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ABSTRACT

Two experiments were performed to evaluate multitracking (branching) in a linear program. In experiment one, the multitracking consisted of providing additional cues at each frame for use by those students who felt unsure of their response. Results indicated no significant difference in efficiency between the regular linear program and the multitrack program. In experiment two, the multitracking consisted of large frames followed by more detailed frames whenever the student made an error. Large frames were developed by combining an average of three small frames. Again, the results indicated no difference in instructional efficiency between the regular linear program and the multitrack program. Although more errors were made on the large-step branching program, performance on criterion tests was as good as for the regular small-step linear program. Although branching seems a reasonable way to accommodate individual differences, the two methods attempted in this research did not show an advantage. More promising methods of branching might be (a) less frequent branches at critical points in the program, and (b) large-step frames followed by special remedial frames, rather than by mere repetition of parts of the original large frame. (Author)

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# AN EVALUATION OF MULTIPLE TRACKS IN A LINEAR PROGRAM


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## FOREWORD

This research represents a portion of the exploratory 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 Programmed Instruction." The research was conducted by the University of Pittsburgh under Contract AF33(616)-7175. 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 essentially 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 in October 1961 and was completed in 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. Special recognition is due to the following individuals for their contribution to the research. Dr. Halmuth H. Schaefer was largely responsible for the development and tryout of the original programs. Mr. Theodore Harakas prepared the multitrack versions of the program and assisted in the editing of the linear version. Dr. John C. Knipp, Professor of Mathematics and Acting Chairman of the Mathematics Department of the University of Pittsburgh, cooperated in carrying out the experiment. Dr. Felix Kopstein, Mr. J. R. Anderson, and Mr. E. Dugan helped coordinate the administration of the program at Wright-Patterson Air Force Base, Procter and Gamble, and Westinghouse Electric Corporation, respectively. Thanks are offered to those who carried out the task of frame writing in the development of the original program, both linear and multitrack versions: John A. Barthen, Donald Conine, Suzanne P. Berwind, Richard Pike, Gordon Purucker, Abe Schwartzman, Louis Tamburino, I. B. Turksen, and Harry Zwibel.

This technical report has been reviewed and is approved.

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## ABSTRACT

Two experiments were performed to evaluate multitracking (branching) in a linear program. In experiment one, the multitracking consisted of providing additional cues at each frame for use by those students who felt unsure of their response. Results indicated no significant difference in efficiency between the regular linear program and the multitrack program. In experiment two, the multitracking consisted of large frames followed by more detailed frames whenever the student made an error. Large frames were developed by combining an average of three small frames. Again, the results indicated no difference in instructional efficiency between the regular linear program and the multitrack program. Although more errors were made on the large-step branching program, performance on criterion tests was as good as for the regular small-step linear program. Although branching seems a reasonable way to accommodate individual differences, the two methods attempted in this research did not show an advantage. More promising methods of branching might be (a) less frequent branches, at critical points in the program, and (b) large-step frames followed by special remedial frames, rather than by mere repetition of parts of the original large frame.

## SECTION I

## INTRODUCTION

One of the advantages of programed instruction is the individualization of training. A trainee can go at his own rate with materials designed to teach the specific trainee group involved. Most linear programs have only one track or sequence of frames for all students to follow. Intrinsic programing, on the other hand, does provide branching whereby correct and incorrect responses are differentially treated. Computer-based programs can assess an individual's progress and assign different sequences as required. By and large, studies have indicated that the efficiency of branching and multitracking procedures have thus far provided little consistent advantage over linear sequences. Coulson and Silberman (ref 4) found that subjects with a very limited form of branching learned as well as and in a shorter time than those taught without branching. Using a computer as a control unit in a followup study, Silberman and others (ref 9) found no significant difference between a branching and a fixed-sequence version of a logic program. Modification of the remedial items and the branching structure of this program resulted in superior learning by the branching group (ref 3). Campbell (ref 2) compared a branching program with three linear programs of different length and found no significant difference on a post-test. In a comparison between a branching and a linear program, Mager (ref 7) found superior performance on the part of the linear group on a calibration task, but this group had taken more training time" (ref 6).

The two experiments reported here investigate some further techniques of multitracking in a linear program to assess any instructional efficiency that may be gained over a straight-line program.

## SECTION II

## EXPERIMENT 1

Correct responding is one of the major requirements of linear programs. The program is constructed so that responses are always within the repertoire, or ability, of the student. Each step prepares him to respond correctly to the succeeding steps. When the program fails to evoke correct responses, the learning efficiency may suffer. The erroneous answer may cause trouble in the learning of succeeding program steps. To eliminate as entirely as possible the occurrence of wrong answers, a multitrack program was devised which would provide additional cues to students who were unsure of the correct answer. The student could make use of as many of the cues provided as he needed before responding. Since different students would call for different amounts of cueing, the program is an example of branching within a generally linear program.

### MATERIALS

A lengthy program of 2,600 frames was devised for the experiment. The title of the linear program is "Mathematical Bases for Management Decision-Making: Matrices and Mathematical Programming."[1] Titles of the twenty sections of the program are:

1 - Symbolic Notation
2 - Transportation Problem in Matrix Form
3 - Production Scheduling in Matrix Form
4 - Basic Matrix Notions
5 - Matrix Multiplication
6 - Row Operations
7 - The Inverse of a Matrix
8 - Systems of Linear Equations
9 - Industrial Applications of Systems of Linear Equations
10 - Systems of Linear Inequalities
11 - Optimum Solution by Graphical Method to Two-Dimensional Linear Inequality Problem
12 - Linear Combination of Vectors, Linearly Dependent and Linearly Independent Vectors, and Vector Spaces
13 - Bases and Convex Sets
14 - Introduction to Linear Programming
15 - Fundamental Matrix Concepts in Linear Programming
16 - Simplex Method -- Determining $P_k$, the Vector to Enter the Basis, and $P_r$, the Vector to be Removed from the Basis
17 - Simplex Method -- Transformation of Tableaus
18 - Simplex Method -- Solution of Example Problems
19 - Mixed Systems of Restrictions, Alternate Optima, and Degeneracy
20 - Transportation Problem in Simplex Form

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1. These materials have been revised and are now available from Encyclopaedia Britannica Press, Chicago, Ill.

The multitrack program first presents the student with an ordinary linear frame. He is instructed to answer only if he is sure that his response is the correct one. If he has any doubt, he can use another frame, found immediately below the frame he has just attempted. This frame covers the same material, but is more highly cued. If the student is still unsure, he can choose yet another version of the frame which provides still more cueing. The last frame is very likely to supply the answer through very direct prompting, eg., a copy or echoic prompt. After getting the correct answer, the student returns to the ordinary version of the next frame — the version which supplies only the amount of cueing necessary for most students. This multitrack program was compared with a linear program covering the same subject matter. The linear program was made up of the first-level-of-difficulty frames used in the branching program.

## SUBJECTS

Three separate groups of subjects participated in this experiment. Twelve subjects were from Wright-Patterson Air Force Base, Ohio; twelve more were from Westinghouse Electric Corporation, East Pittsburgh, Pa; and eight were from the Procter and Gamble Company, Cincinnati, Ohio, thus, a total of 32 subjects participated. Some of the subjects had college degrees, others did not. In general, they presented a wide variety of vocational backgrounds and interests.

## PROCEDURE

The experimental procedures differed for the three groups participating in this research; therefor, procedures will be described separately for each group.

### WRIGHT-PATTERSON GROUP

For sections 1 through 10, 7 of the subjects used the linear version and 5 of them used the multitrack version. Assignment of subjects to the two versions was made at random. The linear format was used by all subjects on sections 11 through 20.

The subjects were issued the program one section at a time. The programed instructional material was completed either at home, or if time permitted, during the course of their regular work assignments. Upon completion of a section, the subject submitted it to the coordinator who administered the criterion test at that time. The succeeding section was then issued to the subject. After all 20 sections were finished, the subject was given a final examination. The examination consisted of 21 constructed-response items.

### PROCTER AND GAMBLE GROUP

Five of the subjects were assigned the linear format for the entire course and three of the subjects were assigned the multitrack format for the entire 20 sections. Three of the degree subjects and two of the noncollege subjects worked on the linear version; two of the degree subjects and one of the noncollege subjects worked on the multitrack version.

The programed materials were completed at home or at work if time permitted. One section at a time was distributed to each participant. When a section was finished, the subject returned it to the coordinator and the criterion test was taken at this time. Then the next section was given to the subject to complete at his own pace. An examination covering the first 10 sections was taken by each subject after having completed all 20 sections. The examination was a 20 item constructed-response examination.

WESTINGHOUSE ELECTRIC

All subjects used both the linear and multitrack versions. A subject would complete five sections using one format (linear or multitrack) and then use the other format for the next five sections. Thus every subject was exposed to both linear and multitrack versions. The assignment of the format type was made to insure that each section had approximately the same proportion of college and noncollege educational backgrounds.

Again, the programed instructional materials were studied at home or at work, if time permitted. As was the case with both the Air Force and Procter and Gamble subjects, one section at a time was given to each subject. However, only about half of the criterion tests were given immediately after having completed a section of the programed materials; the other half of the criterion tests were delayed 3 to 4 weeks after a section was completed. An examination covering the material in the first 10 sections was given to those subjects who completed the entire 20 sections. This is the same examination as that taken by Procter and Gamble participants.

RESULTS

Criterion test scores, error data and time information for all three subject groups were analyzed. Since the results from the three groups correspond closely, the combined results for all groups are reported here. Table I shows the percent correct on a criterion test designed especially for the program. Table II shows error rate during use of the program. The results are shown separately for college and noncollege subjects, since they differed so widely in their performances.

TABLE I

CRITERION TEST SCORES

| | Linear | Multitrack |
|---|---|---|
| College | 89.13% | 86.92% |
| Noncollege | 75.40% | 71.60% |

TABLE II

ERROR RATES

| | Linear | Multitrack |
|---|---|---|
| College | 0.029 | 0.036 |
| Noncollege | 0.044 | 0.052 |

Table III shows learning time in minutes per frame. It compares the college group learning time with the noncollege group learning time for the subjects who used the linear program, and for those who used the multitrack program (Air Force subjects were not included since these times were not available for this group).

The data are based on the time the subjects used completing the equivalent of a frame in the regular linear program, ie, students requiring additional cueing in the branching program were not credited with completing additional frames.

TABLE III

TIME IN MINUTES PER FRAME

| | Linear | Multitrack |
|---|---|---|
| College | 0.67 | 1.04 |
| Noncollege | 1.08 | 1.18 |

In all three comparisons (criterion test score, error rate, learning time): (1) the college group was superior to the noncollege group, (2) the college group on linear was superior to the college group on multitrack, and (3) the noncollege group on linear was superior to the noncollege group on multitrack. Statistical tests were not performed on these data. The results are the combined findings from separate replications using different types and numbers of subjects. The results, although tentative, give no indication that the branching (multitrack) procedure tried here offers any advantage over the more usual linear program.

TABLE IV

RETENTION TEST SCORES (%)

| | Immediate Testing | 4-week Delayed Testing |
|---|---|---|
| Linear | 80.88 | 81.34 |
| Multitrack | 76.99 | 82.87 |

Table IV shows retention data for the Westinghouse Electric Corporation subjects. (Similar data were not available from the other groups). Statistical tests were not performed because of a low N for each cell (3 to 5 subjects). These tentative data suggest more reminiscence for the multitrack program, but the immediate testing might have been unreliable due to procedural or other factors. The final scores on delayed testing suggest good retention for both the linear and multitrack versions.

## CONCLUSIONS

The data obtained in the program tryouts on the various groups was adequate for program evaluation. The data also permitted a comparison of a straight-line program and one form of multitrack program. Under the conditions of this experiment, no advantage could be shown for the multitrack program over a regular linear program. Records of subject responses indicated that few branches were taken in the multitrack program. Students may have been reluctant to admit they needed additional cues. However, the first-level-of-difficulty frames were already so highly cued (easy) that subjects simply did not need the branching option for the vast majority of frames. As shown in table 2, error rates were very low for both versions of the program. Both versions of the programs were identical to the extent that the available branches were not used.

Additional data obtained in the course of the experiment provided information for tentative conclusions about the relation between subject characteristics and program performance. The performance of the subjects who had college mathematics was superior to those who had no college mathematics. The noncollege groups did not consist of recent high school graduates: they had very little mathematical background other than basic arithmetic. The performance of subjects who had recently completed their courses in high school mathematics as it is now taught probably would be better.

## SECTION III

## EXPERIMENT 2

The multitrack program used in experiment 1 was based on a linear program having a low error rate. The branching feature was designed to eliminate even those few errors that might be made on the linear version by providing additional cues and prompts when the student was not sure of the correct response. The branching feature did not lead to higher attainment levels under these conditions. In order to force more subjects to use extra tracks or branches, a more difficult version was prepared. For this purpose, frame difficulty was increased by combining several frames from the linear program. Students who found a large combined step too difficult could branch to the series of small linear program steps dealing with the same content.

### MATERIALS

The first nine sections of the Management Decision Making Program (1060 frames) were used (see page 2). These sections teach Matrix Theory, Summation Symbolism, and the Industrial Application of Matrix Theory. When the sections are combined, they represent a self-contained unit of study.

For the construction of the multitrack experimental version, frame sequences consisting of an average of 3.2 of the original small step linear frames were grouped, on the basis of subject matter content, into one large frame which usually required only one response. The entire program was reconstructed in this manner. Figure 1 shows an example of a frame sequence in the linear program, and Figure 2 shows the same set of frames combined into one large frame. A student using the original linear program would respond three times to three different frames and receive confirmation each time. A student taking the new large-step program, however, would read one long frame, then make a single response and receive confirmation only once. All frames in the nine sections were reconstructed in this manner. At times it was necessary to insert transitional phrases, but usually the exact wording of the linear small-step frames was satisfactory.

The branching aspect of the large-step experimental version consisted of shifting individuals who responded incorrectly to large-step frames back to the original sequence of small steps from which the large frames were constructed. The original small steps were printed on the reverse of each page containing the corresponding large step. The student could refer to the back of the page when he responded incorrectly. In comparison with the small-step linear program, this multitrack program involved less overt responding and confirmation (333 frames, requiring approximately 1/3 the number of responses), plus the possibility of branching to smaller steps. The programs covered the same material.

149. The coefficients in an expansion may often be expressed as an index.

$\sum_{j=1}^{5} jy_j$

$$x_1 + 2x_2 + 3x_3 + 4x_4 = \sum_{j=1}^{4} jx_j .$$

$$y_1 + 2y_2 + 3y_3 + 4y_4 + 5y_5 = \_\_\_\_\_\_\_\_ .$$

150. $6x_6 + 7x_7 + 8x_8 + 9x_9 = \sum_{j=6}^{9} jx_j .$

$\sum_{j=2}^{20} jy_j$

$$2y_2 + 3y_3 + \ldots + 19y_{19} + 20y_{20} = \_\_\_\_\_\_\_\_ .$$

151. If all our terms have coefficients twice the index of the summand, we may use $2_j$ as the coefficient index. Then $2x_1 + 4x_2 +$

$\sum_{j=1}^{4} 2jy_j$

$6x_3 + 8x_4 + 10x_5 = \sum_{j=1}^{5} 2jx_j$. $2y_1 + 4y_2 +$

$8y_4 = \_\_\_\_\_\_\_\_$.

Figure 1. Three Frames From The Straight Linear Program (Control Program)

149-151 The coefficients in an expansion may often be expressed as an index. Consider the following examples:

$$x_1 + 2x_2 + 3x_3 + 4x_4 = \sum_{j=1}^{4} jx_j$$

$$y_1 + 2y_2 + 3y_3 + 4y_4 + 5y_5 = \sum_{j=1}^{5} jy_j$$

$\sum_{j=7}^{11} x_j$

$$6x_6 + 7x_7 + 8x_8 + 9x_9 = \sum_{j=6}^{9} jx_j$$

$$2y_2 + 3y_3 + \ldots + 19y_{19} + 20y_{20} = \sum_{j=2}^{20} jy_j$$

If all our terms have coefficients twice the index of the summand, we may use $2_j$ as the coefficient index.

Thus

$$2x_1 + 4x_2 + 6x_3 + 8x_4 + 10x_5 = \sum_{j=1}^{5} 2jx_j$$

$$2x_1 + 4x_2 + 6x_3 + 8x_4 = \_\_\_\_\_\_\_\_.$$

[Note: The small-step branching sequence was available to the student on the back of the page.]

Figure 2. A Large-Step Combining the Frames in Figure 1. (Experimental Program)

## SUBJECTS

Subjects were high school teachers attending a National Science Foundation Summer Institute for Mathematics Teachers. Of the 35 students in the class, 34 were selected and matched into 17 two-person blocks. The subjects were matched on the basis of five variables: (1) age; (2) number of years since last math course; (3) number of credits in past math courses; (4) cumulative grade average for math courses; (5) performance on a 15 item pretest of basic matrix operations selected from the post-program criterion test. During the study, three blocks were dropped — two because of individual dropouts, and one because of a seriously inadequate background.

## PROCEDURE

The program was administered three times weekly for 2 weeks at regular intervals. Class sessions were scheduled for periods of 1-1/2, 1-1/2, and 1 hours, respectively. During the last week of the study, a "catch up" session of 1 1/4 hours was scheduled for 17 of the students. In addition, 17 students worked from periods of 1-1/2 - 4-1/4 hours at home. These students kept individual records of their working time at home. The programs were collected at the end of each class session and the subjects were instructed not to study any related material.

During the scheduled sessions, the control group worked with the small-step linear program. The experimental group used the large-step program, after receiving detailed instructions on how to use a branch whenever they responded incorrectly to a large-step frame. The subjects took a 63-item criterion test following completion of the program. The test items were multiple-choice questions with five alternatives.

## RESULTS

The performance of experimental and control groups was compared on the criterion test. Time in hours to complete the program was also examined. See Table V.

### Criterion Performance

A *t* test for matched groups showed no significant difference between the criterion test performances of the experimental and control groups ($t = 0.35$, $p > .05$). The combined score for the linear group was 44.3 and for the multitrack group was 43.2. The total possible score was 63, hence average proficiency was 69.4% of a perfect criterion performance.

### Performance Time

The average time taken to complete the program was 10.6 hours for the control group and 11.1 hours for the experimental group. The difference between these group means was not significant ($t = 0.94$, $p > .05$). The average number of frames per hour was 101.7 small-step frames for the control group and 30.3 large-step frames for the experimental group.

TABLE V

TEST RESULTS AND TIME SCORES

| Subject Pair | Criterion Test | | Time (hr.) | | Frames per hour | | Error Rate | |
|---|---|---|---|---|---|---|---|---|
| | Exp. | Control | Exp. | Control | Exp. | Control | Exp. | Control |
| A | 41 | 32 | 12.2 | 10.0 | 27.3 | 106.0 | 13.2% | 3.6% |
| B | 51 | 47 | 10.7 | 9.5 | 31.1 | 111.6 | 8.1% | 3.4% |
| C | 42 | 35 | 13.3 | 9.7 | 25.0 | 109.3 | 6.0% | 6.6% |
| D | 57 | 49 | 10.2 | 14.4 | 32.6 | 73.6 | 6.0% | 1.7% |
| E | 25 | 53 | 10.0 | 10.2 | 33.0 | 103.9 | 12.6% | 6.7% |
| F | 44 | 32 | 12.1 | 10.0 | 27.5 | 106.0 | 6.3% | 18.2% |
| G | 58 | 55 | 9.7 | 10.1 | 34.3 | 105.0 | 10.5% | 1.6% |
| H | 46 | 57 | 9.7 | 8.9 | 34.3 | 119.1 | 3.6% | 1.1% |
| I | 36 | 48 | 11.5 | 11.9 | 29.0 | 89.1 | 19.8% | 6.4% |
| J | 32 | 40 | 10.7 | 12.2 | 31.1 | 86.9 | 12.9% | 1.9% |
| K | 44 | 31 | 11.9 | 12.4 | 28.00 | 85.5 | 3.3% | 2.4% |
| L | 46 | 52 | 9.1 | 9.0 | 36.6 | 117.8 | 4.2% | 2.7% |
| M | 52 | 54 | 11.5 | 8.8 | 28.0 | 120.5 | 6.0% | 2.7% |
| N | 31 | 35 | 12.7 | 11.9 | 26.2 | 89.1 | 12.6% | 2.6% |
| $\Sigma$ | 605 | 620 | 155.3 | 149.0 | 424.0 | 1423.5 | | |
| $\bar{X}$ | 43.2 | 44.3 | 11.1 | 10.6 | 30.3 | 101.7 | 8.9% | 4.3% |
| $\sigma$ | 10.3 | 9.3 | 1.4 | 1.6 | 3.4 | 13.9 | | |

## Program Characteristics

Table VI shows the average error rate for each of the nine sections of the experimental program and the total error rate for the program. Error rate was computed by dividing the total number of errors by the total number of possible correct answers. For example, the total number of errors made by the 14 subjects on section 1 was 130; the total possible number of correct answers is the number of frames (68 frames in section 1) multiplied by the number of subjects, or 952. Thus the error rate for section 1 was $\frac{130}{952} \times 100 = 13.7\%$. Table VII shows the error rate for each of the nine sections for the small-step single-track program. The error rate for each subject is shown in the last two columns of Table V. The difference between error rates for the two programs is statistically significant.

The use made of the branching feature in the experimental program was analyzed. Subjects used a branch only 37.6% of the time that they made errors on the program. Interrogation of the subjects indicated that when a branch was not used, it was, in general, obvious to them what their error was. Subjects reported that they generally used the branch only when they did not understand why a response was incorrect after receiving confirmation.

TABLE VI

ERROR RATE FOR THE MULTITRACK PROGRAM (N = 14)

| Section | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| No. Frames | 68 | 26 | 20 | 40 | 70 | 26 | 45 | 22 | 16 | 333 |
| Total No. Errors for All Subjects | 130 | 46 | 32 | 14 | 65 | 42 | 43 | 26 | 19 | 417 |
| Error Rate | 13.7% | 12.6% | 11.4 | 2.5% | 6.6% | 11.5% | 6.8% | 8.4% | 8.5% | 8.9% |

TABLE VII

ERROR RATE FOR THE SINGLE-TRACK PROGRAM (N = I4)

| Section | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| No. Frames in Section | 282 | 82 | 68 | 111 | 215 | 73 | 112 | 62 | 55 | 1060 |
| Total Number Errors | 194 | 70 | 63 | 38 | 135 | 51 | 45 | 32 | 26 | 654 |
| Error Rate | 4.9% | 6.1% | 6.6% | 2.4% | 4.5% | 5.0% | 2.9% | 3.7% | 3.4% | 4.3% |

CONCLUSIONS AND IMPLICATIONS

The results of this study are clear. When the small steps of an effective linear program were combined into larger steps with provision for branching to smaller steps, there was no change in instructional effectiveness. Criterion test scores and time to go through the program were the same for the two programs. Subjects went through the small-step program at a rate of about 100 frames per hour; for the large-step program, in which the frames were on the average three times as long as the small-step frames, the subjects went one-third as fast or about 30 frames an hour. However, frame error rate was significantly different for the two groups, fewer errors being made in the small-step, single-track program.

The two main differences between the programs were size of step and the branching possibility. With respect to size of step, three previous studies comparing small-step and large-step programs " . . . have demonstrated superior learning with the small-step program, but only at the expense of added training time (ref 5,4,2). Smith and Moore (ref 10) . . . found no differences in learning with different step sizes." (ref 8, p 182). The size of step is not a uniformly defined variable, and its definition must be carefully examined in the context in which it is used (ref 6). In the present study it is defined as the combination of small steps from an existing linear program. More reading and less overt responding was thus required, and confirmation was received less often.

In the present study a direct test of the size of step variable was not possible because the large-step program offered opportunity for branching. Errors were made on the multitrack program at a rate of 8.9%. However, branches were actually taken after only about one-third of these errors. Thus, branches were taken at a rate of 3.34%. For the most part, then, the multitrack program was used as a large-step program. Consequently, the results obtained suggest that size of step is not as sensitive a variable as previously considered in its influence upon maximizing reinforcement and minimizing error.

In general, branching might serve two functions: (1) adjust or tune the instructional characteristics of the program to the individual learner and (2) provide correction of incorrect responses. With respect to adjusting program characteristics to the individual learner, much more needs to be determined about the dimensions involved in individual differences in learning. Just what are the properties that make a difference: size of step, learning rate, number of reinforcements? With respect to correction of errors, little seems to be known about its effect on learning. Most basic learning studies have emphasized the contingencies involved in reinforcement and extinction trials. Some recent verbal learning studies have considered the effects of information through announcement of "right" or "wrong" following a response (ref 1). Much less concern has been evidenced in studies where an incorrect response is followed by a correction.

Average criterion test performance for both groups was approximately 70% of perfect score. This is in contrast to the group in the first experiment where criterion performance for college-trained subjects was about 89% for the small-step program. When a heterogeneous group of subjects used this program, they did not acheive equal performance on the criterion test. The specification of prerequisite knowledge prior to program instruction is a significant predictor of success in learning from the program. It should be taken into account in both the experimental and operational use of program instructional sequences.

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