiment I.

Source	Sum of Squares	Degrees of Freedom	Mean Square	F	P
Total	1562.06	89			
A (Instructions)	79.49	2	39.74	2.54	.10<.05
B (Association Level	96.11	1	96.11	6.15	<.025
A X B	73.28	2	36.54	2.34	N.S.
Error	1313.18	84	15.63		

TABLE 2

Newman-Keuls analysis: Trials to criterion of Experiment I.

Order	(1)	(2)	(3)	(4)	(5)	(6)
Group	S-HA	P-LA	P-HA	C-HA	S-LA	C-LA
Tj	113	118	125	133	167	179
S-HA	-	5	12	20	54	66*
P-LA		-	7	15	49	61*
P-HA			-	8	42	54
C-HA				-	34	46
S-LA					-	12
C-LA						-

*$\underline{P} < .05$

Truncated range r	(2)	(3)	(4)	(5)	(6)
q.95 (r ,84) $\sqrt{n\ M\ S\ error}$	43.30	52.02	57.22	60.89	62.73
q.99 (r ,84 $\sqrt{n\ M\ S\ error}$	57.53	65.48	70.38	73.75	74.51

TABLE 3

Analysis of variance of the mean errors of

Experiment I.

Source	Sum of Squares	Degrees of Freedom	Mean Square	F	P
Total	54115.29	89			
A (Instructions)	3915.02	2	1957.51	3.80	$<.05$
B (Association) Level	3144.71	1	3144.71	6.10	$<.025$
A X B	3757.91	2	1878.96	3.65	$<.05$
Error	43297.59	84	515.45		

TABLE 4

Newman-Keuls analysis: Errors of Experiment I.

Order	(1)	(2)	(3)	(4)	(5)	(6)
Group	S-HA	P-LA	P-HA	C-HA	S-LA	C-LA
Tj	564	583	665	751	948	981
S-HA	-	19	101	187	384*	421*
P-LA		-	82	168	365*	398*
P-HA			-	86	283	316
C-HA				-	197	230
S-LA					-	33
C-LA						-

* $P < .05$

Truncated range r		(2)	(3)	(4)	(5)	(6)
$q_{.95}$ (r .84)	$\sqrt{\text{NMS error}}$	248.84	298.96	328.86	349.96	360.51
$q_{.99}$ (r .84)	$\sqrt{\text{NMS error}}$	330.62	376.34	404.48	423.82	428.22

TABLE 5

Analysis of variance of the mean number correct on the first quarter trials of Experiment I.

Source	Sum of Squares	Degrees of Freedom	Mean Square		
Total	144.5512	89			
A (Instructions)	1.0414	2	0.5207	< 1	N.S.
B (Association Level)	1.9184	1	1.9184	1.2028	N.S.
A X B	7.6140	2	3.8070	2.3870	N.S.
Error	133.9774	84	1.5949		

TABLE 6

Analysis of variance of the mean trials to criterion of Experiment II.

Source	Sum of Squares	Degrees of Freedom	Mean Square	F	P
Total	2425.12	89			
A (chunk size)	21.61	2	10.51	0.76	N.S.
B (list length)	1246.94	1	1246.94	91.02	$<.005$
A X B	6.18	2	3.09	0.23	N.S.
Error	1150.39	84	13.70		

TABLE 7

Newman-Keuls analysis: Trials to criterion of Experiment II.

Order	(1)	(2)	(3)	(4)	(5)	(6)
Group	II-S	IV-S	I-S	II-L	I-L	IV-L
Tj	107	112	120	210	230	234
II-S	-	5	13	103**	123**	127**
IV-S		-	8	98**	118**	122**
I-S			-	90**	110**	114**
II-L				-	20	24
I-L					-	4
IV-L						-

** $P < .01$

Truncated range r	(2)	(3)	(4)	(5)	(6)
$q_{.95}(r, 84)\sqrt{\text{NMS error}}$	40.55	48.72	53.59	57.03	58.75
$q_{.99}(r, 84)\sqrt{\text{NMS error}}$	53.88	61.33	65.92	69.07	69.79

TABLE 8

Analysis of variance of errors in

Experiment II.

Source	Sum of Squares	Degrees of Freedom	Mean Square	F	P
Total	380500.40	89			
A (chunk size)	8119.26	2	4059.63	2.72	<.10>.05
B (list length)	241077.38	1	241077.38	161.28	<.005
A X B	5746.31	2	2873.16	1.92	N. S.
Error	125557.45	84	1494.73		

TABLE 9

Newman-Keuls analysis: errors of Experiment II.

Order	(1)	(2)	(3)	(4)	(5)	(6)
Group	II-S	IV-S	I-S	II-L	I-L	IV-L
Tj	538	586	618	1793	2179	2428
II-S	-	48	80	1255**	1641**	1829**
IV-S		-	32	1207**	1593**	1842**
I-S			-	1175**	1561**	1810**
II-L				-	386	635*
I-L					-	249
IV-L						-

* $P < .05$

** $P < .01$

Truncated range r	(2)	(3)	(4)	(5)	(6)
q.95 (r ,84) $\sqrt{\text{NMS error}}$	424.5	510	561	597	615
q.99 (r ,84) $\sqrt{\text{NMS error}}$	564	642	690	723	730.5

TABLE 10

Analysis of the probability of an

error in Experiment II.

Source	Sum of Squares	Degrees of Freedom	Mean Square	F	P
Total	0.5777	89			
A (chunk size)	0.0303	2	0.0151	2.60	.10 <>.05
B (list length)	0.0393	1	0.0393	6.78	<.025
A X B	0.0240	2	0.120	2.07	N.S.
Error	0.4841	84	0.0058		

TABLE 11

Newman-Keuls analysis: Probability of an error of Experiment II.

Order	(1)	(2)	(3)	(4)	(5)	(6)
Group	II-L	II-S	I-S	IV-S	I-L	IV-L
Tj	6.25	6.28	6.34	6.35	7.10	7.50
II-L	-	0.03	0.09	0.10	0.85	1.25*
II-S		-	0.06	0.07	0.82	1.22*
I-S			-	0.01	0.76	1.16*
IV-S				-	0.75	1.15
I-L					-	0.40
IV-L						-

* $P < .05$

Truncated range r	(2)	(3)	(4)	(5)	(6)
$q_{.95}(r, 84)\sqrt{\text{NMS error}}$	0.82	0.99	1.08	1.15	1.19
$q_{.99}(r, 84)\sqrt{\text{NMS error}}$	1.09	1.24	1.33	1.40	1.41

TABLE 12

Analysis of the number correct on

the first quarter trials

of Experiment II.

Source	Sum of Squares	Degrees of Freedom	Mean Square	F	P
Total	251.1987	89			
A (chunk size)	13.5776	2	6.7888	2.8833	.10 $<>$ .05
B (list length)	18.1530	1	18.1530	7.7099	$<$ .01
A X B	21.6839	2	10.8419	4.6047	$<$ .025
Error	197.7842	84	2.3545		

TABLE 13

Newman-Keuls analysis:

Number correct on first quarter trials of Experiment II.

Order	(1)	(2)	(3)	(4)	(5)	(6)
Group	II-S	IV-L	IV-S	I-S	I-L	II-L
Tj	34.04	35.33	40.25	43.52	57.77	65.13
II-S	-	1.29	6.21	9.48	23.73*	31.09**
IV-L		-	4.92	8.19	22.44*	29,80**
IV-S			-	3.27	17.52	24.88*
I-S				-	14.25	21.61*
I-L					-	7.36
II-L						-

* $P < .05$

** $P < .01$

Truncated range Π	(2)	(3)	(4)	(5)	(6)
q. 95 $(\Pi, 84)\sqrt{\text{MS error}}$	16.81	20.20	22.22	23.64	24.35
q. 99 $(\Pi, 84)\sqrt{\text{MS error}}$	22.33	25.42	27.32	28.63	28.93

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