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LEARNING SET FORMATION IN PROGRAMMED INSTRUCTION

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AEROSPACE MEDICAL RESEARCH LABORATORIES

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FOREWORD

This research represents a portion of the technical development program of the Technical Training Branch, Training Research Division of the Behavioral Sciences Laboratory. The research was documented under Project 1710, "Training, Personnel and Psychological Stress Aspects of Bioastronautics," Task 171007, "Automated Training and Programed Instruction." The research was conducted by the University of Pittsburgh under Contract AF 33(616)-7175. The research was also supported in part by the Cooperative Research Branch, U. S. Office of Education under Contract OE 2-10-057. Dr. Robert Glaser was the principal investigator. Air Force personnel associated with the research were changed several times during the effort. Dr. Gordon A. Eckstrand was the project scientist throughout the entire period. Dr. Felix Kopstein was the initial Air Force technical monitor. He was succeeded by Dr. Theodore E. Cotterman and Dr. Ross L. Morgan. Likewise, task scientists were Dr. Marty R. Rockway, Dr. Theodore E. Cotterman, and Dr. Ross L. Morgan. The authors acknowledge the various contributions of the above Air Force personnel to the planning, execution and reporting of the research. This research began October 1961 and was completed October 1962. The present version of this report was prepared by Dr. John S. Abma, using material submitted to the Air Force by the contractor.

In the accomplishment of the work reported, special appreciation is due to Dr. W. Robert Paynter, Supervising Principal; Dr. Warren D. Shepler, Director of Instruction; and Mr. J. Ernest Harrison, Director of Curriculum of the Baldwin-Whitehall Schools. The devotion of these educators to constantly seeking to improve the quality and efficiency of instruction on the basis of modern science and technology was a major inspiration to the project staff. The cooperation of the teachers in the Baldwin-Whitehall Schools deserves a futher note of appreciation. Theodore Harakas and Nancy Hoisman contributed to test development and data analysis.

This technical report has been reviewed and is approved.

WALTER F. GRETHER, PhD
Technical Director
Behavioral Sciences Laboratory

ABSTRACT

Two different orders of three units of programed instruction were administered to groups of students matched on (a) intelligence or (b) relevant achievement tests. Comparisons were made between groups that were (a) high or (b) average on each matching variable. The hypotheses being tested were that after varied amounts of prior practice in programed instruction, (a) learning set formation would not be demonstrated by the high intelligence and high achievement groups, and (b) learning set formation would be demonstrated by the average intelligence and average achievement groups. Only partial support was obtained for each hypothesis. The data indicated the following:

(a) In a programed sequence, error rate is a more appropriate measure than achievement for observing learning set formation.

(b) Learning set formation is observable in programed instruction for all learners regardless of individual differences. Since, reduced error rate was the indication of learning set formation, the phenomenon can be measured only in programs involving a moderately high error rate.

(c) Since error rate differed for some of the experimental groups while achievement remained the same, the results were interpreted to mean that a moderately high error rate program which offers opportunity for correction of response errors may be as effective in producing learning as a low error rate program which confirms correct responses.

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SECTION I

INTRODUCTION

Harlow (ref 1) has shown that lower organisms improve in learning efficiency as they gain experience in responding to problem-solving tasks. In these tasks, the learner is presented with a series of small problems one at a time. The successive problems vary in content, but the set of operations required to find and make the correct response is the same for each, eg, differentiating shape and position of objects, making a second response choice dependent upon the first choice, etc. On every problem, the response made by the organism is immediately confirmed if it is correct, reinforcing the operations that precede it. Under these conditions, the organism gradually develops proficiency in discriminating the cues within the problem that will lead to making successful responses. In the process, the organism not only learns the solutions to the individual problems, but learns also how to perform the operations necessary for arriving at a solution. This increase in efficiency with continued practice in new learning situations has been called learning set formation. The phenomenon also has been observed in human subjects and different learning tasks (refs 2, 3).

Like the learning situations used by Harlow, programed instruction requires the learner to make responses to a sequence of problems. Knowledge of the correctness of the response follows immediately after each response is made. Further, the operations employed in determining the correct response often are similar for each item in the sequence presented, eg, the learner must attend to the information presented, discriminate the information-giving cues for the response required, and recall cues from preceding items that relate to the current item to arrrive at the correct response. This similarity between the sequential aspects of many programed learning tasks and the sequential aspects of the tasks used in learning set studies suggests that human learners when exposed to the programed instruction method for the first time may initially show some degree of inefficiency in utilizing the materials presented, but with experience will learn the operations necessary for effective and successful learning. Were this the case, the increased learning proficiency would be reflected in progressively higher achievement as the learner gains experience with the new learning situation.

The possibility that learning sets are formed with increased exposure to programed instruction sequences has been implied in Skinner's statement that the programing principle of immediate confirmation "encourages a more careful reading of the programed material than is the case in studying a task where the consequences of attention or inattention are so long deferred that they have little effect on reading skills" (ref 4). The degree of improvement in attention and other behaviors necessary for learning will depend upon the extent to which these behaviors already exist. In the human organism, the development of learning skills that define learning set formation may be expected to vary with certain individual differences that are assumed to be related to human learning in general. For example, one of the correlates of existing intelligence measures that is usually assumed is the ease or speed with which the learner can adapt to new learning situations. If such a relationship between intelligence and learning adaptability does exist, high aptitude learners should demonstrate learning set formation soon after they are introduced to a new learning situation, whereas those of lower aptitude should require more time to develop a learning set.

A second variable possibly related to the ease with which a learner adapts to a new learning situation is the degree of prior knowledge of the material being taught. The learning situation is made up of two components in addition to the learner -- the material to be learned, and the instructional conditions under which the learning is to take place. The learner having some prior familiarity with the material presented may adapt more readily to a new learning situation than the one who either has no familiarity with the material or has been unsuccessful in learning similar material in the past. Previous studies of learning set, using lower organisms, have controlled the effects of prior knowledge by using learning materials which are completely unfamiliar to the animal. In most human learning situations, however, such control methods are more difficult to implement. The alternative is to manipulate prior relevant knowledge rather than eliminate it.

The experiment reported here was an exploratory effort to observe learning set formation in human learners exposed to programed instruction. We hypothesized that (a) learners of high intelligence and prior school achievement would not demonstrate differences in achievement and response accuracy as practice learning from programed instruction accrued, but that (b) learners of average intelligence and average prior school achievement would demonstrate improvements in achievement and response accuracy with increased practice in programed instruction.

SECTION II

METHOD

SUBJECTS

The subjects used were matched groups drawn from a pool of 120 junior high school students receiving programed instruction in science. None of the 120 students, and consequently none of the experimental subjects, had been exposed to programed instruction prior to the experiment. Therefore, learning by programed instruction methods was considered to be a new learning situation for all subjects.

MATERIALS

Three chapters from a linear program on General Science[1] were used as learning materials. The chapters, covering independent science topics commonly taught in junior high school, were Measurement (235 frames), Chemistry (825 frames), and Sound (230 frames). These were presented in a programed textbook format that required the learner to read the frame, write down one or more responses, turn the page and confirm the correctness of the response(s), and then proceed to the next frame. Students were permitted to respond at their own rates of speed in as many 40-minute work sessions as were necessary to complete the three chapters.

The Otis Test of Mental Ability (Beta) and the Cooperative Science Achievement Test were used as measures of intelligence and prior knowledge of the learning material, the two independent variables assumed to be related to learning set formation.

At the end of each chapter all learners received a multiple-choice test which had been constructed specifically for that unit. Scores on these chapter tests were used as measures of the amount of learning that took place during the programed instruction.

DESIGN AND PROCEDURE

Before the experiment, measures of intelligence and prior science knowledge were obtained for 120 students in the classes from which the experimental subjects were drawn. These two measures served as the basis for establishing high and low matched experimental groups.

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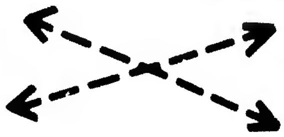
1. Published commercially in three volumes as "General Science" by Teaching Materials Incorporated, Division of Gralier, Inc., 575 Lexington Avenue, New York 22, N.Y.

In the learning phase, two of the four classes containing the experimental subjects received the Measurement chapter first, followed by the Chemistry and Sound chapters (Order 1). The remaining two classes received the same units, but in the reverse order (Order 2). These presentation orders are summarized in table I. Groups matched on intelligence level and groups matched on prior science achievement level were selected from each presentation order, and compared on two learning measures. Arrows indicate the comparisons that bear upon the experimental hypotheses.[2]

TABLE I

SUMMARY OF PRESENTATION ORDERS

Order 1 (H-IQ$_1$ and L-IQ$_1$)	Order 2 (H-IQ$_2$ and L-IQ$_2$)
1. Measurement	1. Sound
2. Chemistry	2. Chemistry
3. Sound	3. Measurement



The selection procedures for the groups, and the comparisons made in testing the hypotheses, are described below.

1. Design for Groups Matched on Intelligence. Of the 60 subjects who received Order 1, the 15 with the highest scores on the intelligence test and the 15 with the lowest scores were selected as experimental subjects. These groups were designated H-IQ$_1$ and L-IQ$_1$, respectively. From the 60 students in the Order 2 classes, 15 high intelligence subjects (H-IQ$_2$) and 15 lower intelligence subjects (L-IQ$_2$) were matched by pairing with the experimental subjects chosen from Order 1.

As may be seen in Table 1, the Measurement chapter constituted the initial exposure of H-IQ$_1$ to the new programed learning situation, while H-IQ$_2$ received this chapter after prior practice with the Sound and Chemistry programed sequences.

2. This design is predicated upon minimum differential transfer among the subject-matter areas. Interpretation of the comparisons would be made more difficult if the study of chemistry were to benefit the study of measurement more than the study of sound, or vice versa. A similar difficulty would be encountered if, for some reason, it were better to study measurement before sound, or vice versa. The subject matters used in the study were considered to be relatively free from such differential transfer effects.

These groups were used to test the first hypothesis, which predicted that the learning performance of high intelligence groups would be equivalent regardless of differences in prior practice in a new learning situation. The test of this hypothesis was made by comparing $H\text{-}IQ_1$ and $H\text{-}IQ_2$ on two criterion measures of learning performance, chapter test achievement and frame error rate, for the Measurement chapter.

Table 1 indicates also that the $L\text{-}IQ_1$ and $L\text{-}IQ_2$ groups received the Measurement chapter after different amounts of practice in the programed learning situation. These groups were used to test the second hypothesis, which predicted that the lower intelligence group receiving prior practice in programing ($L\text{-}IQ_2$) would demonstrate higher performance than the group receiving no such practice ($L\text{-}IQ_1$). The dependent variables on which these groups were compared were also the chapter test and frame error rate.

The design permitted a replication of these tests of the hypotheses by using the Sound chapter as the learning material presented with or without prior practice in the programed learning situation. Using the Sound chapter test as the achievement measure and frame errors in the Sound chapter as the error rate measure, it was predicted that no differences between the $H\text{-}IQ_1$ and $H\text{-}IQ_2$ groups would be found, but that $L\text{-}IQ_1$ would show a higher performance than $L\text{-}IQ_2$ on both measures, because of the practice received prior to working on the Sound unit.

2. <u>Design for Groups Matched on Achievement.</u> Matched groups with high and lower achievement scores were also chosen from the pool of learners who had taken Order 1 and Order 2. The Cooperative Science Test score was used as the criterion for group placement. The four groups thus chosen were designated $L\text{-}Ach_1$, $H\text{-}Ach_1$, and $L\text{-}Ach_2$, and $H\text{-}Ach_2$, with 15 subjects in each group.

These achievement groups were subjected to the same comparisons as described above for the intelligence groups. The procedure for selecting subjects allowed a given subject to be in one of the achievement groups and also in one of the intelligence groups, eg, high achievement and high intelligence.

SECTION III

RESULTS

ACHIEVEMENT MEASURES

The data obtained from the four matched IQ groups on the Measurement and Sound chapter tests are presented in table II. Correlated _t_ tests of differences between $H\text{-}IQ_1$ and $H\text{-}IQ_2$ means for the measurement and Sound chapter tests yielded values of 1.49 and 1.12, respectively. These values indicate that the obtained mean differences are well within the limits of chance. Thus, there is no basis to refute the first hypothesis that high intelligence groups would learn to equivalent degrees regardless of differences in amount of prior practice with programed instruction.

To test the second hypothesis, that prior practice in the new learning situation would increase achievement performance of learners of average intelligence, $L\text{-}IQ_1$ and $L\text{-}IQ_2$ means on the Measurement and Sound chapter tests were compared. Again, correlated _t_ tests indicated that the differences were not statistically significant ($t = 1.36$ for Measurement and 1.49 for Sound). The difference on the Sound test was in the opposite direction from that predicted. Thus, the data do not support the second hypothesis.

The Measurement and Sound test means of the groups matched on prior science achievement were also used to test the hypotheses. Table III presents mean scores on both tests for the $H\text{-}Ach_1$, $H\text{-}Ach_2$, $L\text{-}Ach_1$, and $L\text{-}Ach_2$ groups. The mean differences between $H\text{-}Ach_1$ and $H\text{-}Ach_2$ were not significant ($t = 0.87$ and 0.98 for Measurement and Sound, respectively), again offering no basis to refute the first hypothesis. The difference between $L\text{-}Ach_1$ and $L\text{-}Ach_2$ means on the Measurement test was significant in the direction predicted by the second hypothesis ($t = 3.41$; df/14; $P < .01$). The mean difference between these groups on the Sound test, however, was significant in the opposite direction from that predicted ($t = 2.70$; df/14; $P < .02$).

In an effort to account for the contradictory results obtained from the L-Ach groups, the means of all groups on the Chemistry chapter test were compared. Since the Chemistry chapter was received by each group after equivalent practice in the new learning situation, no differences between the matched sets of groups should be found if the matching procedures were adequate. A series of correlated _t_ tests revealed no differences in Chemistry achievement large enough to reach significance for the $H\text{-}IQ_1$ and $H\text{-}IQ_2$, the $H\text{-}Ach_1$ and $H\text{-}Ach_2$, and the $L\text{-}IQ_1$ and $L\text{-}IQ_2$, matched groups. However, the Chemistry mean score of $L\text{-}Ach_2$ was significantly higher than the $L\text{-}Ach_1$ group with which it was matched ($t = 2.65$; df/14; $P < .05$). Apparently the latter two groups, although matched on a measure of prior science knowledge, were not equivalent in learning ability. The significantly higher performance of $L\text{-}Ach_2$ on both the Measurement and Sound chapter tests was probably due to this inadequacy in matching, rather than to the experimental treatments received. Because L-Ach_2 was significantly higher than L-Ach_1 on all three program achievement tests, comparisons of these groups must be considered inappropriate for testing the second hypothesis.

TABLE II

MEANS AND STANDARD DEVIATIONS ON IQ AND THE MEASUREMENT AND SOUND CHAPTER TESTS FOR HIGH AND LOWER MATCHED INTELLIGENCE GROUPS RECEIVING ORDERS 1 AND 2

Groups		IQ	Measurement*		Sound*	
			Received First	Received Last	Received First	Received Last
H-IQ_1	M	123.87	20.93			22.07
	SD	3.48	7.19			6.24
H-IQ_2	M	123.87		23.93	24.00	
	SD	4.03		4.68	4.44	
L-IQ_1	M	101.13	11.60			14.20
	SD	3.79	4.58			5.82
L-IQ_2	M	102.07		14.53	15.40	
	SD	3.17		5.42	3.42	

* Perfect score = 30.

TABLE III

MEANS AND STANDARD DEVIATIONS ON PRIOR SCIENCE ACHIEVEMENT
AND THE MEASUREMENT AND SOUND CHAPTER TESTS FOR
HIGH AND LOWER ACHIEVEMENT GROUPS RECEIVING ORDERS 1 AND 2

Groups		Prior Achievement	Measurement		Sound	
			Received First	Received Last	Received First	Received Last
$H\text{-}Ach_1$	M	82.87	21.53			22.40
	SD	12.60	4.52			3.60
$H\text{-}Ach_2$	M	81.93		23.07	23.53	
	SD	13.07		5.62	3.80	
$L\text{-}Ach_1$	M	49.07	10.13			12.60
	SD	6.83	4.12			4.97
$L\text{-}Ach_2$	M	49.00		15.87	15.73	
	SD	6.77		5.29	4.59	

ERROR RATE MEASURE

The proportions of errors made in the Measurement and Sound program chapters were calculated for all subjects by finding the number of errors the subject made in the chapter and dividing by the total number of frames. Mean error proportions were then calculated for each group in both the matched intelligence and the matched achievement categories, and comparisons of these mean error proportions were made to test the hypotheses. Since error rate data was not available for all subjects, from one to four matched pairs had to be eliminated in making some of the comparisons. The decreased N's resulting from these eliminations are reflected in the varying degrees of freedom of the correlated t tests reported below.

Table IV presents the mean error proportions of the high and lower matched achievement groups taking the Measurement and Sound chapters either first or last in the instruction sequence. Comparisons of the $H\text{-}Ach_1$ and $H\text{-}Ach_2$ groups showed that the error difference on the Sound chapter was not significant ($t = 1.98$; df/14; $P > .05$). However, the difference between the high groups on the Measurement chapter is significant at the .05 level ($t = 2.43$; df/11), contradicting the hypothesis that the matched high groups would show equivalent response accuracy regardless of variation in amount of pr or learning practice.

Differences in mean error rate between the L-Ach_1 and L-Ach_2 groups were significant for both the Measurement chapter ($t = 4.86$; df/11; $P < .002$) and the Sound chapter ($t = 2.89$, df/11; $P < .02$). The latter difference was in the opposite direction from that predicted. As indicated previously, however, differences between the L-Ach groups may be due to factors other than the experimental treatments, and cannot be considered as adequate tests of the second hypothesis.

Mean error proportions of the high and lower matched IQ groups on the Measurement and Sound chapters are presented in table IV. As was found for the high achievement groups, the difference in error rate between H-IQ_1 and H-IQ_2 was significant on the Measurement chapter ($t = 2.83$; df/12; $P < .02$) again contradicting the first hypothesis. Error rate differences between the high groups on the Sound chapter did not differ significantly ($t = 1.95$; df/12). For the lower intelligence groups, the difference in error proportion on the Measurement chapter was significant ($t = 2.26$; df/10; $P < .05$), in the direction predicted by the second hypothesis. The error rate difference between L-IQ_1 and L-IQ_2 on the Sound chapter was in the opposite direction from prediction, but not significant ($t = 1.26$; df/11).

TABLE IV

MEASUREMENT AND SOUND ERROR RATE MEAN OF HIGH AND LOWER MATCHED ACHIEVEMENT GROUPS RECEIVING ORDERS 1 AND 2

Mean Proportion of Errors

Groups	Measurement		Sound	
	Received First	Received Last	Received First	Received Last
H-Ach_1	.13			.08
H-Ach_2		.07	.04	
L-Ach_1	.26			.15
L-Ach_2		.08	.10	

TABLE V

MEASUREMENT AND SOUND ERROR RATE MEANS OF HIGH AND LOWER MATCHED INTELLIGENCE GROUPS RECEIVING ORDERS 1 AND 2

Mean Proportion of Errors

Groups	Measurement		Sound	
	Received First	Received Last	Received First	Received Last
H-IQ_1	.11			.07
H-IQ_2		.05	.04	
L-IQ_1	.23			.13
L-IQ_2		.13	.10	

SECTION IV

DISCUSSION

The prediction that differences on the achievement and error proportion measures would not occur between the high groups in the different orders was supported in six of the eight analyses made. The two contradictions occurred when error proportions on the Measurement chapter were compared, indicating that both the high intelligence group and the high achievement group receiving Order 2 made significantly fewer frame errors than the high groups receiving Order 1. Although these differences contradict the first hypothesis, the directions of the differences were consistent with that predicted for the lower groups by the second hypothesis. This consistency suggests that some learning set formation occurred for the high groups in the Measurement chapter, and the error rate was the only measure sensitive enough to show it. For the original hypothesis made concerning high-group performance, therefore, the data indicate just partial confirmation.

The second hypothesis, that learners of average intelligence and average prior school achievement would demonstrate increased learning performance as prior practice in the new learning situation increased, was also tested in eight separate analyses. Four of these analyses were considered inconclusive because of data indicating that the L-Ach_1 and L-Ach_2 groups were not matched in terms of learning ability. Of the remaining four tests made, one supported the second hypothesis. The supporting analysis occurred when the error rate of the L-IQ_1 and L-IQ_2 groups were compared in the Measurement chapter. This analysis showed that the groups receiving Measurement after prior practice with programed instruction made significantly fewer errors than its matched group, which had no such prior practice.

Although the two hypotheses originally tested received only partial confirmation, there are certain consistencies in the results that imply alternative hypotheses about learning set formation in programed instruction. First, significant differences between the matched groups, whether confirming or disconfirming a hypothesis, were found only for error rate. In contrast, achievement on the chapter tests remained equivalent for the matched groups regardless of the treatment to which they had been exposed. These data fail to establish that differences in amount of practice in programed instruction have any effect upon achievement, although error rate in certain cases was significantly affected.

Some negative results were obtained even though error rate was used as the criterion measure. To understand the reason for these latter disconfirmations, another consistency found in the data must be clarified — ie, that in all cases where differences in error rate were found, whether the difference was confirming or not, the program being analyzed was the Measurement chapter.[3] No error rate differences between matched groups were found in the Sound chapter.

The consistent restriction of error differences to the Measurement chapter indicates that the two chapters used in testing the hypotheses were different in some way with respect to the responses required. Inspection of the error rate data reveals that error rate proportions were low for the Sound chapter (ranging from .04 to .15), regardless of when that chapter was given, while the Measurement chapter error rates were generally higher (ranging from .05 to .26), particularly if that chapter was the first programed instruction the subjects received. The response task was generally more difficult for the latter chapter. Apparently the reason that error rate differences were found only for the Measurement program was that the learning trials (frames) in that chapter were difficult enough to permit improvement with practice, while those in the Sound chapter were less difficult so that the error rate was low regardless of prior practice. The analogy to the studies of learning set formation seems clear — the problem tasks presented must be difficult enough initially so that improvement can be measured.

These interpretations of the data permit the formulation of some alternative hypotheses about the presence of learning set formation in programed instruction. First, there are indications that learning sets of the kind identified by Harlow (ie, continued practice results in a decreasing number of error trials to solution) do form as practice in programed instruction accrues, but only under certain programing conditions. Learning set formation is observable when the program used has frames which are sufficiently difficult to allow response accuracy to improve. A second hypothesis suggested by these data is that learning set formation will be observed in all learners receiving programs of moderate intratrial difficulty for the first time, regardless of individual differences in intelligence or prior learning success in other instruction situations. This hypothesis, contradicting rather than merely restricting those originally posed, is based upon the results from the present study showing that error rate on the Measurement chapter decreased significantly for the high groups as well as the lower groups.

The results of the current study also have certain implications for the generally accepted rule that a low error rate is a necessary requirement for efficiently producing high achievement. In the present data, achievement scores on the Measurement chapter test were equivalent for the H-IQ, the H-Ach, and the L-IQ matched groups, even though significant differences in error rate were demonstrated for the two groups in each set. Similar evidence was obtained in another recent study (ref 5). One explanation for this learning success in spite of decreased confirmation is that when incorrect frame responses occur, the immediate feedback serves as a correction trial. This explanation implies that ter-

3. Comparisons between L-Ach groups are not considered because of demonstrated inequality in learning ability.

minal achievement in linear programing is not solely a function of the opportunity for immediate confirmation of correct responses, but rather that the frames of a program provide both confirmation of correct responses and correction for wrong responses, both of which contribute to producing the desired terminal behavior. If this explanation is correct, under certain conditions, correction is as effective as confirmation of correct responses in producing learning.

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13 ABSTRACT

Two different orders of three units of programed instruction were administered to groups of students matched on (a) intelligence or (b) relevant achievement tests. Comparisons were made between groups that were (a) high or (b) average on each matching variable. The hypotheses being tested were that after varied amounts of prior practice in programed instruction, (a) learning set formation would not be demonstrated by the high intelligence and high achievement groups, and (b) learning set formation would be demonstrated by the average intelligence and average achievement groups. Only partial support was obtained for each hypothesis. The data indicated the following: (a) In a programed sequence, error rate is a more appropriate measure than achievement for observing learning set formation. (b) Learning set formation is observable in programed instruction for all learners regardless of individual differences. Since, reduced error rate was the indication of learning set formation, the phenomenon can be measured only in programs involving a moderately high error rate. (c) Since error rate differed for some of the experimental groups while achievement remained the same, the results were interpreted to mean that a moderately high error rate program which offers opportunity for correction of response errors may be as effective in producing learning as a low error rate program which confirms correct responses.

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