REPETITION AND SPACED REVIEW IN PROGRAMED INSTRUCTION

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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, and Dr. Ross L. Morgan 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 is a major inspiration to the project staff. The cooperation of the teachers in the Baldwin-Whitehall Schools deserves a further note of appreciation. Theodore Harakas and Nancy Hoisman contributed to test development and data analysis.

This technical report has been reviewed and is approved.

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ABSTRACT

The effects of repetition and spaced review in programed instruction were studied. Experiments 1 and 2 covered a one-semester course in General Science at the Junior High School level. In Experiment 3, a 1280-frame portion of the total course was used. In Experiments 1 and 2, comparisons were made among (a) a conventional course, (b) a regular linear version of the program, and (c) a spiral version of the program. The results indicate that the programed course was at least as effective as the conventional instruction in terms of both learning and retention after 15 weeks. The linear program was superior to conventional instruction on some measures. The spiral program offered few, if any, advantages over the regular linear program. Experiment 3 allowed a more precise evaluation of the separate effects of repetition and spaced review. Spaced review produced significant increases in learning which persisted, and even increased, through a 3-week retention interval. Repetition did not produce increased learning or retention. The general conclusions are: (a) repetition of instructional materials above the usual level in a linear program is not beneficial; (b) spaced review is potentially beneficial; and (c) some techniques of obtaining spaced review, eg, spiral programing, may offer disadvantages that equal or outweigh the potential advantages of spaced review.

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INTRODUCTION

Spaced review is defined as a sequence of learning conditions in which a second topic is interpolated between successive presentations of the first topic. For example, following the initial presentations of material A and material B, any further presentation of material A would constitute repetition, but not spaced review.

Spaced review bears some relation to laboratory investigations of both distributed practice and transfer, however, the experimental paradigms used in both of these areas fail to duplicate exactly the spaced review conditions defined here. Studies of distributed practice, while presenting learning trials at spaced intervals, generally interpolate very simple tasks, such as color-naming or even rest periods, between spaced trials rather than interpolating meaningful learning materials between trials. In the transfer paradigm, learning tasks are presented in the A-B-A' sequence; but investigators usually are interested in the effect of the B task upon A' performance, rather than the effect of A' upon later retention.

The condition that usually defines amount of repetition in a learning situation is the number of trials eliciting a correct response. Unlike spaced review, considerable data indicates that repetition is a relevant learning variable. Incremental learning theories (Estes (ref 3); Hull (ref 5); Spence (ref 12)) assume that each correct repetition of a response increases the strength of that response and makes it more resistant to forgetting. Investigations of overlearning (Kreuger (ref 6); Postman (ref 9)), have shown that retention increases with the number of repetitions. Research investigating the one-trial learning hypothesis (Estes, Hopkins, and Crothers (ref 4); Lockhead (ref 7); Reynolds (ref 10); Rock and Heimer (ref 11) also has demonstrated that associations formed in one trial are strengthened by subsequent repetition. These data support the nearly universal assumption that learning and retention are positive functions of the number of repetitions.

No attempt has been made as yet to determine the effects of repetition and spaced review in programed instructional materials. An understanding of the effect of these variables upon learning from a programed sequence would have important consequences for the construction of programed materials, particularly if a set of rules could be established regarding the optimal use of each variable. To obtain some of the desired information about repetition and spaced review in programed instruction, three studies were conducted. The first two concerned the combined effect of repetition and spaced review upon learning and retention. The third study represented an attempt to determine more precisely the effect of each variable by independently varying the amount of repetition and spaced review in the experimental programs.

In Experiments 1 and 2, a programed sequence containing combined repetition and spaced review was compared with another programed sequence containing the same learning frames but no repetition and spaced review frames. Since each of the programed sequences presented the same materials, but had different lengths because of the added repetition and review frames, comparisons were made under two conditions. In Experiment 1, groups were given a fixed amount of learning time (one school semester) to study their programs. This amount of time was insufficient to finish either program. Under this condition the nonreview group had an advantage, since the omission of spaced review frames should have permitted coverage of more basic material. In Experiment 2, the comparison was made after each group had completed the entire course, regardless of the time required. Under this fixed-amount-of-material condition the review group had a possible advantage, since it received more practice on the materials, received more recent practice on most of the materials, and took more time than the nonreview group. In both experiments, the programed instruction groups were compared with a third group receiving conventional lecture instruction. Experiment 1 and Experiment 2 will be described separately but discussed jointly prior to the presentation and discussion of Experiment 3.

SECTION II

EXPERIMENT 1: COMBINED REPETITION AND SPACED REVIEW UNDER FIXED TIME CONDITIONS

MATERIALS

The program materials used in Experiment 1 were two versions of a junior high school General Science Program.[1] The linear version presented a series of ten science topics one after the other, in a standard programed textbook format. The total linear program, designed to teach a full year course in general science, was approximately 7000 frames in length. The ten topics covered are presented in table I. In this linear version there was no provision for spaced review. As the learner finished a topic, he progressed to a new chapter and did not receive additional spaced review frames on previous topics at any time during the remainder of the programed course.

The basic linear program was revised to provide repetition and spaced review. This version contained the same frames for each of the ten topics as the linear version, but the order in which the frames were presented was changed to facilitate insertion of additional spaced review sequences at selected points. Each linear sequence was broken up into a number of component parts and ordered in terms of difficulty. These parts were then arranged so that the learner was required to work through the least difficult portion of all ten topics first, then advance to the next level of difficulty, and so on, until the entire course was completed. Before beginning a new topic at a higher level of difficulty, a sequence of frames reviewing previous coverage of that topic was inserted. Thus, the learner began with the easiest material for all topics, then spiraled upward through increasingly difficult levels. He received spaced review of each topic before being presented with more difficult material. This version of the program is called the "spiral program."

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

TABLE I

ORDER AND NUMBER OF FRAMES FOR THE TEN TOPICS PRESENTED IN THE LINEAR VERSION OF THE GENERAL SCIENCE PROGRAM

Chapter	Topic	Number of Frames
1	Measurement	235
2	Chemistry	825
3	Sound	230
4	Communications	250
5	Astronomy	845
6	Light	349
7	Electricity	763
8	Meteorology	784
9	Work and Machines	1227
10	Biology	1280
	Total	6788

Figure 1 presents a diagram of the spiral program showing the learner's progress through the various learning and review sequences. All of the reviews (shaded areas) contained frames that were not included in the standard linear program. These added frames totaled nearly 3000, making the spiral program approximately 10,000 frames in length as compared with 7,000 frames in the linear version of the program.

The general content of the two programs was also presented using so-called "traditional" methods and materials. These included the usual lectures and demonstrations, class discussion, text assignments, periodic tests, etc.

The achievement tests used in Experiment 1 were: (a) the Cooperative Science Test[2], and (b) two forms of the Science Program Test. The Cooperative Science Test, 150 multiple-choice items, is a test of general knowledge of science, measuring achievement in all science subject matter that is designated as appropriate for junior high school students. The Science Program Tests were designed to measure achievement in the specific subject matter areas presented in the General Science Program.

METHOD

Subjects. Students in six junior high school general science classes were used to compare the linear and spiral programs under the fixed-time condition. Two classes were given science instruction with the linear program, and two received instruction with the spiral program. A third group, also consisting of two

[2] A standardized junior high school science achievement test published by the Educational Testing Service, Princeton, N. J.

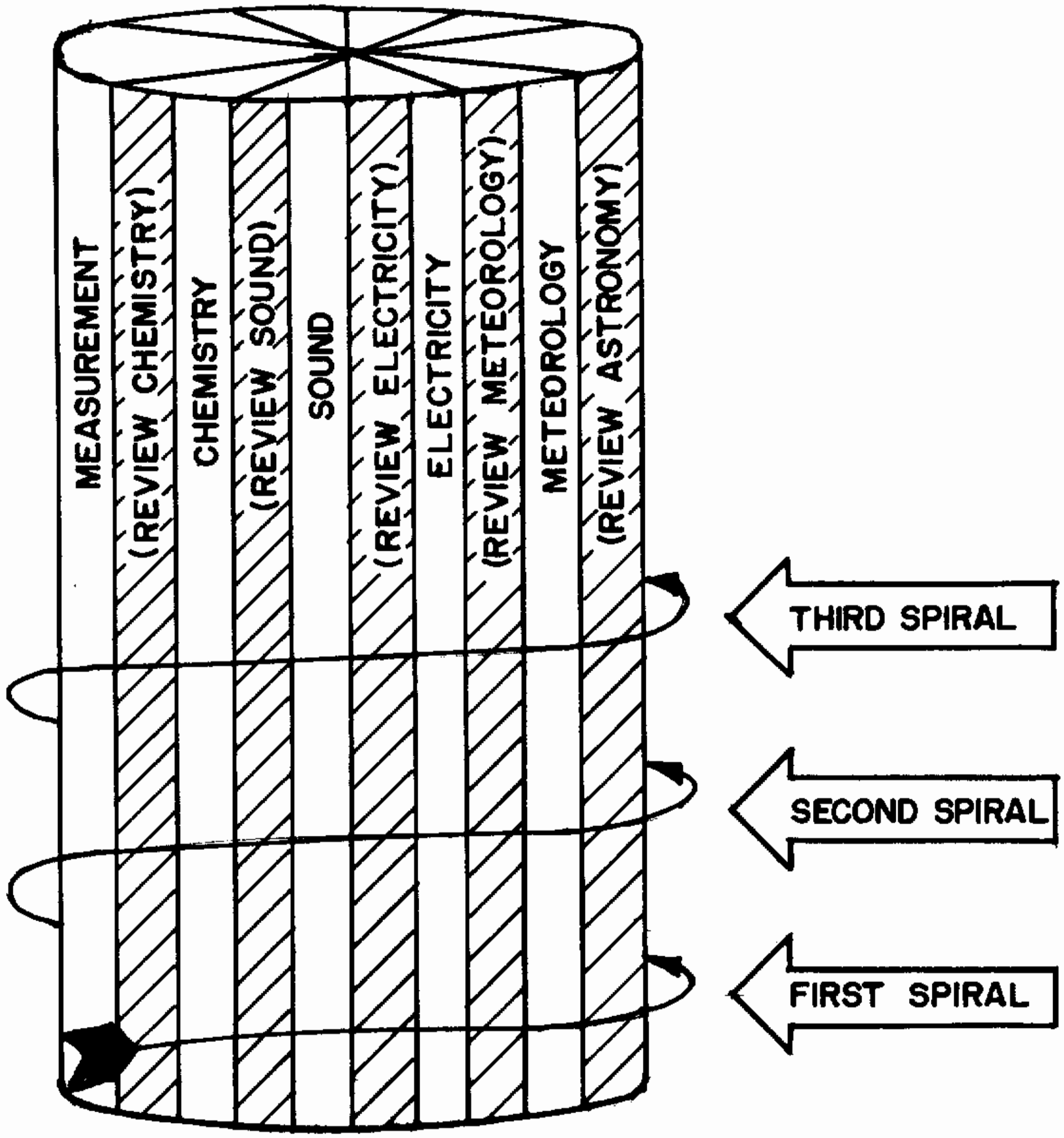

Figure 1. A Model of the General Science Spiral Program

classes, received instruction in science by traditional teaching methods. The number of subjects completing all of the experimental requirements were 47, 50, and 41 for the linear, spiral, and traditional groups respectively.

Procedure. At the beginning of the experiment, subjects in all groups were given the Cooperative Science Test and the Science Program Test, Form A. Scores from the Stanford Achievement Test (Intermediate) and the Otis Quick-Scoring Mental Ability Test (Beta) were obtained for each subject from the school records. Following pretesting, the groups received science instruction by the various methods during daily 40-minute periods throughout the semester. The program materials were administered in class. The teacher was always present and the students could ask questions whenever they wished. None of the groups was able to finish the entire year's course in the fixed time allotted (17 weeks . Each group was permitted to progress as rapidly as the instructional method being used would allow.

As each subject in the linear and spiral groups finished a chapter or level of programed instruction, he was given the appropriate test for the material covered in that unit before proceeding to the next unit of work. Subjects in the traditional group also received periodic unit tests which were constructed by the teacher. No analyses were made of these data. At the end of the semester, the Cooperative Science Test and the Science Program Tests A and B were administered to all groups.

Following the end-of-semester achievement tests, subjects in each instructional condition were divided into three subgroups, the subgroups were matched on the post-learning Cooperative Science Test scores. These subgroups were used to investigate retention of science knowledge at intervals of 5, 10, and 15 weeks after the end of the science semester. None of the groups received science instruction during the 15-week retention interval. Five weeks after the semester's end the Cooperative Science Test and the Program Test B were readministered to the first subgroup in each condition. The second subgroup in each condition was administered the retention tests after 10 weeks, and the third subgroup was retested 15 weeks after the semester ended.

RESULTS

Achievement. Since intelligence test scores varied significantly among the original groups, smaller groups with equivalent intelligence were used in making achievement comparisons on the post-learning tests. These groups were formed by selecting only those subjects from the linear, spiral, and traditional methods with intelligence scores falling between 100 and 130. The resulting data are shown in Table II.

Table II presents the means and standard deviations of intelligence and the pre- and post-learning Cooperative Science Test measures for the various groups. The t tests indicated no significant differences among the groups in intelligence, on pre-learning and post-learning measures on the Cooperative Science Test. However, comparisons among the mean gains on the achievement tests show that the linear group gain is significantly greater than both the spiral group gain ($t = 3.38$; df/54; $P < .01$) and the traditional group gain ($t = 3.43$; df/51; $P < .01$). The regular linear program produced significantly greater gains in general knowledge of science than did instruction by either the repetition and and spaced review (spiral) program or traditional methods.

TABLE II

INTELLIGENCE AND COOPERATIVE SCIENCE TEST SCORES
FOR LINEAR, SPIRAL, AND TRADITIONAL GROUPS

Groups and Numbers Tested		Intelligence	Prelearning Cooperative Science Test	Postlearning Cooperative Science Test	Cooperative Science Test Gain
Linear	Mean	113.25	62.36	80.46	18.1
N = 28	SD	7.83	14.70	15.74	7.0
Spiral	Mean	111.68	64.00	75.87	11.9
N = 28	SD	7.25	15.76	16.92	6.6
Traditional	Mean	112.36	66.72	78.54	11.8
N = 25	SD	9.19	20.74	25.49	6.2

Estimated percentages of the total course content completed by each of the program groups are; linear program, 87%; and spiral program, 66%.[3] The conventional group of course covered what was considered a year's material by the teacher. The topics covered were in general the same as in the programs, so that on tests the students were roughly equivalent on the kind of material covered.

Analysis of changes in variance within the groups (see standard deviation, SD) indicated no significant differences between pre- and postlearning Cooperative Science Test variance for either the linear or spiral program groups. The increase in variance for the traditional group is significant ($t = 3.52$; df/24; $P < .01$), suggesting that the traditional instruction method resulted in more variability of achievement than did the programed methods. However, a comparison of the Cooperative Science pretest score distributions of the three groups indicated that the traditional group distribution was initially bimodal while the distributions of the two programing groups were nearly normal. The increased variance of the traditional group was probably due to the different rates of gain of the high and low achievers in this bimodal group, rather than to the type of instruction received. The difference was not found when the data for all 41 subjects in the original traditional group were analyzed.

Scores for the linear, spiral, and traditional groups on the Science Program Tests A and B are presented in table III. The low prelearning means are equivalent, indicating that prior knowledge of the subject matter was minimal for

[3]These program data were not directly available from the present experiment. They are estimates based on total time required by similar student groups to complete the programs as reported in Experiment 2, described later in this report.

TABLE III

MEANS AND STANDARD DEVIATIONS FOR LINEAR, SPIRAL, AND TRADITIONAL GROUPS ON SCIENCE PROGRAM TESTS A AND B ADMINISTERED BEFORE AND AFTER INSTRUCTION

		Science Program Test A (Perfect Score = 91)			Science Program Test B (Perfect Score = 81)
		Prelearning	Post-learning	Gain	Postlearning
Linear	Mean	23.15	46.86	23.73	47.07
N = 47	SD	8.64	9.28	8.82	8.23
Spiral	Mean	24.29	48.89	24.85	47.89
N = 50	SD	7.98	8.79	7.27	10.09
Traditional	Mean	24.00	39.29	15.74	32.76
N = 41	SD	8.95	11.75	20.07	13.21

all three groups. Differences between the traditional group and the two program groups on both postlearning measures were statistically significant, with *t* values ranging from 2.59 to 4.71. Mean differences between the linear and spiral groups were not significant (t = 0.32 and 0.81 for Tests A and B, respectively). These program test data indicate, first, that the program groups learned factual science materials which the traditional group did not, and second, that the presence or absence of spaced review (spiral programing) did not affect the degree to which the program groups learned the specific material.

Retention. The mean Cooperative Science Test scores obtained by the 5, 10, and 15 week retention subgroups from each of the three instruction conditions are plotted in figure 2. Figure 3 presents the Science Program Test B means for the three conditions at the same retention intervals. On both tests, no significant retention losses were found for any of the instruction conditions. Retention following programed instruction was as good as that following traditional instruction; and the use of the spiral program did not result in greater retention than was obtained from the linear program. The difference between groups taught by either of the programing techniques and the traditional instruction group is maintained or increased on the retention tests.

Achievement Prediction. In addition to the achievement and retention results, Experiment 1 provided data on the effectiveness of intelligence and achievement prelearning scores as predictors of the amount of gain resulting from the linear, spiral, and traditional instructional methods. Table IV shows the correlations between Otis intelligence and pre- and postlearning Cooperative Science Test scores for each of the three original instruction groups. The change in the

TABLE IV

CORRELATIONS BETWEEN INTELLIGENCE† AND PRE- AND POSTLEARNING SCIENCE ACHIEVEMENT‡ MEASURES FOR THE LINEAR, SPIRAL, AND TRADITIONAL GROUPS

	Intelligence-Prelearning Ach.	Intelligence Postlearning Ach.	Correlation Change
Linear N = 49	r = .64	r = .47	- .17*
Spiral N = 50	r = .47	r = .50	+ .03
Traditional N = 41	r = .82	r = .81	- .01

* Significant at .05 level

† Otis

‡ Cooperative Science Test

TABLE V

CORRELATIONS BETWEEN PAST SCHOOL ACHIEVEMENT‡ AND PRE- AND POSTLEARNING SCIENCE ACHIEVEMENT† MEASURES FOR THE LINEAR, SPIRAL, AND TRADITIONAL GROUPS

	Battery-Median-Prelearning Ach.	Battery Median-Postlearning Ach.	Correlation Change
Linear N = 49	r = .79	r = .59	- .20**
Spiral N = 50	r = .75	r = .66	- .09
Traditional N = 41	r = .86	r = .87	+ .01

** Significant at .01 level

† Cooperative Science Test

‡ Median Score on Stanford Achievement Test Battery

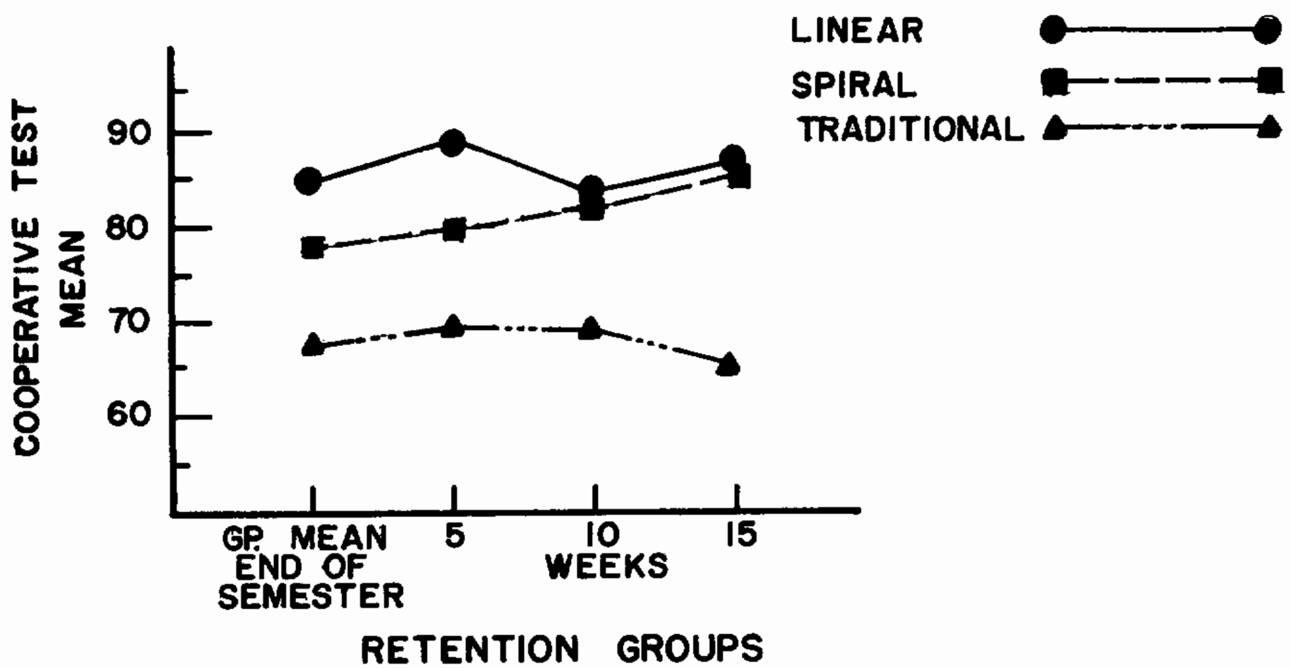

Figure 2. Mean Retention as Measured by the Cooperative Science Test Administered 5 , 10 , or 15 weeks after the end of the Semester

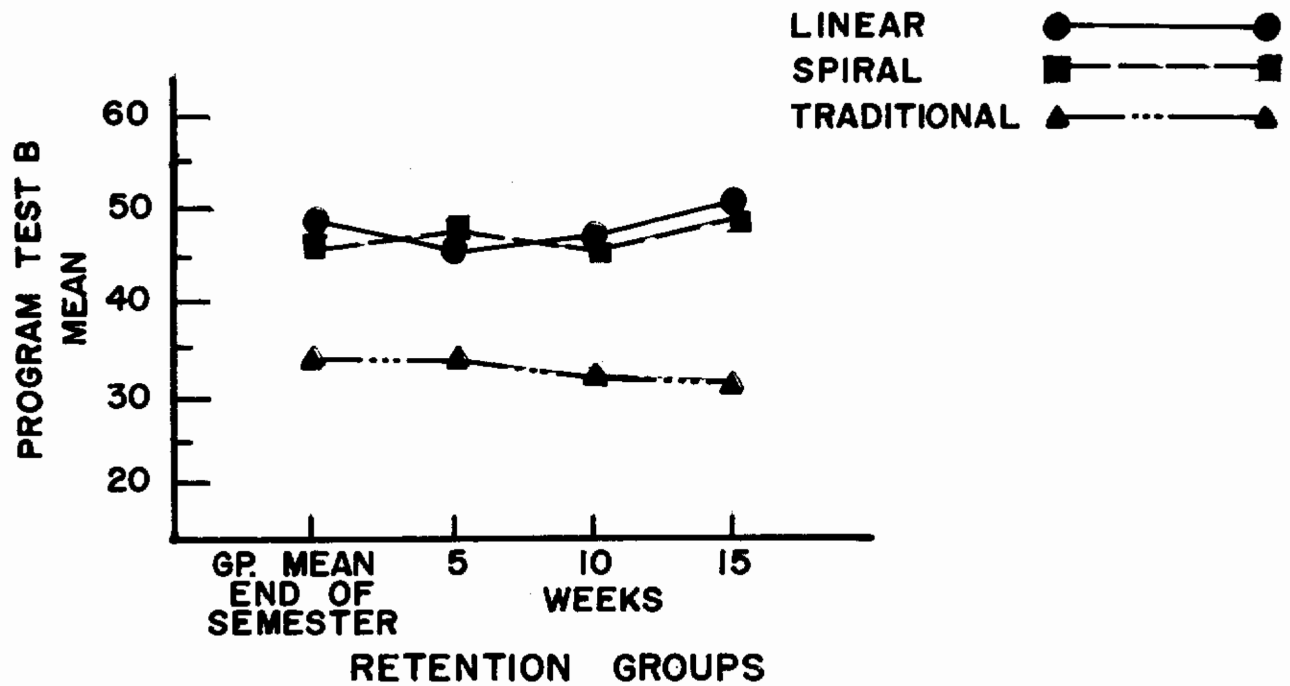

Figure 3. Mean Retention as Measured by the Science Program Test B Administered 5 , 10 , and 15 weeks after the end of the Semester.

linear group correlation over the semester was significant ($t = 2.11$; df/38; $p < .05$). Correlation changes for the other instruction groups were well within chance limits. Similar data are presented in Table V for correlations between past school success (as measured by the battery median of the Stanford Achievement Test) and pre- and postlearning Cooperative Science scores. Again, only the correlation drop for the linear group is significant ($t = 3.30$; df/38; $p < .01$). These data suggest that intelligence and overall achievement measures may not be as predictive of achievement resulting from linear programed instruction as they are for either the spiral program or traditional methods.

Experiment 1 will be discussed more fully after the presentation of Experiment 2. It will be recalled that the basic difference between the two experiments is that in Experiment 1 all groups studied an equal amount of time (one semester) while in Experiment 2 all students completed the instruction regardless of the amount of time required. In Experiment 1, none of the student groups completed the planned course in the allotted time.

SECTION III

EXPERIMENT 2: COMBINED REPETITION AND SPACED REVIEW UNDER FIXED-MATERIAL CONDITIONS

MATERIALS

The same materials described for Experiment 1 were used in Experiment 2.

METHOD

Subjects. Two additional junior high school general science classes were used. The number of subjects completing the program and all necessary tests were 31 for the linear group and 24 for the spiral group.

Procedure. At the beginning of the experiment, all subjects were given the Cooperative Science Test and the Science Program Test A, as in Experiment 1. Scores from the Stanford Achievement Test (Intermediate) and the Otis Quick-Scoring Mental Ability Test (Beta) were available for each subject from past school records. Following the prelearning testing, the groups received science instruction by the two methods in daily 40-minute periods. Rather than stopping at the end of the semester, however, the subjects in Experiment 2 were permitted to continue with the daily 40-minute work schedule until the entire program was completed. Thus, all subjects were exposed to all of the material in either the linear or spiral program, without restriction in working time. As each subject finished the program, he was again given the Cooperative Science Test, and the Science Program Tests A and B.

An additional factor studied in Experiment 2 was the effect of linear and spiral programing upon student interest in science. Data for science interest were obtained by giving a Science Interests Inventory and a Science Activities Inventory to each subject before and after the period of instruction.

RESULTS

Achievement. The average time taken to finish the two programs was 19.6 weeks and 25.9 weeks for the linear and spiral groups, respectively. The mean difference of 6.3 weeks is attributable to the extra time required by the spiral group to complete the nearly 3000 additional review frames.

The means and standard deviations of the Science Program Tests A and B are presented in table VI. No significant differences between group means were found for either of the postlearning measures. However, the prelearning difference between the groups on Science Program Test A was significant ($t = 2.95$; $P < .01$), indicating that the linear group knew more of the specific science facts contained in the General Science Program before the experiment started than did the spiral group. Consequently, gain scores for Test A showed that the spiral group's gain was significantly greater than the nonreview group gain ($t = 3.57$; df/53; $P < .01$).

Table VII summarizes the data obtained from the linear and spiral groups on the Otis Intelligence and Cooperative Science Test measures. Mean differences between the groups in intelligence and prelearning knowledge of science were not significant, and no significant differences were found between groups on the Cooperative Science Test given at the end of the course. Although the review group was superior in gaining knowledge of specific content of the program, there was no significant difference between the groups in the amount of general knowledge of science that was acquired.

Interest. Pre- and postlearning data for linear and spiral groups on the Sciece Interests Inventory and the Science Activities Inventory are shown in table VIII. The group means were equivalent on both prelearning measures. Although for the linear group, the prelearning means exceeded the postlearning means on both measures, in neither case was the difference significant. The *t* tests made for group differences in postlearning means were not significant for either the Interests Inventory ($t = 1.23$; df/53; $P > .05$) or the Activities Inventory ($t = 1.40$; df/53; $P > .05$). The differential programing treatments evidently had no substantial effect upon student interest in science.

Achievement Prediction. The results of Experiment 1 indicated that intelligence and overall achievement measures were less predictive of achievement gains resulting from linear programing than from spiral programing. Using data from Experiment 2, intelligence test scores and the battery medians of the Stanford Achievement Test were again correlated with pre- and postlearning Cooperative Science Test scores. As can be seen in tables IX and X, the previous findings were not replicated. All correlation changes were slight, failing to reach statistical significance.

TABLE VI

MEANS AND STANDARD DEVIATIONS OF PRE- AND POSTLEARNING SCORES ON SCIENCE PROGRAM TESTS A AND B FOR LINEAR AND SPIRAL GROUPS

		Prelearning Test A*	Postlearning Test A	Postlearning Test B	Gain Test A*
Linear	Mean	38.34	64.65	64.97	25.39
N = 31	SD	7.97	7.23	6.30	6.93
Spiral	Mean	31.75	65.00	66.29	33.24
N = 24	SD	8.15	7.30	5.62	9.42

*Mean Difference significant at .01 level

TABLE VII
MEANS AND STANDARD DEVIATIONS OF INTELLIGENCE AND PRE- AND POSTLEARNING COOPERATIVE SCIENCE TESTS FOR LINEAR AND SPIRAL GROUPS

		Intelligence	Prelearning Coop. Science Test	Postlearning Coop. Science Test
Linear	Mean	123.19	89.39	103.55
N = 31	SD	7.52	14.36	13.50
Spiral	Mean	120.50	89.21	103.21
N = 24	SD	5.66	14.02	11.07

TABLE VIII

MEANS AND STANDARD DEVIATIONS OF PRE- AND POSTLEARNING SCIENCE INTERESTS AND SCIENCE ACTIVITIES INVENTORIES FOR LINEAR AND SPIRAL GROUPS

			Linear N = 31	Spiral N = 24
Science Interests Inventory	Prelearning	Mean	55.36	56.08
		SD	13.58	16.60
	Postlearning	Mean	51.77	57.68
		SD	17.48	17.11
Science Activities Inventory	Prelearning	Mean	58.58	56.46
		SD	16.36	18.29
	Postlearning	Mean	54.26	61.46
		SD	17.78	19.52

TABLE IX

CORRELATIONS BETWEEN INTELLIGENCE* AND PRE- AND POSTLEARNING SCIENCE ACHIEVEMENT† FOR LINEAR AND SPIRAL GROUPS FINISHING THE PROGRAM

	Intelligence-Prelearning Ach.	Intelligence Postlearning Ach.	Correlation Change
Linear N = 31	r = .53	r = .53	.00
Spiral N = 24	r = .17	r = .12	- .05

*Otis
†Cooperative Science Test

TABLE X

CORRELATIONS BETWEEN PAST SCHOOL ACHIEVEMENT† AND PRE- AND POSTLEARNING SCIENCE ACHIEVEMENT* FOR LINEAR AND SPIRAL GROUPS FINISHING THE PROGRAM

	Battery Median-Prelearning Ach.	Battery Median-Postlearning Ach	Correlation Change
Linear N = 31	r = .48	r = .53	+ .05
Spiral N = 24	r = .69	r = .55	- .14

* Cooperative Science Test
† Median Score on Stanford Achievement Test Battery

DISCUSSION OF EXPERIMENTS 1 AND 2

Experiment 1 indicated that the linear program was superior to traditional instruction and spiral program on achievement test scores. The spiral and traditional methods were equally effective. Retention after a 15-week interval was high in all groups. The program seemed to offer some advantage for retention.

The original assumption, that combined repetition and spaced review in a programed instructional sequence facilitates learning, was supported in only one of the achievement analyses made in Experiments 1 and 2, and this may well have been an artifact of group differences prior to learning. When learning time was equated (Experiment 1), the nonreview (linear) group gained more than the review (spiral) group on the standardized test of general knowledge of science. The groups were equivalent in specific knowledge gains. The nonreview group's opportunity to cover a greater amount of new material within the fixed time more than compensated for the added review received by the spiral group. When the groups were allowed to complete the entire program, regardless of time, the spiral (review) group demonstrated a significantly larger gain in factual knowledge than the nonreview group. However, this greater gain probably was supported by the review group's lower prelearning test score. Also, despite the longer learning time required by the review group, that group was not superior in gains on the test of general science knowledge.

Considering both Experiment 1 and Experiment 2, the results indicate that the use of combined repetition and spaced review--at least in the spiral programing format--is a less efficient programing method than the standard linear sequence. The linear group required only three-quarters of the time used by the spiral group to finish the course, and achievement scores were the same. Of course, potential benefits of repetition and/or spaced review are being offset by some facet of the particular method of obtaining the combined repetition and spaced review, ie, spiral programing. One potential disadvantage of spiral programing is the separation of meaningful units of instruction, that results from presenting the same topic at different levels of difficulty.

The finding in Experiment 1 that intelligence and overall achievement measures were not as predictive of linear program achievement as they were of achievement from other instruction was not replicated in Experiment 2. The reason for the discrepant results is not clear from the data, however, in view of the importance of any decrease in predictive effectiveness, this problem warrants further study.

SECTION IV

EXPERIMENT 3: THE SEPARATE EFFECTS OF VARYING AMOUNTS OF REPETITION AND SPACED REVIEW IN A LINEAR PROGRAM

Experiments 1 and 2, involving a combination of repetition and spaced review, did not permit an assessment of the relative effects of the two variables. Experiment 3 was performed to study these variables by a different method. Experiment 3 attempts to determine the extent to which repetion alone, spaced review alone, and the combination of the two variables facilitate learning and retention. In order to accomplish this, the variables being investigated were inserted in to a linear program sequence. The spiral format used in the preceding investigations was not used in this experiment.

MATERIALS

The program sequence used in Experiment 3 was the 1280-frame Biology chapter taken from the linear version of the General Science Program. The original Biology chapter covers ten topics in biology, arranged sequentially without spaced review. By rewriting certain topical sequences, and rearranging the order of presentation of some topics, five variations of the Biology program were constructed for experimental use. The resulting experimental program included three versions containing different levels of repetition, and two versions containing spaced review.

Repetition Sequences. The original 115-frame sequence covering the topic of Mitosis, called the M-1.0 sequence, was used as a basis for constructing three repetition levels. First, the number of stimulus and response repetitions of the 11 new terms taught in the M-1.0 sequence were tabulated. The new sequences were then constructed, one sequence containing one-half as many repetitions of each of the 11 terms, and the other sequence containing one-and-one-half as many repetitions of each of the 11 terms, as the original sequence M-1.0. These additional sequences, designated M-.5 and M-1.5 respectively, constituted the low and high levels of repetition of the new material being learned, and the original M-1.0 section was considered the intermediate repetition level. Any one of the three sequences could then be inserted into the Biology program. The total program is represented in table XI.

Review Sequences. The Mitosis topic was also reorganized in a manner that permitted two versions containing spaced review. Two review sequences, consisting of 28 and 22 frames containing practice in the 11 critical Mitosis terms, were written. The total number of stimulus and response repetitions in these two sequences combined was equivalent to the number of repetitions in the M-.5 section. By adding these sequences to the Biology program after the two topics that followed mitosis, ie, after Plant Reproduction and Animal Reproduction, respectively, the requirements for spaced review were met, and at the same time the amount of repetition necessitated by the additional spaced review frames was controlled. Following this procedure, a spaced review program (R-1.0) containing an amount of repetition equal to M-1.0, and another spaced review program (R-1.5), containing an amount of repetition equivalent to M-1.5, was constructed.

A general description of the five different program versions obtained by these methods is presented in table XI.

TABLE XI

TITLE AND ORDER OF TOPICS PRESENTED IN THE THREE REPETITION VERSIONS AND TWO SPACED REVIEW VERSIONS OF THE BIOLOGY PROGRAM

Order of Topics	Repetition Versions (M-.5, M-1.0, M-1.5)		Review Versions (R-1.0*, R-1.5†)	
1	Cells		Cells	
2	Protozoa		Protozoa	
3	Tissues	581 frames	Tissues	581 frames
4	Organs and Systems		Organs and Systems	
5	Green Plants		Green Plants	
6	Mitosis (M-.5 or M-1.0 or M-1.5)		Mitosis (M-.5 or M-1.0)	
7	Plant Reproduction (107 frames)		Plant Reproduction (107 frames)	
(Review)	- - - - - -		Review Mitosis (28 frames)	
8	Animal Reproduction (217 frames)		Animal Reporduction (217 frames)	
(Review)	- - - - - -		Review Mitosis (22 frames)	
9	Classification (165 frames)		Classification (165 frames)	
10	Heredity (95 frames)		Heredity (95 frames)	

* R-1.0 = M-.5 + Review sections
† R-1.5 = M-1.0 + Review sections

Tests. Measures of unaided recall, aided recall, and recognition of the 11 mitosis terms presented in the five experimental treatments were used to assess retention at various points during the experiment. The Unaided Recall test required the subject to reproduce drawings from memory and to describe in writing the cell changes that take place at each stage. This test was scored for 22 possible answers. The Aided Recall test (15 items) consisted of incomplete sentences which required the subject to use the 11 experimental mitosis terms as fill-ins. The Recognition measure was a multiple-choice test, in which recognition of the 11 experimental terms was required in answering 18 questions.

Two additional measures, an Aided Recall (completion) test and a Recognition (multiple-choice) test covering material from the program topics Cells, Plant Reproduction and Animal Reproduction, were also used. These tests (39 and 20 items, respectively) were used as control measures, since repetition was constant for all groups on each of the three topics covered. The particular topics chosen represented learning before and after the experimental Mitosis section, so that possible effects of repetition and review on prior and subsequent learning could be assessed.

SUBJECTS. A total of 75 junior high school students participated in the experiment. Scholastic aptitudes, as measured by the Otis Quick-Scoring Mental Ability Test (Beta), ranged from 100 to 134, with a median IQ of 117. At the time of the experiment, all subjects belonged to one of three classes taking a general science course. None of the subjects had taken previous courses in biology, and none had had previous experience with programed instruction.

DESIGN AND PROCEDURE. Prior to the experiment, subjects of equivalent intelligence were assigned to one of five groups by a randomized blocks method (Edwards, ref 2). Each of the five groups received one of the experimental versions of the program. The programs were administered with Min-Max I teaching machines to all groups in 20 work sessions, each session lasting 40 minutes. At the beginning of every work session, the experimenter assigned to each group the number of frames that were to be completed in that session. Since the programs contained slightly different numbers of frames because of the experimental variations, daily work assignments to the groups varied from session to session, ranging from 50 to 80 frames for any single 40-minute session. By regulating the daily assignments, all of the five groups completed the experimental mitosis section during work sessions 10 and 11, and completed the entire program in the twentieth session.

Before beginning the program, subjects were given the Recognition test as a pretest to determine the equivalence of the five groups on prelearning knowledge of mitosis. The first retention tests (T_1) were administered in the two days immediately following completion of the program. In T_1, Aided Recall tests were given first for both the experimental and control material; these were followed by the experimental and control Recognition tests. After a 3-week interval, during which subjects were not exposed to any of the material learned in the programs, a second retention testing (T_2) was administered. T_2 was composed of four separate tests, presented in order of decreasing difficulty; first the Unaided Recall and Aided Recall (completion) experimental tests, then the experimental Recognition Test (multiple-choice), and finally the control Recognition test. The subjects were unaware that this T_2 battery was to be administered, and all four tests were given in a single session to prevent the possibility of reviewing.

RESULTS

Table XII presents the means and standard deviations of all groups on the pretest and the various measures obtained during T_1 and T_2. Analyses of variance of the randomized blocks design (Edwards, ref 2, Ch. 11), were used to compare the groups on each of these measures. Several subjects were absent at various times during the testings. Each absence required that the entire block with which the absent subject was matched be eliminated from the analysis, reducing the size of all groups by one. Fortunately, the absences were distributed over the testing periods in a way that necessitated removal of only one or two blocks of subjects from each of the analyses made. However, it was necessary to remove different blocks on different analyses.

As can be seen in table XII, mean scores among the five groups on the pretest ranged from 2.54 to 3.92. An analysis of variance showed that the pretest differences among groups were not significant ($F = 1.22$; df/4, 64; $P > .05$). A series of correlated t tests, made for each group on the differences between the Recognition pretest scores and the T_1 Recognition scores, yielded significant t values ranging from 2.34 to 3.84, indicating that the higher mean scores for each group at the time of T_1 were due to the effect of the program treatments rather than chance.

Repetition Effects. The M-.5, M-1.0, and M-1.5 groups received the experimental T_1 measures of Aided Recall and Recognition 9 days following instruction of the mitosis topic. A simple analysis of variance showed no significant differences among the groups on the T_1 Recognition test ($F = .98$; df/2, 24; $P > .05$). For the T_1 Aided Recall Test, however, a significant difference among means was indicated ($F = 4.50$; df/2, 26; $P < .025$). Further analysis of the Aided Recall results showed that the M-.5 group mean was significantly lower than the mean for the M-1.5 group ($t = 3.12$; df/13; $P < .01$), but that all other mean differences were within chance limits. The results of analyses of variance performed for the T_1 control measures were not significant ($F < 1.00$ and $F = 1.17$ for Aided Recall and Recognition control tests, respectively). Apparently, repetition of the mitosis topic neither helped nor hindered retention of preceding or subsequent materials.

Twenty-one days after T_1, and 30 days following original instruction on the topic of mitosis, the T_2 measures were administered. Groups M-.5, M-1.0, and M-1.5 were given the experimental Aided Recall and Recognition tests again, and received the Unaided Recall test as well. There were no significant mean differences among the repetition groups on any of the T_2 retention measures. Mean differences on the single control measure given at the time of T_2 were also well within chance limits. The partial effect of repetition upon retention found at the time of T_1 apparently dissipated during the interval between T_1 and T_2, leaving the M-.5, M-1.0, and M-1.5 groups with equivalent levels of retention on the 30th day following original learning. In nearly all cases T_2 performance exceeds T_1 performance. This trend will be discussed later.

Effects of Spaced Review. The R-1.0 and M-1.0 groups received the same number of learning frames. The same was true for the R-1.5 and M-1.5 groups. The data from these four groups were evaluated in a series of 2 x 2 analyses of variance

TABLE XII

MEANS AND STANDARD DEVIATIONS FOR ALL GROUPS ON PRETEST AND THE RETENTION TESTS ADMINISTERED AT T_1 AND T_2

Test	Total Score Possible		Groups: Repetition M-.5	Repetition M-1.0	Repetition M-1.5	Spaced Review R-1.0	Spaced Review R-1.5
I. Pretest							
A. Recognition N = 13	18	M	3.62	2.92	2.54	3.92	2.92
		SD	1.66	1.98	1.76	2.43	2.22
II. T_1							
A. Aided Recall N = 14	15	M	3.79	5.21	7.57	10.00	9.79
		SD	3.49	4.59	5.67	4.76	4.69
B. Recognition N = 13	18	M	6.00	7.08	8.54	10.00	8.92
		SD	4.26	5.22	4.79	5.93	3.66
C. Control Aided Recall N = 14	39	M	18.57	17.50	17.79	22.14	19.36
		SD	9.15	7.05	9.25	9.85	7.37
D. Control Recognition N = 13	20	M	11.31	12.77	12.69	13.08	12.38
		SD	3.55	4.17	3.61	3.25	2.47
III. T_2							
A. Unaided Recall N = 14	22	M	2.93	4.29	3.14	6.57	6.14
		SD	3.60	4.92	3.80	4.90	4.87
B. Aided Recall N = 14	15	M	4.86	6.14	6.71	9.50	10.07
		SD	4.45	5.19	5.40	4.77	4.75
C. Recognition N = 14	18	M	6.79	7.71	8.29	10.50	10.93
		SD	4.21	5.92	5.72	6.35	6.08
D. Control Recognition N = 14	20	M	12.29	12.86	12.86	15.00	13.93
		SD	3.77	3.51	3.57	2.83	2.62

in which 1.0 vs 1.5 "repetition" of frames was one variable and spaced review (R) vs massed (M) presentation of the frames was the other variable. The first variable was labeled "repetition" (1.0 vs 1.5) and the second variable "review" (R vs M).

Results of the factorial analyses for the experimental T_1 Aided Recall and Recognition tests are presented in tables XIII and XIV. Neither the repetition (1.0 vs 1.5) nor the interaction between repetition and review (R vs M) were significant on either measure. The effect of review was not significant on the Recognition test. On the Aided Recall test, however, the performance of the R groups, receiving review, was superior to that of the nonreview M groups.

Tables XV and XVI report similar analyses made for the control T_1 Aided Recall and Recognition tests. No significant differences were obtained for either variable or for the interaction on the control Recognition measure. As can be seen in table XV, however, a reliable difference was found between R and M groups on the control Aided Recall test. Further analysis of the items on the latter test was made to determine the source of this difference. Three analyses of variance, made separately for the items covering Cells (10 items), Plant Reproduction (18 items), and Animal Reproduction (11 items), showed that the M and R groups were equivalent in their retention of the Cells and the Plant Reproduction material ($F = 3.79$ and 1.04, respectively; $P > .05$), but that performance of the spaced review groups was significantly higher than that of the nonreview groups on the Animal Reproduction items ($F = 4.37$; df/1, 39; $P < .05$). The Animal Reproduction topic was the one interpolated between the two spaced review sequences received by the R groups but not by the M groups. These data suggest that spaced review facilitated aided recall at the time of T_1 not only on the material reviewed, but on the material interpolated between the review sections as well.

Tables XVII, XVIII, and XIX show the analyses of the data obtained from the M-1.0, M-1.5, R-1.0 and R-1.5 groups at the time of T_2. At this time, the review groups demonstrated significantly higher performance than the nonreview groups on all three retention measures taken -- Unaided Recall, Aided Recall, and Recognition. The effect of repetition and the interactions were not significant for any of the retention measures. The fourth measure given at T_2 was the control Recognition test, on which no T_1 differences had been found. As shown in table XX, however, the difference between the M and R groups in recognition of control materials was significant at the time of T_2. At this time, spaced review apparently had a facilitating effect upon recognition of control materials, as well as influencing all retention measures of the experimental material.

Reminiscence. Mean scores of the combined M-1.0 and M-1.5 groups and the mean scores of the combined R groups on the T_1 and T_2 Aided Recall test, Recognition test, and Control Recognition test, are plotted in figures 5, 6, and 7. Figure 4 shows no decrement in added recall for either group over the 21-day period between T_1 and T_2. In figures 5 and 6 the mean scores of both the M and R groups were higher on the experimental and control Recognition tests given at the time of T_2 than they were on the T_1 administrations of these measures. On each of the recognition tests, the R group increment was greater than that of the M group, accounting for the significant T_2 differences found in the factorial analyses of variance (tables 18 and 19). Evidently the effect of repetition and review was not to produce different amounts of forgetting over the 21-day period, but rather to produce different degrees of improvement (reminiscence).

TABLE XIII

COMPARISONS OF REPETITION AND REVIEW GROUPS
ON THE T_1 AIDED RECALL TEST

Source		SS	df	MS	F
Repetition		16.08	1	16.08	1.24
Review		171.50	1	171.50	13.17 ($P < .01$)
Repetition X Review		23.13	1	23.13	1.78
Within					
	Blocks	764.36	13		
	Error	507.79	39	13.02	
	Total	1482.86	55		

TABLE XIV

COMPARISONS OF REPETITION AND REVIEW GROUPS
ON THE T_1 RECOGNITION TEST

Source		SS	df	MS	F
Repetition		.48	1	.48	---
Review		35.56	1	35.56	2.31
Repetition X Review		20.94	1	20.94	1.36
Within					
	Blocks	631.31	12		
	Error	553.76	36	15.38	
	Total	1242.06	51		

TABLE XV

COMPARISONS OF REPETITION AND REVIEW GROUPS
ON CONTROL T_1 AIDED RECALL TEST

Source	SS	df	MS	F
Repetition	21.88	1	21.88	---
Review	135.16	1	135.16	4.22 ($P < .05$)
Repetition X Review	33.01	1	33.01	1.03
Within				
Blocks	2478.09	13		
Error	1246.69	39	31.97	
Total	3914.84	55		

TABLE XVI

COMPARISONS OF REPETITION AND REVIEW GROUPS
ON CONTROL T_1 RECOGNITION TEST

Source	SS	df	MS	F
Repetition	1.92	1	1.92	---
Review	0.00	1	0.00	---
Repetition X Review	1.23	1	1.23	---
Within				
Blocks	261.73	12		
Error	303.35	36	8.43	
Total	568.23	51		

TABLE XVII

COMPARISONS OF REPETITION AND REVIEW GROUPS ON THE T_2 UNAIDED RECALL TEST

Source	SS	df	MS	F
Repetition	7.35	1	7.35	---
Review	88.82	1	88.82	7.76 ($P < .01$)
Repetition X Review	.15	1	.15	---
Within				
Blocks	672.10	14		
Error	480.42	42	11.44	
Total	1248.85	59		

TABLE XVIII

COMPARISONS OF REPETITION AND REVIEW GROUPS ON THE T_2 AIDED RECALL TEST

Source	SS	df	MS	F
Repetition	9.60	1	9.60	---
Review	166.66	1	166.66	13.15 ($P < .01$)
Repetition X Review	2.40	1	2.40	---
Within				
Blocks	882.73	14		
Error	532.33	42	12.67	
Total	1593.73	59		

TABLE XIX

COMPARISONS OF REPETITION AND REVIEW GROUPS
ON THE T_2 RECOGNITION TEST

Source	SS	df	MS	F
Repetition	4.81	1	4.81	---
Review	88.81	1	88.81	4.54 ($P < .05$)
Repetition X Review	3.76	1	3.76	---
Within				
Blocks	1131.23	14		
Error	822.36	42	19.58	
Total	2050.98	59		

TABLE XX

COMPARISONS OF REPETITION AND REVIEW GROUPS
ON THE CONTROL T_2 RECOGNITION TEST

Source	SS	df	MS	F
Repetition	4.01	1	4.01	---
Review	36.16	1	36.16	5.56 ($P < .05$)
Repetition X Review	4.02	1	4.02	---
Within				
Blocks	264.80	13		
Error	253.55	39	6.50	
Total	562.55	55		

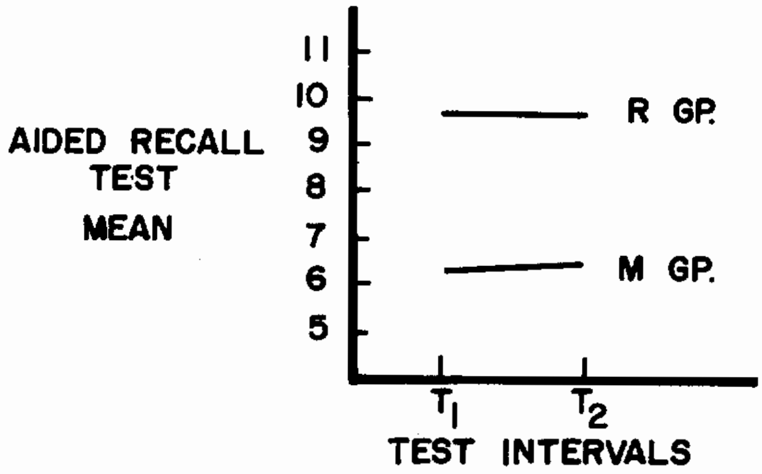

Figure 4: Retention of M and R Groups on the Experimental Aided Recall Test.

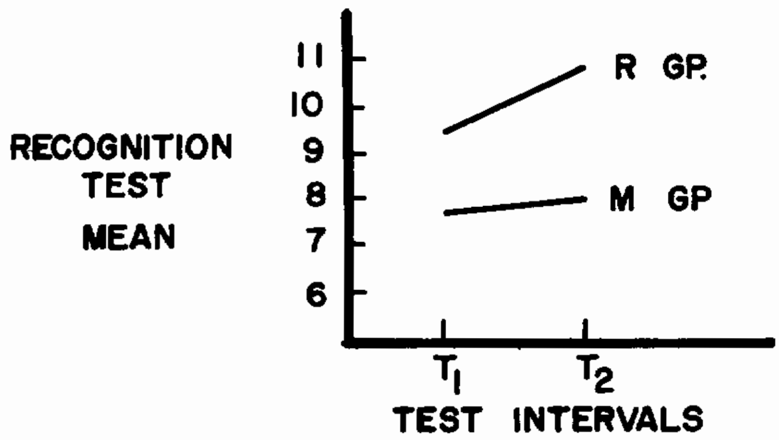

Figure 5: Retention of M and R Groups on the Experimental Recognition Test.

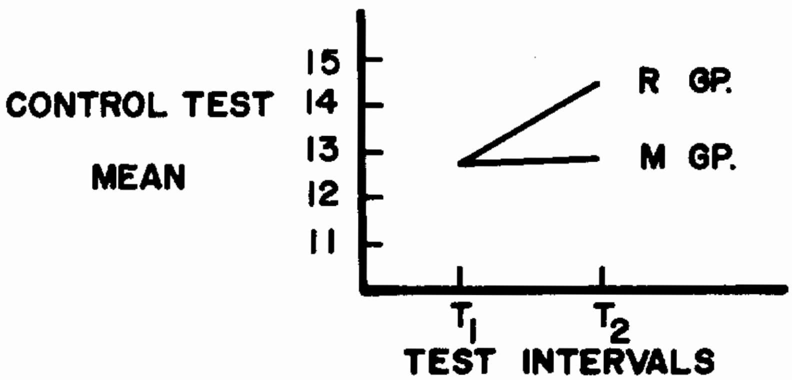

Figure 6: Retention of M and R Groups on the Control Recognition Test.

DISCUSSION

From Experiment 2 there was limited evidence that combined repetition and spaced review facilitated learning. In Experiment 3, using a portion of the standard linear program and controlling for the effect of repetition, spaced review alone rather than repetition and review in combination was found to be the variable facilitating learning and retention. There was only slight evidence that differences in repetition produced differences in retention. The repetition effect was demonstrated only between M-.5 and M-1.5 on T_1 Aided Recall. The factorial analyses comparing repetition and review as independent variables consistently indicated spaced review as a significant factor facilitating retention, but in no case demonstrated differential retention from the two repetition levels that were studied.

One contribution of spaced review is to reduce the time between the last practice trial and the tests. In Experiment 3, the groups receiving the M and R treatments were exposed to the original learning materials at the same time (11th day). Also, the amount and order of prior and subsequent new material was equivalent for the two conditions. However, for the M groups, the intervals between the final learning trial and T_1 and T_2 were 9 and 30 days, respectively. Comparable intervals for the R groups were 4 and 25 days. The superiority of the R groups on the retention tests may have been due in some small part to the shorter intervals between final practice trials and testing.

It was not possible in the present experiments to isolate the effects of the difference in time between the last learning trial and the tests. Further research might be conducted on this factor, but two cautions are appropriate. First, control of the recency factor may require the use of unrealistic instructional conditions. And, second, in order to control recency, other equally important discrepancies may be introduced.

The superior retention of the R group on the control materials was somewhat unexpected. One possible explanation for the finding is that the periodic insertion of review gave the R groups practice in discriminating between the experimental and control topics. Such discrimination training might reduce the confusion between the experimental and control materials in the retention tests. Another possible explanation is that the students were able to use their knowledge of the experimental material in learning and covertly reviewing the control material. The material was all meaningfully interrelated. Increased mastery of one part might well benefit other parts.

The reminiscence effect obtained on the T_2 recognition measures undoubtedly was partly due to the learning effects of the earlier test. However, there is no clear reason why the spaced review instruction produced greater amounts of reminiscence than did nonreview instruction. The improved performance after 21 days probably is due to factors considerably different from those involved in most studies of reminiscence (eg, Ammons and Irion, ref 1). Past research on reminiscence has generally indicated that it is not evident after rest intervals of more than a few days, and that it is less likely to occur following distributed (spaced) learning practice than massed practice (McGeoch and Irion, ref 8, Ch. 5). An explanation of the present findings must await further research.

SECTION V

CONCLUSION

Programed instruction can be at least as effective as traditional instruction in learning and retention of full courses of instruction as shown in Experiments 1 and 2.

Spaced review in programed instruction is potentially beneficial as shown in Experiments 1, 2, and 3. Some techniques of obtaining spaced review, eg, spiral programing, offer few, if any, advantages over a regular linear program.

SECTION VI

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DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) University of Pittsburgh Pittsburgh, Pennsylvania	2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED 2b GROUP N/A

3 REPORT TITLE

REPETITION AND SPACED REVIEW IN PROGRAMED INSTRUCTION

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Final report, October 1961 - October 1962

5. AUTHOR(S) (Last name, first name, initial)

Reynolds, James H., PhD
Glaser, Robert, PhD
Abma, John S., PhD
Morgan, Ross L., PhD

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
December 1964	28	12

8a. CONTRACT OR GRANT NO. AF 33(616)-7175 b. PROJECT NO 1710 c. Task No. 171007 d.	9a. ORIGINATOR'S REPORT NUMBER(S) 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report) AMRL-TR-64-128

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Qualified requesters may obtain copies of this report from DDC.
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11. SUPPLEMENTARY NOTES Also supported in part by Cooperative Research Branch, U.S. Office of Education, under Contract No. OE-2-10-057.	12. SPONSORING MILITARY ACTIVITY Aerospace Medical Research Laboratories, Aerospace Medical Division, Air Force Systems Command, Wright-Patterson AFB, Ohio

13. ABSTRACT The effects of repetition and spaced review in programed instruction were studied. Experiments 1 and 2 covered a one-semester course in General Science at the Junior High School level. In Experiment 3, a 1280-frame portion of the total course was used. In Experiments 1 and 2, comparisons were made among (a) a conventional course, (b) a regular linear version of the program, and (c) a spiral version of the program. The results indicate that the programed course was at least as effective as the conventional instruction in terms of both learning and retention after 15 weeks. The linear program was superior to conventional instruction on some measures. The spiral program offered few, if any, advantages over the regular linear program. Experiment 3 allowed a more precise evaluation of the separate effects of repetition and spaced review. Spaced review produced significant increases in learning which persisted, and even increased, through a 3-week retention interval. Repetition did not produce increased learning or retention. The general conclusions are: (a) repetition of instructional materials above the usual level in a linear program is not beneficial; (b) spaced review is potentially beneficial; and (c) some techniques of obtaining spaced review, eg, spiral programing, may offer disadvantages that equal or outweigh the potential advantages of spaced review.

DD FORM 1 JAN 64 1473

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14. KEY WORDS	LINK A ROLE	LINK A WT	LINK B ROLE	LINK B WT	LINK C ROLE	LINK C WT
Training						
Training methods						
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