In continuing research into the technology of training, a study was undertaken to devise guidelines for applying programed instruction to training courses that involve the learning of principles and rules for use in problem solving. As a research vehicle, a portion of the material in the Army's Programing Specialist Course was programmed to explore several different factors in using automated instruction to teach computer programming. Experimental versions of the course were administered to over 900 subjects in various experimental groups. Criterion and retention tests based on actual job problems were used to measure subject's performance, along with in-training measures. Results in a series of prompting/confirmation variations indicated that giving subjects extensive stimulus support during training helps motivate them and improves scores during training, but hampers them in using what they have learned. Requiring subjects to fully write out rules during training hindered them in developing problem-solving skills applying these rules; however, using mnemonics during training aided subjects in retaining what they had learned. (Author)
Technical Report 68-4

The Application of Theoretical Factors in Teaching Problem Solving by Programmed Instruction

by

Robert J. Seidel and Harold G. Hunter

HumRRO Division No. 1 (System Operations)

April 1968

Prepared for:
Office, Chief of Research and Development Department of the Army

Contract DA-44-008-ARO-2

HumRRO

The George Washington University
HUMAN RESOURCES RESEARCH OFFICE

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HumRRO Division No. 1 (System Operations)
Alexandria, Virginia
The George Washington University
HUMAN RESOURCES RESEARCH OFFICE

Technical Report 68-4
Work Unit METHOD
Sub-Unit II
The Human Resources Research Office is a nongovernmental agency of The George Washington University. The research reported in this Technical Report was conducted under contract with the Department of the Army (DA-14-188-ARO-2). HUMRO's mission for the Department of the Army is to conduct research in the fields of training, motivation, and leadership.

The findings in this report are not to be construed as an official Department of the Army position, unless so designated by other authorized documents.
FOREWORD

The research described in this report was performed by the Human Resources Research Office under Work Unit METHOD, Research for Programed Instruction in Military Training. The objectives of Sub-Unit II of that Work Unit were to develop guidelines for applying programed instruction to military tasks requiring the learning of principles and rules, especially those applying to computer programming.

The vehicle for the research was the development of an automated instructional package for teaching basic computer programming instructions in the FIELDATA symbolic coding language. The final version of the course is entitled, Basic Computer Programming: A Self-Instructional Course (with Answer Booklet), June 1967.

The research was conducted at HumRRO Division No. 1 (System Operations). The present Director of Research of the Division is Dr. J. Daniel Lyons; Dr. Arthur J. Hoehn was Director of Research when METHOD II was initiated; Dr. Robert J. Seidel was Work Unit Leader.

HumRRO staff members who contributed to the research include Dr. Iris C. Rotherg, in the early stages; Dr. Eugene F. MacCaslin, task analysis; Dr. Donald Reynolds, Dr. Harold Wagner, and Dr. Richard D. Behringer, data collection; Dr. Harold G. Hunter, course preparation and report preparation; and SP 4 Wayne S. Carpenter, course preparation.

The superintendents of the school systems in the metropolitan Washington, D.C., area who provided facilities and students for the administration of the experimental programed instructional course were: Dr. J.C. Albohm, Alexandria, Virginia; Dr. H. Wilson, Associate Superintendent for Instruction, Arlington County, Virginia; Dr. C.F. Hansen, Washington, D.C.; Mr. E.C. Funderburk, Fairfax County, Virginia; Dr. H. Elseroad, Montgomery County, Maryland; and Mr. W.S. Schmidt, Prince Georges County, Maryland.

HumRRO research for the Department of the Army is conducted under Contract DA 44-188-ARO-2 and Army Project 2J024701A712 01, Training, Motivation, Leadership Research.

Meredith P. Crawford
Director
Human Resources Research Office
SUMMARY AND CONCLUSIONS

Military Problem

The military problem to which this study was addressed is primarily that of the need for research in the technology of training, with development of a potentially useful course serving both as the research vehicle and as a secondary objective.

In recognition of the need for more efficient training of military personnel to meet the increasing demands for more complex knowledge and skills, research and development on automated instruction is continuing on a widespread scale. While solution of training problems for a particular course represents an important activity, contributions that have broader application can be made by establishing general guidelines for developing automated instruction for a class of instructional content. Toward this end, the principal objective of METHOD II research has been to develop general guidelines for the application of programmed instruction to tasks requiring the use of principles and rules in problem solving.

Increasing complexities in military systems have created a need for faster and more efficient methods of information processing and a consequent increase in the importance of training for computer programmers, whose work involves the application of principles and rules. The activity chosen for the research, therefore, was the development of an automated instructional package for a portion of the Automatic Data Processing Specialist (ADPS) programming course (MOS 745.1). The instructional content was concerned with the basic computer programming instructions and FIELDATA symbolic coding language, pertinent to the MOBIDIC computer. Emergence of a usable military course of instruction would be a desirable by-product of the research.

Research Problem

Although programmed instruction is beginning to find application in full-length operational courses, much of the research on the technique has been restricted to short-course laboratory studies, using material requiring simple memorization. Most operational training, on the other hand, requires learning complex material—"connecting" a set of stimuli (concepts) and symbolic "mediating" responses, in contrast to "connecting" a single stimulus and a single overtresponse. Further, for training, a distinction must be made between learning per se (i.e., developing a base knowledge of and ability to use what was learned to solve problems.

To help bridge the gap between laboratory research and training, the METHOD II research was planned as a large-scale experimental study to explore a variety of factors in using automated instruction to teach fundamentals of computer programming. The study provided "real" training content, an environment more like a school than a laboratory, and complex material to be learned.

Variables studied experimentally in presenting programed instruction were (a) degrees of prompting—providing correct answers to the student before he responds, (b) degrees of confirmation—providing correct answers for the student after he responds, (c) effects of verbalization—requiring students to write or name rules, and (d) effects of variety of practice.

Since prompting and confirmation affect the smallest unit of a program, the individual instruction frame, study of these variables deals with the fundamental aspects of preparing programed instruction. Verbalization which has been used in other research to indicate whether the student understands the material, was used in this study to explore the relationship between the student's ability to verbalize rules and principles and his ability to actually use them in problem-solving performance on realistic materials.
Approach

The research involved four major types of activities:

1. **Literature review.** The literature on programmed instruction and learning principles was reviewed to select concepts and techniques for experimental study.

2. **Program development.** After attending military and industrial computer programmer classes, researchers analyzed the programmer's work, with the aid of operational military personnel. Portions of the ADPS programming course were selected for experimentation, and training content for an experimental course was developed jointly by military instructors and research personnel.

3. **Experimentation.** Materials for the experimental course were divided into five parts of increasing difficulty. Training content was translated into programmed instruction format and then prepared to reflect varying degrees of the experimental variables. Training experiments, factorial in design, were then conducted: a relatively small experiment using the first two parts of the course, and a larger-scale effort using all five parts of the course.

4. **Course revision.** The principal research findings were applied in developing a revised version of the course in programmed instruction format.

The experimentation phase of the research may be summarized as follows:

**Experiment 1A**—The prompting/confirmation and the verbalization variables were studied during a three-day period of training and testing, using 60 high school students. The first two portions of the five-part course were the subject matter. As the prompting/confirmation training condition, one-half the subjects wrote answers after being given the needed information, and the other half wrote answers before receiving the information. Alternative versions of verbalization were used; during training, one group of subjects was required to write the entire rule applicable to the computer programming problems they were solving, a second group wrote the appropriate mnemonics (name) for the rule, and a third group neither wrote nor named the rule during their instructional work.

**Experiment 1B**—This experiment was the first portion of the large-scale study. It initially involved 805 volunteer subjects from local high schools, about half of whom remained in the program at the close of the 1B portion of the training. It covered Parts I and II of the course and the materials used were identical to those in Experiment 1A. The same prompting/confirmation conditions also applied; study of the use of mnemonics was continued with groups that named the rule or did not name the rule in training, but the treatment requiring writing of the entire rule was omitted. This experiment and Experiment 2, together, covered 10 weeks, with instruction given once a week.

**Experiment 2**—This experiment was the second portion of the large-scale study, following Experiment 1B in time and covering the more complex content of the course (Parts III, IV, and V). The students who had completed Experiment 1B continued into Experiment 2; a total of 345 completed the whole five-part program. The treatments included expanded variations of the prompting/confirmation conditions. They also included a variety-of-practice variable; during learning one group of subjects practiced solving problems in a single context while a second group was given three different variations of problems.

For all of the experimentation, the performance tests used as final criterion measures (and also as retention tests given at periods of one day to four weeks after training) represented the kinds of computer programming problems typically encountered on the job by programmers.
with a comparable amount and kind of training. Work on similar practice problems within the course provided error rate data on learning during training.

Following the experimental administrations, the course was revised to incorporate findings from the research and apply experience gained. This revision included simplifying the content and improving the format. The course was then administered to seven college freshmen and six high school seniors, all of whom completed it.

Results

Experimental Effects

(1) The results of Experiment 1A showed that:
(a) Writing out rules of computer programming during training hindered students on the performance tests, despite the fact that they learned to write the rules better than the other students.
(b) Prompting was associated with significantly better learning than was confirmation, as measured by error rates during training. However, a reverse tendency appeared on the application of learning to problem solving in the criterion performance test.
(c) Practice in naming the rules of computer programming (rather than writing them out) appeared to aid criterion performance.

(2) Experiment 1B added to the reliability and generalizability of Experiment 1A results by duplicating them under different administrative procedures.

(3) The results of Experiment 2 showed that:
(a) The more information (either prompting or confirmation) the students received during training, the more likely they were to complete the course.
(b) For those who completed the course, more prompting or confirmation reduced error during learning, but increased error on the criterion tests.
(c) Students who dropped out had performed much more poorly than they had thought they would. Students who finished the course had expected to perform only slightly better than they did.
(d) Variety in practice problems led to better criterion scores than did no-variety.
(e) Results on the final retention test four weeks later yielded the same pattern as the criterion tests.

Course Effectiveness

(1) Taking into consideration the differences in administration conditions between the Army school situation and an experimental setting aimed primarily toward comparing techniques rather than maximizing scores, the course seemed to be effective in certain of the experimental conditions. Specifically, the average scores on criterion tests in the first two parts of the course were approximately 80-85% correct. Under the optimal experimental conditions in the most complex portion of the course, the scores dropped to approximately 50% correct. Average time for completion of the full five-part course (Experiments 1A and 2) was about 27 hours.

(2) In the pilot administration of the final revision of the course, four of the seven college freshmen given the course had scores of 90% or better on the final criterion test and the lowest score was in the high 70s; median completion time was 26 hours. The high school students' scores averaged slightly lower, in the 80s, with a median completion time of 31 hours. The two
high school students who obtained the highest scores were in the bottom third of their senior class.

Conclusions

(1) Results suggest the following guidelines for preparing programed instruction for learning rules and principles:

(a) A large amount of prompting and confirmation is important as a motivational device to keep students interested in continuing training. However, a smaller amount of prompting and confirmation, while producing more errors during learning and lowering motivation, appears to foster better ability to use the results of training. The advantage of less prompting/confirmation for ability to use learning seems consistent and long-lasting.

(b) Requiring students to write out rules during their training hinders the development of problem-solving skills using these rules.

(c) Variety in practice problems facilitates the learning of problem-solving skills.

(d) Early training using mnemonics (naming the rules) aids later learning and retention, particularly as material becomes more complex.

(2) Because of the nature of the course content, it would appear to be useful for either officer or enlisted personnel who need some introduction to computer programming, whether for administrative or supervisory activities, or for some allied operational activity.
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The Application of Theoretical Factors in Teaching Problem Solving by Programmed Instruction
MILITARY PROBLEM

As present and future defense systems continue to increase in size and complexity, greater demands for information and skills are being placed on military personnel. Besides the requirements of learning new weapons systems, changes in current equipment and tactics impose broad, continuing requirements for adaptation of skills already learned. Taken together, these conditions demand the continuing development of methods for constructing shorter, more effective training programs.

Much necessary training research has been directed toward solving problems in specific courses of instruction. Less research has been aimed at establishing a body of knowledge, sets of principles, and effective guidelines for training development in general, or for specific categories of training content. Besides the need for more effective individual training programs, then, there is a need to develop a body of training technology. Specific findings need to be brought together in a systematic way, so that they may be more readily applied to future Army training programs.

A category of training content that has both great importance and broad application is the learning of principles and rules for use in problem solving. It was therefore decided that the METHOD II research would deal with guidelines for applying programed instruction (PI) to Army training courses that involve the learning of principles and rules.

The use of principles and rules is typified in the task of programming for automatic data processing systems. The programmer's job is problem solution, that is, he analyzes information given and prepares a solution to the problem in a form acceptable to a computer. For the Army, training computer programmers is a matter of considerable urgency because the increasing complexity of weapons and operations systems requires highly effective information processing possible only with computers. Therefore, the vehicle chosen for METHOD II research was an automated instructional package for selected portions of the Automatic Data Processing Specialist (ADPS) (FIELDATA) programming course.

From work with such materials, it was hoped that the experimental findings of METHOD II would provide a beginning toward the establishment of guidelines for programming training content that consists of rules and principles. A secondary research goal would be development, as a research by-product, of course material that could be used for military instruction.

SCIENTIFIC BACKGROUND FOR THE RESEARCH

Several facets of theory and exploration which led to the current set of experiments are summarized in this section:

(1) The area of programed instruction is examined from theoretical aspects, as well as for its practical value as a controlled environmental setting in which to do training research.

(2) The role of errors in training and training research is discussed.
The range, difficulty, and variety of instructional content are considered in terms of concept formation processes, as contrasted with simple learning such as rote memorization.

The distinction between learning concepts and using them in solving problems is given emphasis.

These factors are considered against a backdrop of the various kinds of content that have been used in the laboratory setting. Traditional psychological research (generally using isolated bits of verbal material) is contrasted with the kinds of material that must be dealt with in the everyday teaching and training situation, that is, connected discourse, hierarchically ordered and related conceptual material. Research pertinent to the specific studies undertaken in Work Unit METHOD is discussed in order to bring into focus the particular experimental hypotheses to be investigated.

Programed Instruction: Value as Theory and Technique

Because of its potential for applying Skinnerian experimental techniques to the area of education, programed instruction has been viewed as a panacea for problems of teaching; it is not that. On the other hand, programed instruction has also been termed merely another teaching aid; it is not that either. It is a medium of instruction that can readily provide for the application of psychological principles to teaching. It can also provide a testing ground for uncovering laws of learning, using as a laboratory the highly controlled educational environment that PI makes possible.

Ironically, the advances in programed instruction to date have come not from applications of theoretical developments but rather from a technique incidental to programed instruction per se—that of task analysis, which has existed in the field of military and industrial psychology for many years. With this tool a curriculum developer who is planning instruction is directed to a focus on the behavioral end-products of training (or education). There is no doubt that this analytic tool has been helpful in improving curricula through the development of programed instruction; however, it provides marked improvement in conventional teaching as well. Curriculum improvement deriving from this technique is best considered an engineering improvement, to distinguish it from advances that might be due to the development of learning theory.

The advent of programed instruction has also resulted in a focus upon the individual student. This represents an administrative breakthrough rather than a development from the psychology of individual differences. For years teachers have been aware of the importance of a student's individual characteristics in instruction, but crowded classrooms and the need to serve the "average" student have interfered with teachers' attempts to take advantage of individual capacities. The teaching machine and the programed booklet have provided a distinct step forward in this regard.

Educational research literature is rife with studies showing no differences between the so-called "conventional" and the programed instructional technique (cf., Schramm, 1). Usually, the data indicate that one can teach the same amount in less time using programed instruction than using conventional instruction, or else the development of proper behavioral objectives for a course results in improvement for both programed instruction and conventional teaching.

Existing courses in programed instructional format represent constellations of learning factors such as frequency of reinforcement, amount of information per presentation unit, and activity of the student. No PI product truly represents a particular learning theory. The intent in the present research has been to try
to examine some of the training factors (e.g., amount of information given prior to requiring a response) without attempting to label the program according to whether it is related to one or another or some combination of PI viewpoints.

To date, simple devices (the programmed booklet and small teaching machines) have been the primary vehicles for PI. Such devices, in turn, have been quite adaptable to the techniques of operant conditioning—learning a response by being rewarded as a "consequence" of the response. These techniques (developed mostly with rats and pigeons) for increasing the likelihood of a response have become more or less the modus operandi of the curriculum developer in the field of programed instruction. They include the training procedure of successive approximation (with minimal, if any, errors), particular reinforcement schedules, immediate feedback, and active participation by the student.

Cook and associates (e.g., 2) and Angell and Lumsdaine (3), and others as well, have found that prompting (giving the student specific information before asking him to respond) is significantly more effective than confirmation (giving him correct information after he responds) for serial learning. Gagné and Brown (4), in a study dealing with conceptual material, compared several combinations of prompting and confirmation (although they did not use those terms) in the learning of principles for generating number series. Their guided discovery (confirmation) group, medium difficulty condition, appeared to be most effective, while the rule and example (prompting) condition, low difficulty level, was least effective.

Thus, the results obtained by Angell and Lumsdaine suggest that the subjects should be given substantial information before being required to respond, while the findings of Gagné and Brown suggest that subjects should be required to discover the answers themselves. The precise factor that caused these experimental differences cannot be determined because of the differences in the research paradigms used and because of many other factors that were not comparable across the experiments or between conditions within an experiment.

Effects of Errors on Learning

The use of operant conditioning techniques, together with an insistence on a low error rate during learning have combined to produce PI materials characterized by low difficulty. Low error rate requires easy-to-understand material, and the operant maxim of high student participation encourages the breaking of the material into small (hence, low error rate) segments, with a student response after each segment.

Whether a low rate of error is desirable during learning may be questioned on the basis of data developed in studies dealing with level of aspiration. It has been found, for instance, that an individual performs to his maximum when the learning task is neither too easy (low error rate) nor too hard (high error rate). If the task is too easy the student refuses to set a level of aspiration, or personal goal, and will not perform the task, through lack of interest (inattentiveness) or lack of motivation. On the other hand, if the task is too difficult the student will refuse to try, because of frustration (Lewin, 5).

The emphasis on low error rates is based, for the most part, on studies of lower organisms (rats and pigeons) and, thereby, of simple types of learning. Human learning, particularly in education, tends to be much more complex—primarily in terms of concept formation and problem solving.

The focus of the present study with respect to error rate during learning has been to manipulate certain stimulus conditions that might produce greater or smaller error rate in a conceptual, hierarchically ordered setting. It was
expected that, unlike the effects obtained in rather simple discrimination learning, those conditions leading to greater difficulty during training (e.g., few hints) might well result in better overall criterion performance and retention.

Range of Instructional Content

In simple operant learning, the organism is taught to discriminate, or respond differently to different stimuli—for example, to perform in one way in the presence of A and a different way in the presence of B. In most types of human learning, however, the student not only must discriminate A from B, but must also learn that A and B each are to be treated as belonging to classes of As and Bs. For example, a child learns that the fork in his hand is but an example of forks in general, all of which have common properties; human beings tend to make such inductive leaps even if not told to.

Even in supposed rote learning, subjects structure the stimuli into groups, as shown by results of a number of studies in paired-associate learning (Battig, 6). Battig has proposed an interference-facilitation theory of learning—that high intra-task interference promotes inter-task facilitation. This view is consistent with the motivational ideas expressed above. That is, the dual assumption that error rate should be minimal during the teaching-learning process and that human learning is analogous to a simple discrimination problem is open to question, on the grounds of lowered motivation and of oversimplification.

In general terms, most human learning requires that the student develop transformational behavior with respect to given stimuli. These transformations can be called mediating responses or hypotheses, which exist, as it were, in the student's "head" and allow him to apply his learning from one situation to another.

The wholesale adoption of operant conditioning principles can be viewed in another way. Skinner (9) has criticized the use in textbooks of materials he termed irrelevant—materials such as analogies and examples, which might confuse the student. Such materials are often included to challenge the student's thinking or to make the topic more interesting; similarly, an instructor, in translating a book and other course materials into analogies and examples, tries to make the student "understand" rather than memorize concepts. What is being accomplished in the teaching-learning process is the establishment of connections between a delimited set of stimulus elements and a delimited set of response elements. Instead of covering only narrowly defined "relevant" material, the instructor or textbook writer who makes use of materials such as analogies may teach a much more complex set of relations.

Three classes of stimulus elements can be considered: irrelevant, correct, and omitted. The same three classes exist for the response, but there is also an additional class, the incorrect response. The outcome of training experience may be viewed as a set of incorrect stimulus-response (S-R) tendencies competing with correct ones.

One prevalent approach to programed instruction limits content to only those stimuli that are relevant, and tries to limit responses, as much as is feasible only to those that are correct. Although this means that no competing response tendencies are established, the range of S-R coverage is considerably narrowed. In other words, a limited sample of appropriate elements becomes connected but the coverage is incomplete in terms of the total stimulus and response populations. The problem of defining what is "relevant" in instruction, to develop the appropriate concepts and to allow the person to discriminate "correct" from
"incorrect," is a crucial theoretical and practical problem for programmed instruction, especially for that dealing with problem-solving behavior.

Once one considers a broad range of instructional content, and departs from operant conditioning concepts, new research questions unfold. One such question derives from Harlow's error factor theory (10). In learning set research, Harlow (11) inferred that the increased conceptual proficiency shown by subjects stemmed from eliminating erroneous hypotheses during training. His conclusion, and the essence of his theory, suggests that encouraging certain kinds of errors (i.e., incorrect S-Rs) during learning could result in more effective elimination of erroneous hypotheses.

Thus while concepts are being formed (as is the case in most education), variety of content probably facilitates the elimination of erroneous hypotheses during training. It also allows the individual student to abstract the appropriate mediating skills and responses more effectively than he could in a homogeneous context. The individual can then use these mediating skills and responses to generalize to other stimulus contexts after training.

Knowing and Using: Levels of Learning

The distinction between rote and problem-solving learning is made as follows. Rote learning involves connecting specific stimuli to specific responses during training, and the test of success in training is simply whether the connections have been made. Problem-solving learning, on the other hand, involves training the student to abstract a common (identity) response to a class of stimuli; while a test of success in such training consists of knowing (being able to name, state, or describe a concept), the main test rests in being able to use the concept effectively in solving problems (cf., Kendler, 12, and Gagné, 13).

A more detailed analysis of problem-solving learning heightens the difference between it and rote learning. For problem-solving learning, distinction is usefully made between (a) responding during training, (b) abstracting concepts from responses, (c) knowing a concept, (d) being able to use the concept.

Making this distinction is not new. For years, Gestalt psychologists have delivered polemics (and included some demonstrations of principle learning) on the distinction between rote and conceptual learning. The thrust of Katona's work on learning number series is another example. However, only recently has a study by Smith, Jones, and Thomas (14) clearly separated the two types of responding. Their experiment directly compared rote and conceptual learning where number of stimuli per response was varied from one to four. (Rote learning involved random grouping of stimuli, whereas conceptual organization included a meaningful link among stimuli within each grouping.) Increasing the number of stimuli per response improved concept learning but not rote learning, thus showing two distinct learning processes.

Added to the identity response in most human learning are the solving responses; that is, the identity response is used in development strategies to put concepts together in order to perform some task. Will the optimal techniques for teaching concept formation per se (identity responding) be the same as those for teaching problem solving? Gagné (13, p. 312) suggests that they may indeed be different forms (or at least levels) of learning. Concept learning consists of "establishment of mediating response to stimuli which differ from each other physically ('classifying')." Problem solving, he feels, is the establishment of a process which 'combines' two or more previously learned rules in a 'higher-order rule'." A study by Gagné and Smith (15) suggests that the verbalization of principles takes on importance as the problem becomes more complex.
The distinction between concepts and problem solving can be illustrated in electronics troubleshooting. The student must understand the concept of a schematic diagram which represents the wires, connectors, and other parts. He must know the color coding system for resistors and the system of naming pins on electronic vacuum tubes, as well as how one reads a multimeter. Superimposed on all of these is another requirement: the student must determine the likelihood that following a given path of potential defects will be successful in troubleshooting the overall system. The effects of each factor may be taught. So might the mechanical responses or a total task in isolation. Given the learning and isolated practice, the student may be asked to actually troubleshoot a malfunctioning piece of equipment; this activity comprises applying the complex of concepts to solve a problem.

Viewing the troubleshooting illustration from a theoretical point of view provides a more technical analysis. The student might learn (from making certain kinds of controlled errors during training) to recognize the effects of various kinds of errors in the system, and to abstract from his training experience an understanding (conceptual set of responses) for the task. Having learned the proper identity responses (concepts), the student must put these together into a strategy to perform the task of troubleshooting successfully (the problem-solving aspect of the process). Here, it seems, is a meaningful distinction between understanding (concepts) of a class of stimuli and their use (problem solving) in a series of acts required to turn out a useful solution.

**RESEARCH OBJECTIVES**

**Background for the Experimental Hypotheses**

Unfortunately, much of the research that has been done concerning the effects of learning factors in programed instruction has been conducted with paired associates or serial learning. Little has been done where experimental treatments have been manipulated for hierarchically organized conceptual discourse. Yet this type of discourse—meaningful course content—is precisely the medium for most, if not all, programed instructional applications. Paired-associate experiments generally require the subject to make a series of rote responses, and his learning is measured by his ability to give back these rote responses. Conceptual learning, however, requires the subject to abstract mediating responses, and learning is measured by his ability to apply these mediating skills to a variety of different situations.

As indicated earlier, the present study was undertaken to examine some of the psychological factors in programed instruction. The review of previous research led to selection of the following factors for exploration:

First, the value of a rule-giving or naming type of verbalization response was investigated. This factor deals with the distinction between rote learning and concept formation, and was intended to explore the efficacy of repeating or naming concepts in training, for the purpose of applying learning to problem-solving situations. Many current programed instruction programs are parallel to paired-associate learning situations in that they seem to emphasize reproducing material presented. Yet the program developers seem to be interested in teaching concepts (mediating skills). Does verbalizing a rule aid or hinder learning to use the rule in problem solving?

1) This view of such a teaching problem has recently been implicitly expressed by Cronbach (16) in an excellent review of discovery experiments.

2) A recent study by Hickey and Newton (17) is a welcomed attempt. Also, for an excellent discussion of problems in doing PI research on conceptual material, see Trab (18).
Second, the principle of minimal error rate as applied to learning complex, meaningful materials was questioned. Level of aspiration studies have shown that a certain amount of difficulty (e.g., error) during learning will lead to maximum motivation (and implicitly, high scores on a criterion test).

Third, the importance of varieties of examples in such human learning was examined to see whether this principle generalized from simpler concept (learning set) studies, in which variety of examples has been found to foster concept formation. It would be expected to aid subjects to generalize from training content to operational application.

Fourth, attention was given to another pair of factors of interest in programmed instruction research—"prompting" (providing the student specific information prior to asking him to respond) and "confirmation" (giving him correct information after he responds). For a meaningful comparison of prompting and confirmation, the sole element manipulated should be the amount of information given to the subject prior to requiring him to respond; whatever is not given to him then should be given after he responds to make the total information each subject receives comparable for the confirmation and prompting conditions.

Experimental Treatments

In summary, the background for the METHOD II research rested on the need to study, using meaningful course content, those factors that seem most relevant to learning how to use rules and principles. The first experiment (1A) examined the influence of prompting vs. confirmation, and of alternate ways of verbalizing rules. The results of this experiment were taken into consideration in further exploration of the same variables in the second experiment (1B). In the third experiment (2) other aspects of these variables were explored, and, through work with a variety of practice problems, the development of connections between conceptual stimuli and mediating responses was considered.

With the training content (writing a computer program) put in the form of programmed instruction, experiments were conducted with the following factors:

1. Amount of information to be given to trainees prior to requiring responses (degrees of prompting vs. degrees of confirmation) (Experiments 1A, 1B, and 2). This factor was judged especially valuable to study since its influence is felt in the smallest unit of a program; namely, the frame itself.

2. Value of written verbalization of rules during training (Experiments 1A and 1B). Verbalization of rules has been generally used in construction of programs to indicate understanding by the student of the material in the program. In this study, interest lay in the relationship between the student's ability to verbalize rules and principles and his use of them in problem-solving performance.

3. Value of variety of context for practice problems during the training on problem solving (Experiment 2). The complexity in most learning demanded consideration of broad connections between conceptual stimuli and mediating responses. Variety of verbal contexts for the practical problems given during training provides the setting for establishing broad connections. Minimal variation of problem context should encourage only simple connections.

4. The effects on a problem-solving criterion of different amounts of error during training, examined throughout the series of experiments.

As the final step in the research effort, an attempt was made to incorporate major findings from the experimental work into a revised self-instructional course in basic computer programming. The desired by-product was a usable military course of instruction.
Chapter 2

RESEARCH PROCEDURE

APPROACH

The major research activities—a literature review, program development, experimentation, and course revision—may be summarized as follows:

1. The scientific literature on learning principles and programmed instruction was reviewed as described in the preceding chapter, to provide a basis for selecting concepts and techniques for experimental study. Selection was based on importance for learning in a military training context, feasibility of manipulation for study, and potential for the advancement of training technology.

2. As the first step in developing the instructional program, the researchers attended computer programmer classes at the U.S. Army Signal School, Fort Monmouth, New Jersey and at IBM. They then interviewed supervisory and computer instructor personnel, systems analysts, and computer programmers at Fort Huachuca, New Mexico. The nature of the tasks performed by the programmer was analyzed with the assistance of operational programmers. Portions of the Automatic Data Processing Specialist (MOS 745.1) programming course were selected for experimentation. Final content was developed jointly by instructors from the Signal School and research personnel.

3. The materials selected were divided into five parts of increasing complexity. Training content was translated into programed instruction format and then prepared to reflect varying degrees of the experimental variables. Three experiments were conducted; their major characteristics are summarized below and in Figure 1. In all three experiments, the final criterion and retention measures were performance tests representing the types of problems typically encountered on the job by computer programmers with a comparable amount and kind of training. The experiments were:

   **Experiment 1A**—The prompting/confirmation and verbalization variables were first studied during a three-day training and test period in 1962, using 60 students from a local high school as subjects. Parts I and II of the five-part course were used as subject matter.

   **Experiment 1B**—This experiment was the first part of a larger study conducted between September 1964 and January 1965, and initially involved 800 student volunteers from local high schools. The variables were the same prompting/confirmation conditions and part of the verbalization condition used in Experiment 1A, and the materials were also the same. Instruction was given once a week during the first part of a 10-week time frame which included Experiment 2.

   **Experiment 2**—This portion of the larger study followed Experiment 1B in time and was applied in weekly instruction to the more complex course content of Parts III, IV, and V. Students who had completed the instruction in Experiment 1B were the subjects. The prompting/confirmation variable was expanded and a variety-of-practice variable was introduced.

"Under the current MOS structure, the ADPS Programming Specialist is MOS 74F."
### Approach Used in the Method II Experiments

<table>
<thead>
<tr>
<th>Experiment</th>
<th>N</th>
<th>Instructional Materials</th>
<th>Factors Studied</th>
<th>Criteria</th>
<th>Time Sequence</th>
</tr>
</thead>
<tbody>
<tr>
<td>1A</td>
<td>60</td>
<td>Part I</td>
<td>Verbalization of rules and principles</td>
<td>Part I-Criterion performance test at end of instruction</td>
<td>Daily Sessions</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Part II</td>
<td>a. Writing the Rule (Rules Group)</td>
<td>Criterion tests on writing and naming rules at end of instruction</td>
<td>3 days</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>b. Naming the Rule (Naming Group)</td>
<td>Retention performance test the next day</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>c. Neither (CP-Only Group)</td>
<td>Error rates during training</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Prompting/Confirmation</td>
<td>Part II-Same as Part I</td>
<td></td>
</tr>
<tr>
<td></td>
<td>345</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1B</td>
<td>805</td>
<td>Part I</td>
<td>Verbalization</td>
<td>Same as in experiment 1A except that the retention test for each Part</td>
<td>Weekly Sessions</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Part II</td>
<td>a. Naming the Rule (Naming Group)</td>
<td>was given one week after instruction</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>b. Not Naming the Rule (No-Naming Group)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Prompting/Confirmation</td>
<td>In addition, criterion performance test at end of instruction for each</td>
<td>10 weeks</td>
</tr>
<tr>
<td>2</td>
<td>345</td>
<td>Part III</td>
<td>Exploration of various degrees of prompting and confirmation</td>
<td>Part.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Part IV</td>
<td>Variety of Practice</td>
<td>A final retention test was given four weeks after the close of instruction</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Part V</td>
<td>a. Similar practice (No-Variety Group)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>b. Varied practice (Variety Group)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Figure 1**

(4) A final version of the course in programmed instruction format was developed by applying the principal research findings, and a pilot test was conducted, using 13 students as subjects.

**OVERALL DESCRIPTION OF THE PROGRAMMED COURSE**

The experimental programmed course was directed toward the level of high school seniors and first-year college students. This level was chosen because the content material was originally drawn from portions of the Army training course for the ADPS Programming Specialist, at the U.S. Army Signal School, in which the background of the Army trainees corresponds to a high school education.

The aim of the experimental course was to provide understanding of fundamental computer programming concepts and, more important, to produce proficiency in writing elementary computer programs. From the very beginning of the course, its entire context was oriented toward the writing of computer programs. That is, a concept was introduced, then a problem incorporating the concept was presented, and the student programmed the problem. The practice problems and the problems used in the criterion and retention tests were chosen from actual ADP job situations.
The repertoire of primary programming commands and the symbolic language in which the computer programs were written were chosen from material which had been used by the Army to teach trainees to program the MOBIDIC computer. The language is the FIELDATA Symbolic Language which, although representing a set of symbols interpretable by the MOBIDIC, is sufficiently general in form that it largely applies to almost any other computer and to the English language (the addresses).

As nearly as possible, the goals of all subjects were made comparable by orienting them with an overview of the concepts of computer programming in an Introduction to the course. Specific attention was paid to the concepts of command, address, the accumulator, memory locations, input, and output. Also included were a brief description of how a computer functions, and some sample mnemonics as they are used in computer commands. The coverage of these topics was interspersed with periodic review and with questions which students answered to themselves. The student was instructed to continue reviewing the material preceding each of the sets of questions until he could answer the material to his own satisfaction. As the last item in the introductory material, the student worked through a short sample program.

The five parts of the experimental course proceeded from the simple to the complex. Parts I and II dealt with primary programming; the student was introduced to storage locations, the concept of a central work area, the movement of numbers from place to place, and simple arithmetic operations, along with an introduction to elements of a symbolic data language. Part III covered basic looping concepts, including general transfer commands, counting the loops, leaving the loops, and program preparation. Parts IV and V dealt with data processing, covering address modification and address arithmetic (effective addressing), sorting and counting data into various categories, and multiple address modification.

The programmed instruction materials were all prepared in the form of linear programs so that a student moved step-by-step straight through the course. It would not be correct to characterize the steps as frames, however, because the steps—rather than single sentences or two sentences at a time—constituted conceptual or functional units. Thus, there could have been as many as two or three paragraphs given to the student prior to questioning him on the content.

Details on the course materials and the variations for the experimental treatments are presented in the descriptions of the individual experiments. Content and presentation of the course are illustrated in samples in Appendix A.

The criterion tests at the end of each part of the course consisted of actual computer programming problems submitted by a programmer group from Fort Huachuca and by programming instructors from the Signal School. Where necessary, problems were simplified by removing aspects that would require techniques beyond the scope of the course.

EXPERIMENT 1A

Design

A 2x3 factorial design was used in Experiment 1A (illustrated schematically in Figure 2). Six independent groups of subjects in a PI environment learned to write increasingly complex computer programs (CPs). One-third of the subjects periodically wrote out the content of the rules used to guide the writing of computer programs (Rules Group), one-third periodically wrote down the names of
Design for Experiment 1A

<table>
<thead>
<tr>
<th>Training Variation</th>
<th>Writes Computer Program and Rules</th>
<th>Writes Computer Program and Names of Rules</th>
<th>Writes Only Computer Program</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Computer Program</td>
<td>Computer Program</td>
<td>Computer Program</td>
</tr>
<tr>
<td></td>
<td>Rules</td>
<td>Names of Rules</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Answer given before student response</td>
<td>Answer given before student response</td>
<td>Answer given before student response</td>
</tr>
<tr>
<td></td>
<td>Computer Program</td>
<td>Computer Program</td>
<td>Computer Program</td>
</tr>
<tr>
<td></td>
<td>Rules</td>
<td>Names of Rules</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Answer given after student response</td>
<td>Answer given after student response</td>
<td>Answer given after student response</td>
</tr>
</tbody>
</table>

Figure 2

the rules (Naming Group), and one-third wrote CPs without any verbalization of the rules (CP-Only Group). Also during learning, one-half of the subjects were required to write their answers after being given explicit information needed in the response (prompting), and one-half were required to write their answers prior to receiving the information (confirmation). During learning, error rates were obtained on CP-writing for all groups and on rules and naming for the appropriate groups.

Treatments composed of various combinations of the training conditions were administered during the PI training, and their effects were evaluated on criterion and retention tests given at the end of each of the two parts of the instruction.

Subjects

The subjects were 60 volunteer high school students (juniors and seniors), who had been informed that they were to be paid between $1.50 and $2.00 per hour, depending upon the proficiency they exhibited in learning. They were assigned at random to one of the six training conditions. A combination of scores from the verbal and clerical tests of the Army Classification Battery (ACB) was used to measure intelligence level for the detailed evaluation of results.1

Training Materials

The training materials used in this experiment were Parts I and II, covering an introduction to symbolic language for computer programming and primary programming commands of a business-type digital computer. The learning task was writing computer programs of increasing complexity, with the additional requirements imposed by the experimental treatments. The treatments were applied as each new concept was introduced along with the attendant requirement of writing a computer program.

A different programed instructional booklet was used by each of the six groups of subjects (Figure 2), in accordance with the training conditions assigned to that group. The booklets used by the Rules and Naming (or mnemonics) Groups

1The intelligence measure was the same as that applied by the Army for entrance into the ADPS programming course.
consisted of 90 pages, including the criterion tests; booklets used by the CP-Only groups had half that number of pages. The difference in treatment between the prompting and confirmation conditions did not affect the size of the booklets.

For all groups, the first step was the presentation of a concept. The next step varied according to the experimental treatment. The following sample rule can be used to illustrate the various treatments:

The CIA SOCSEC instruction clears any material already in the accumulator and copies the number from location SOCSEC into it.

After the concept had been presented, the portion underlined above was given to the subjects in the Rules Groups, who were to fill in the rest; the portion not underlined was given to the subjects in the Naming Groups and they filled in the part underlined. Both groups were then given a problem illustrating the concept and they wrote a computer program on the problem. The CP-Only Group went directly from the presentation of the concept to the statement of the problem.

The prompting/confirmation variable was added to the above treatments by having subjects work on only one page at a time. The Prompting Groups saw the entire sentence first; the subjects in those groups turned the page and completed the blank before working on the computer programming problem. The subjects in the Confirmation Groups completed the blank, then turned the page and viewed the entire sentence after working on the problem.

The booklets included criterion tests at the end of each part of the course. As a secondary part of the criterion tests, the ability of all subjects to write the rules and the names of the rules used in writing the CPs was measured.

Procedure

On the first day students were given Part I, the section concerned with primary programming commands, and a criterion test for that material. On the second day they were first given a retention test (for Part I) consisting of four problems to be programmed, which all subjects finished within 30 minutes. Immediately following the retention test, they were given Part II of the course, on more complex computer programs, and the criterion test for that part. On the third day, they were given Retention Test II, consisting of four programming problems covering all the course material, followed by the ACB intelligence measure.

The students were allowed a maximum of four hours on each of the two days of training, but only one or two students required that much time on either day. Each student’s booklets were checked at the end of his working day to ensure that he was actually working with the material. All students appeared highly motivated to perform; many stayed after hours to ask further questions about the course work. (No substantive questions were answered in order not to contaminate the experimental treatments.)

EXPERIMENTS 1B AND 2

Design

Taken together, Experiments 1B and 2 covered all five parts into which the course was divided. The first two parts (used in Experiment 1B) were identical in content to that of Experiment 1A; they provided subjects with the background necessary for the final three parts (Experiment 2), which dealt with looping principles. Each of the five parts had its own criterion test.
All variables in the two experiments were administered factorially during training. Experiment 1B involved the same conditions as Experiment 1A, except that the Rules Group was omitted. That is, in Experiment 1B comparisons were made between (a) prompting and confirmation; and (b) writing the names of rules and writing computer programs, and simply writing the computer programs.

After completing Part II of Experiment 1B, students were reassigned randomly to treatment groups for Experiment 2, which included three variables:

1. 0, 50, or 100% confirmation.
2. 0, 33, 67, 100%, or progressive (67, 33, 0) prompting.
3. No-variety vs. variety conditions on practice problems.

The design of Experiment 2 is an incomplete three-factor study, composed of 29 cells (see Figure 3). The practice problems were given in sets of three instead of singly. The confirmation variable was administered on a more molar level than that of the prompting variable, being applied across sets of problems; that is, either the entire set of three problems received confirmation or it did not, depending upon the confirmation applied. Both the prompting conditions and the variety vs. no-variety treatments were applied within the sets of three problems. Furthermore, the progressive prompting condition was administered as a diminishing prompt within each set of three problems; thus, the first problem received two-thirds prompting, the second one-third, and the third no prompting. A sample application of treatments is shown in Appendix A.

In addition, an attempt was made to obtain data on the relationship between the stage of training at which mnemonics are introduced and the improvement in criterion performance. This was done by continuing the use of mnemonics through the course for three additional groups of students.

---

Figure 3

Design for Experiment 2

<table>
<thead>
<tr>
<th>Percent of Confirmation</th>
<th>Percent of Prompting</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>33</td>
</tr>
<tr>
<td>0</td>
<td>67</td>
</tr>
<tr>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>50</td>
<td></td>
</tr>
<tr>
<td>100</td>
<td></td>
</tr>
<tr>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>

Added Verbalization treatments in the Same Variety condition:
- Naming: 100% prompting and 0% confirmation
- No-Naming: 100% prompting and 0% confirmation

The four cells which would have combined 100% or 50% Confirmation with 100% Prompting (either Variety or No-Variety) were considered somewhat redundant and were to be omitted from the design.

Three cells were added to the design to extend the comparisons of Naming vs. No-Naming and Confirmation vs. Prompting to more complex materials. The cells were: 100% Confirmation plus Naming, 100% Prompting plus Naming, and 100% Prompting with the Naming context provided without any response requirements. A clerical error during preparation of the booklets resulted in 0% Confirmation - 100% Prompting (Variety and No-Variety) cells omitted instead of 100% Confirmation - 100% Prompting cells. Thus, Naming comparisons in Experiment 2 were quite limited.
Groups of 29 subjects or multiples thereof worked in a single experimental room with each student of a set of 29 in a different experimental treatment from those of his classmates. This design effectively eliminated experimenter differences and socio-economic variability between school systems, and provided generally equivalent levels across cells. As a check on ability levels, the CL portion of the Army Classification Battery was administered to the students.

Subjects

The original plan was to use Army subjects at the U.S. Army Signal School for Experiments 1B and 2. Because of difficulties in obtaining an adequate sample of Army subjects there, however, it was necessary to use a civilian population for the experimentation. Subjects were male volunteers recruited, without compensation, from the junior and senior grades of high schools in the metropolitan Washington, D.C., area. The schools participating represented all local area school systems, thus ensuring a sizable range in socio-economic status of the pupils attending. No systematic attempt was made, however, to take stratified samples either within or across schools on the basis of socio-economic status. The school systems, and the number of participating schools per system, were: Alexandria, 1; Arlington, 1; District of Columbia, 3; Fairfax County, 2; Falls Church, 1; Montgomery County, 4; and Prince Georges County, 2.

The number of volunteer subjects beginning the course was 805; the drop-out rate was high (57%), with the number of subjects who completed the entire course being 345. Approximately 75% of the attrition occurred prior to criterion testing for Part III, 21% prior to testing for Part IV, and 4% during Part V. The analyses of the experimental effects, reported in the next chapter, were made on the basis of the subjects who completed the entire course.

Training Materials

Parts I and II were contained in one booklet, the content of which was identical to that used in Experiment 1A. Parts III, IV, and V were also contained in a single booklet (186 pages). Part III introduced the technique of looping, Part IV dealt with address modification, and Part V had to do with address arithmetic (a more advanced technique of addressing).

The performance criterion tests were administered after the students completed each part of the program. A similar test was administered four weeks after the course was completed, as a measure of retention. Upon completion of each criterion test, the students were given a Level-of-Aspiration (LOA) Scale, divided into intervals of 5% (see Appendix B). They were asked to make two judgments: (a) how well they thought they had performed on the criterion test they had just taken, and (b) how well they thought they would perform on the next criterion test. These scales were used in computing discrepancy scores, obtained by subtracting the student's actual performance on the next test from his LOA or expected score. Such scores are traditionally used to obtain an indication of the degree of realism with which a student progresses through a course; for example, a small positive discrepancy score (expectation slightly above performance) exemplifies the realistic, positively adjusted student.

Procedures

Students were trained in a classroom at their own or a nearby high school after school hours (afternoon or evening sessions) or on Saturday. They attended 1

No ACB test data were available for roughly one-fifth of the subjects.
one three-hour session a week. It should be noted that so long a time between
sessions was not intended when the experimental course was constructed because
the delay allows more time for forgetting. Daily sessions would be the most
desirable schedule for the self-instructional course.

Halfway through the three-hour session the students were given a 10 to 15
minute break. Seats were spaced as far apart as room size would allow. The
ratio of proctors to the students was approximately 1:15. The proctors insured
that the students worked independently and tried to prevent review of materials.

Proctors were instructed to assist the students only with procedural or
"structural" questions. (A "structural" question would be one about a suspected
misprint or, in rare cases, a request to define an unfamiliar Army term such
as KP.) Proctors did not answer substantive questions, those pertaining to
understanding the content being taught. In response to those questions, the proc-
tors simply told the students to do the best they could.

Before the course began, the students were given a brief outline along with
a cautionary statement regarding the need for independent work and regular
attendance. Students were informed that they would be given a final test, cover-
ing the complete experimental course, approximately four weeks after they
completed the course, and that they would receive certifications of completion
after the final test.
Chapter 3

RESULTS

Taken together, the three experiments generated a staggering amount of data. To provide a framework for viewing the results, without presenting an overwhelming amount of detail, it may be well to review the basic questions that were being asked. These questions took the form, "What is the effect of X on Y?" For example, "What is the effect of naming rules during training on ability to solve criterion problems?" The "Xs" and "Ys" are listed below, with an indication in parentheses of the experiment in which they were used:

<table>
<thead>
<tr>
<th>Effects of . . .</th>
<th>As Measured by . . .</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level of prompting (all)</td>
<td>Errors during training (all)</td>
</tr>
<tr>
<td>Level of confirmation (all)</td>
<td>Errors on criterion tests:</td>
</tr>
<tr>
<td></td>
<td>Problem solving (all)</td>
</tr>
<tr>
<td>Verbalization in training:</td>
<td>Writing rules (1A)</td>
</tr>
<tr>
<td>Writing rules (1A)</td>
<td>Naming rules (1A and 1B)</td>
</tr>
<tr>
<td>Naming rules (1A and 1B)</td>
<td>Errors on retention tests (all)</td>
</tr>
<tr>
<td>Variety of practice (2)</td>
<td>Time to complete (1A)</td>
</tr>
<tr>
<td>Intelligence (all)</td>
<td>Level of aspiration (1B and 2)</td>
</tr>
<tr>
<td>Combinations of the above</td>
<td>Combinations of the above</td>
</tr>
</tbody>
</table>

Results are presented separately for each experiment. After the evidence of learning has been presented, findings relative to the various treatments (left-hand column, above) and the effects of each treatment on the various measures (right-hand column, above) are discussed.

EXPERIMENT 1A

Treatments studied were prompting/confirmation and verbalization. Instruction was divided into two parts (I and II). After instruction, proficiency measures were taken in the form of criterion tests (I and II) and retention tests (I and II). During instruction, measures were taken in each phase in the form of errors during training and time to complete.

Evidence for Learning. On the criterion test after Part I, nearly two-thirds of the students scored 80% or more correct, and more than a third scored 90% or higher. Results on Criterion Test II were comparable. Mean criterion and retention test scores are given in Table 1.

Time to Complete. For both Parts I and II, there were no significant differences between the prompting and confirmation treatments as to the length of time subjects took to complete the course. The three Verbalization Groups did differ significantly, however, on both parts. In Part I, the Rules Group was slower than the other two verbalization groups. In Part II, the Naming Group

1Unless otherwise indicated, the statistical test used was the Analysis of Variance.
Table 1
Mean Criterion and Retention Test Scores by Treatments: Experiment IA
(N = 60)

<table>
<thead>
<tr>
<th>Measure</th>
<th>Mean</th>
<th>Summary Mean</th>
<th>Percent Correct</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rules + CP</td>
<td>Naming + CP</td>
<td>CP-Only Group</td>
<td>Rules + CP</td>
</tr>
<tr>
<td></td>
<td>Group</td>
<td>Group</td>
<td></td>
<td>Group</td>
</tr>
<tr>
<td>Criterion Test I b</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prompting Group</td>
<td>39</td>
<td>43</td>
<td>47</td>
<td>43</td>
</tr>
<tr>
<td>Confirmation Group</td>
<td>13</td>
<td>19</td>
<td>44</td>
<td>45</td>
</tr>
<tr>
<td>Summary Mean</td>
<td>11</td>
<td>16</td>
<td>16</td>
<td>16</td>
</tr>
<tr>
<td>% Correct</td>
<td>79</td>
<td>88</td>
<td>88</td>
<td>88</td>
</tr>
<tr>
<td>Criterion Test II b</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prompting Group</td>
<td>66</td>
<td>66</td>
<td>75</td>
<td>69</td>
</tr>
<tr>
<td>Confirmation Group</td>
<td>69</td>
<td>79</td>
<td>77</td>
<td>75</td>
</tr>
<tr>
<td>Summary Mean</td>
<td>68</td>
<td>73</td>
<td>76</td>
<td>75</td>
</tr>
<tr>
<td>% Correct</td>
<td>76</td>
<td>82</td>
<td>85</td>
<td>85</td>
</tr>
<tr>
<td>Retention Test I (75)</td>
<td>76</td>
<td>87</td>
<td>84</td>
<td>82</td>
</tr>
<tr>
<td>Retention Test II (75)</td>
<td>70</td>
<td>80</td>
<td>68</td>
<td>73</td>
</tr>
</tbody>
</table>

*For Criterion Test I, the groups differed significantly, p < .01 (Hartley's test, X^2(5) = 13.52). For Criterion Test II, the groups differed significantly, p < .01 (Hartley's test, X^2(5) = 16.41). For Retention Test I and Retention Test II, raw scores of the groups did not differ significantly.

Maximum possible score: 52.
Maximum possible score: 89.

was faster than the other two groups. The mean learning times for the verbalization conditions are shown in Table 2.

As can be noted in Tables 1 and 2, achievement was positively related to speed of learning. To provide an indication of the efficiency of each treatment, a time-weighted score for each individual was computed by dividing the student's criterion (or retention) test score by his time to complete the course. These scores, which reflected the amount learned per unit of time, were used in the subsequent analyses of data for the various treatments.

Prompting and Confirmation Effects. During learning, as measured by error rates in computer programming, the Prompting Group scored significantly higher than the Confirmation Group. However, the groups did not differ significantly on the criterion tests (including the tests on writing and naming rules) or the retention tests. If anything, the Confirmation Group was superior, as shown in Table 3.

Verbalization Effects. Students required to write out the rules of computer programming during training did not do as well on the criterion tests as students in the other verbalization groups. The Rules Group also had the highest spread of scores on the criterion tests, as shown in Table 1. (Later supplementary analyses indicated that this effect was particularly evident in students of lower intelligence.)
Table 3

Mean Time-Weighted Criterion and Retention Test Scores for Prompting/Confirmation Variable: Experiment 1A

<table>
<thead>
<tr>
<th>Measure</th>
<th>Criterion Test I</th>
<th>Criterion Test II</th>
<th>Retention Test I</th>
<th>Retention Test II</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Prompting</td>
<td>Confirmation</td>
<td>Prompting</td>
<td>Confirmation</td>
</tr>
<tr>
<td>CP-Writing</td>
<td>368</td>
<td>389</td>
<td>719</td>
<td>560</td>
</tr>
<tr>
<td>Naming the Rules</td>
<td>34</td>
<td>38</td>
<td>49</td>
<td>16</td>
</tr>
<tr>
<td>Writing the Rules</td>
<td>18</td>
<td>24</td>
<td>21</td>
<td>19</td>
</tr>
</tbody>
</table>

Note: Score Achievement Time (Min.) × 1,000.

The mean score of the Rules Group on tests of computer programming (Criterion and Retention Tests I and II) was consistently lower than the mean of the Naming Group or the CP-Only Group (Table 4). Two-group comparisons (19) indicated that this difference was statistically significant in all four cases.

Table 4

Mean Time-Weighted Criterion and Retention Test Scores for Verbalization Variable: Experiment 1A

<table>
<thead>
<tr>
<th>Measure</th>
<th>Criterion Test I</th>
<th>Criterion Test II</th>
<th>Retention Test I</th>
<th>Retention Test II</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rules + CP</td>
<td>Naming + CP</td>
<td>CP-Only</td>
<td>Rules + CP</td>
</tr>
<tr>
<td>CP-Writing</td>
<td>314</td>
<td>397</td>
<td>426</td>
<td>624</td>
</tr>
<tr>
<td>Naming the Rules</td>
<td>29</td>
<td>40</td>
<td>40</td>
<td>39</td>
</tr>
<tr>
<td>Writing the Rules</td>
<td>24</td>
<td>20</td>
<td>20</td>
<td>27</td>
</tr>
</tbody>
</table>

Note: Score Achievement Time (Min.) × 1,000. All three-group comparisons except Writing the Rules Criterion Test I were significant (p < .05). For Naming the Rules Criterion Test II, p < .01.

On the criterion and retention tests following Part I, the CP-Only Group made the highest scores, while on the tests after Part II the Naming Group seemed to be superior. However, this tendency was not statistically significant.

The inferior scores made by the subjects in the Rules Group in solving criterion problems did not seem to be due to poorer learning per se, since they scored higher on those criterion items specifically related to their training, namely, the writing out of rules. In Part I this difference in performance was not significant, but in Part II it was (p < .05). On the other hand, the Naming Group answered the naming questions on the Part II criterion test significantly better than the other two groups (p < .05), and also performed well on tests of computer programming. Thus, it appeared that both groups learned the additional materials presented during training, but that the subjects in the Rules Group were unable to apply their learning to problem solving.

Intelligence. Intelligence, as measured by scores on parts of the Army Classification Battery, was significantly and positively related to criterion
scores in all cases. No interactions appeared between intelligence scores and criterion scores related to the experimental variables.

EXPERIMENT 1B

The second experiment was basically a repeat of the first. Its primary functions were to confirm the earlier findings and provide the introductory instruction necessary for the more complex materials presented in Experiment 2.

Variables studied in Experiment 1B were the same as those for 1A except that the Rules Group was deleted from the verbalization variable. It was intended that the same measures would also be taken, with the addition of a Level-of-Aspiration measure. However, difficulties attending the administration of a large study over several months, using volunteers from many different school systems, resulted in the loss of the time scores, and a portion (20%) of the intelligence scores. The high dropout rate (57% for Experiments 1B and 2) also affected measurements.

Evidence for Learning. Mean performance on the Part I criterion dealing with problem solving averaged about 87% for students who completed all instruction (including Experiment 2) and 81% for all who took the test. On the Part II problem-solving criterion, the average was about 8.2% for finishers and 72% for all students. Thus, the program taught about as effectively as it had in Experiment 1A.

Since the mean performance scores suggested that the finishers were more homogeneous, the analyses of all experimental findings reported below are confined to them, in order to provide uniformity in the data base throughout the study. Mean criterion and retention test scores are shown in Table 5.16.

Prompting and Confirmation Effects. The Prompting Group scored significantly higher than the Confirmation Group (p < .001) during training on both Part I (96.5% vs. 88.5%) and Part II (91% vs. 87%). The groups did not differ

### Table 5
Mean Criterion and Retention Test Scores of Naming/No-Naming Groups: Experiment 1B

<table>
<thead>
<tr>
<th>Measure</th>
<th>Mean Group</th>
<th>Summary Mean</th>
<th>Percent Correct</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Naming</td>
<td>No-Naming</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Criterion Test I</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CP-Writing a</td>
<td>86.8</td>
<td>84.8</td>
<td>NS</td>
<td>19.7</td>
</tr>
<tr>
<td>Naming the Rules b</td>
<td>11.2</td>
<td>9.6</td>
<td>.001</td>
<td>1.7</td>
</tr>
<tr>
<td>Writing the Rules c</td>
<td>7.9</td>
<td>6.7</td>
<td>.001</td>
<td>2.8</td>
</tr>
<tr>
<td>Criterion Test II</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CP-Writing d</td>
<td>145.2</td>
<td>135.9</td>
<td>NS</td>
<td>29.1</td>
</tr>
<tr>
<td>Naming the Rules b</td>
<td>10.7</td>
<td>9.1</td>
<td>.001</td>
<td>1.8</td>
</tr>
<tr>
<td>Writing the Rules c</td>
<td>6.0</td>
<td>4.2</td>
<td>.001</td>
<td>2.3</td>
</tr>
<tr>
<td>Retention Test I</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>117.6</td>
<td>110.9</td>
<td>.01</td>
<td>30.9</td>
</tr>
<tr>
<td>Retention Test II</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>93.5</td>
<td>85.7</td>
<td>.01</td>
<td>32.2</td>
</tr>
</tbody>
</table>

aMaximum: 98
bMaximum: 12
cMaximum: 10
dMaximum: 169
eMaximum: 172
fMaximum: 141
significantly on the two criterion tests; however, when scores were adjusted for learning error the Confirmation Group was superior (p < .005 for Criterion Test I; p < .10 for Test II). This adjustment was made by means of an analysis of covariance, which provided an estimate of scores that would have been observed if performance during learning had been the same across conditions. The adjusted means for the Confirmation and Prompting Groups on both sets of criterion tests are shown in Table 7.

Table 7

Adjusted Mean Scores* of Naming/No.Naming and Prompting/Confirmation Groups on Criterion Tests: Experiment 1B

<table>
<thead>
<tr>
<th>Part</th>
<th>Prompting</th>
<th>Confirmation</th>
<th>p</th>
<th>Naming</th>
<th>No-Naming</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>81.6</td>
<td>90.9</td>
<td>.007</td>
<td>88.4</td>
<td>87.3</td>
<td>NS</td>
</tr>
<tr>
<td>II</td>
<td>81.4</td>
<td>81.9</td>
<td>.10</td>
<td>81.9</td>
<td>81.3</td>
<td>.10</td>
</tr>
</tbody>
</table>

*Adjusted for learning error by means of an analysis of covariance.

Verbalization Effects. Since the Rules Group was dropped from Experiments 1B and 2, the remaining groups were called the Naming (used mnemonics) and No-Naming Groups, depending upon whether they named rules and worked on practice problems, or simply worked problems during training.

The two groups did not differ on the Part I criterion items dealing with problem solving. However, on criterion items requiring students to name and write out rules, the Naming Group scored significantly higher. (The Naming Group had been given practice in naming rules but not in writing them out.) An analysis that took learning errors into account (analysis of covariance) showed that the superiority could be attributed in part to better performance during training (see Table 6). Retention tests reflected the same findings.

Level of aspiration and intelligence data are presented in the final section of this chapter.
EXPERIMENT 2

Experiments 1B and 2 were conducted in succession, Experiment 2 dealing with the new and more difficult materials of Parts III, IV, and V. The number of treatment combinations was quite high—29. Since attrition was also quite high—about half the students dropped out before the end of Part III—many of the groups in Experiment 2 were rather sparsely populated. Although this situation dampened the hopes of detecting statistically significant effects, those results which did prove reliable can be considered all the more powerful.

Evidence for Learning. Overall mean performance on the criterion test for Part III was about 70% correct; the median was about 78%. Thus, there was evidence of learning at a point three to five weeks after training had begun under Experiment 1B. Overall proficiency dropped to a median of 64% on Part IV and 35% on Part V. This drop was not unexpected since the purpose of the experiment was to obtain comparative data on teaching combinations; many of the less effective combinations were quite ineffectual at the more complex levels. One condition—zero confirmation—however, was effective and yielded medians of 81%, 73%, and 48% on Parts III, IV, and V.

A three-way factorial analysis was performed on Part III criterion data by randomly eliminating subjects to equate cell sizes. No interactions were revealed. Consequently, all subsequent comparisons considered the variables as independent and utilized all the data. The first set of analyses below treats Parts III, IV, and V separately. A second series was performed treating the three parts as replications.

Prompting and Confirmation Effects. Prompting and confirmation are similar in that they both present information pertaining to the correct answer. The amount of information presented will be called the degree of stimulus support, whether it comes from prompting or from confirmation. It had been hoped that errors during training could be manipulated by varying the percentage of stimulus support. An analysis of data from Part III indicated that this was accomplished. As shown in Figure 4, errors ranged from 10% for zero

Relations Between Learning Error and Criterion Test Error Under Prompting and Confirmation Conditions: Part III

![figure](image)

Figure 4
Effects of Prompting and Confirmation on Criterion Test Performance: Part III

Figure 5

stimulus support to 2% for complete support (total prompting). Performance during training was directly related to degree of stimulus support; the greater the support the fewer the errors. However, test performance was inversely related to stimulus support ($p < .01$) when scores were adjusted for learning errors. Test scores for the adjusted data are shown in Figure 5.

The data showed marked variability in Part IV. The overall median dropped to 64% correct; the mean fell to 55%. In Part V the test scores were even lower, 38% correct as the mean and 35% as the median. Therefore, modified nonparametric runs tests were employed using deciles instead of individual scores. Results supported the findings in Part III. Where confirmation and prompting reflected comparable stimulus support—all of the Zero Prompting Groups vs. all of the Zero Confirmation Groups, and all of the 100% Prompting Groups vs. all of the 100% Confirmation Groups—the confirmation treatment proved more effective for criterion performance. A decile analysis of the criterion data relevant to these comparisons from Parts III and IV yielded significant differences ($p < .01$). In Part V the Zero Confirmation-Prompting comparison gave the same result, but the 100% groups did not differ.

On the final retention test, given four weeks after completion of all instruction, the direction of the effects was the same. The lower the stimulus support during training the better the scores. However, significant differences were obtained only among the confirmation levels ($p < .001$). A decile comparison among the prompting conditions revealed that both the Zero and 33% Prompting Groups scored significantly higher than the 100% Prompting Group (both with $p < .01$). The other intermediate prompting groups did not differ from the Zero Prompting Group, but did score significantly higher than the 100% group. In short, the long-term retention test further indicated that the greater the error during learning the better the performance on criterion problem solving. The retention test means and medians are presented in Table 8. These data are not adjusted for learning errors.

### Table 8

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean Percent Correct</th>
<th>Median Percent Correct</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variety</td>
<td>56</td>
<td>56</td>
</tr>
<tr>
<td>No-Variety</td>
<td>57</td>
<td>62</td>
</tr>
<tr>
<td>Zero Confirmation</td>
<td>67</td>
<td>73</td>
</tr>
<tr>
<td>50% Confirmation</td>
<td>56</td>
<td>56</td>
</tr>
<tr>
<td>100% Confirmation</td>
<td>52</td>
<td>44</td>
</tr>
<tr>
<td>Zero Prompting</td>
<td>61</td>
<td>49</td>
</tr>
<tr>
<td>33% Prompting</td>
<td>54</td>
<td>51</td>
</tr>
<tr>
<td>Progressive Prompting</td>
<td>59</td>
<td>69</td>
</tr>
<tr>
<td>67% Prompting</td>
<td>56</td>
<td>55</td>
</tr>
<tr>
<td>100% Prompting</td>
<td>17</td>
<td>36</td>
</tr>
</tbody>
</table>

Variety-of-Practice Effects. There was little difference in learning
between the Variety and No-Variety Groups during training. However, students who had practiced under the Variety condition scored significantly higher on the criterion test for Part III (p < .01; Figure 6). Analyses of criterion test data from Parts IV and V did not reveal any significant differences. However, the Variety students scored higher on the Part IV test on a deciles comparison (p < .01). On the Part V criterion test and on the final retention test the effect disappeared completely, although even in retention the direction of the difference still held (Variety mean, 44%; No-Variety, 38%).

Since the Variety students practiced with three different verbal contexts during training (vacuum tubes, salaries, and inventories of uniforms) and there were four different contexts used in the five criterion problems, it could be argued that their superiority derived from a greater similarity between training and testing than was the case with the No-Variety Group, which practiced on vacuum tube problems only.

This possibility was tested by dichotomizing the criterion problems into those that were stated in a novel context for both groups (4 problems) and those using a setting new only to the No-Variety Group (2 problems). The Variety Group was superior on both types of problems. Thus, it can be inferred that variety of context resulted in better learning of the general mediating skills necessary to write computer programs, and not simply better learning of the overt associations practiced during training.

Verbalization Effects. Due to clerical error in assembling grouping of course materials, and to attenuation of some groups because of high dropout, no meaningful data were generated from the treatments added to get supplementary information on the effects of verbalization.

RELATIONSHIPS BETWEEN EXPERIMENTS 1B AND 2

Since Experiments 1B and 2 were conducted in succession, using the same students and teaching a continuity of subject matter, it became important to determine the relationships between the two studies. Results presented below deal with the question of how various learning conditions in Experiment 1B combined with learning conditions in Experiment 2 to affect the criterion test performance in Parts III, IV, and V. The two variables of Experiment 1B and the three of Experiment 2 yielded six combinations of interest:

<table>
<thead>
<tr>
<th>Experiment 1B</th>
<th>Experiment 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prompting/confirmation</td>
<td>Level of confirmation</td>
</tr>
<tr>
<td>Naming/no-naming</td>
<td>with</td>
</tr>
<tr>
<td>with</td>
<td>Level of confirmation</td>
</tr>
</tbody>
</table>

![Figure 6](image-url)
Since there were no significant interactions among the variables of Experiment 2, they were treated as independent for purposes of analysis. Data from Experiments 1B and 2 were cast into three-way analysis of variance tables to note possible interactions. Parts III, IV, and V were treated as replications. Graphs of the main effects of confirmation levels and prompting levels are shown in Figures 7 and 8 respectively (see also Tables 9 and 11, Analyses of Variance).

Effects of Degrees of Confirmation on Criterion Test Performance: Experiment 2

Effects of Degrees of Prompting on Criterion Test Performance: Experiment 2

Naming/No-Naming (Exp. 1B) With Confirmation Levels (Exp. 2). The analysis of the naming and no-naming conditions of Experiment 1B combined with the three confirmation levels of Experiment 2 is summarized in Table 9. Significant interactions were indicated. The means for the various treatment combinations are shown in Table 10 grouped according to a Duncan Range analysis, which enables a comparison of individual treatment means to be made.

Table 9
Analysis of Variance of the Effects of Confirmation (Experiment 2) by Naming/No-Naming (Experiment 1B) on Criterion Tests for Parts III, IV, and V

<table>
<thead>
<tr>
<th>Source of Variance</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Naming/No-Naming, Exp. 1B (A)</td>
<td>1</td>
<td>541800</td>
<td>24.6</td>
<td>.05</td>
</tr>
<tr>
<td>Confirmation, Exp. 2 (B)</td>
<td>2</td>
<td>730503</td>
<td>9.8</td>
<td>.005</td>
</tr>
<tr>
<td>Replications (C)</td>
<td>2</td>
<td>4571461</td>
<td>37.6</td>
<td>.001</td>
</tr>
<tr>
<td>AB</td>
<td>2</td>
<td>518986</td>
<td>23.5</td>
<td>.025</td>
</tr>
<tr>
<td>AC</td>
<td>2</td>
<td>22060</td>
<td>&lt;1</td>
<td>NS</td>
</tr>
<tr>
<td>BC</td>
<td>4</td>
<td>79496</td>
<td>3.4</td>
<td>NS</td>
</tr>
<tr>
<td>ABC</td>
<td>1</td>
<td>23383</td>
<td>&lt;1</td>
<td>NS</td>
</tr>
<tr>
<td>Within Cells</td>
<td>870</td>
<td>121642</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 10
Duncan Range Groupings of the Effects of Confirmation (Experiment 2) -
Naming/No-Naming (Experiment 1B) Combinations on Criterion Tests
for Parts III, IV, and V

(N 296)

<table>
<thead>
<tr>
<th></th>
<th>Part III</th>
<th></th>
<th>Part IV</th>
<th></th>
<th>Part V</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Percent Correct</td>
<td>Confirmation</td>
<td>Naming</td>
<td>Percent Correct</td>
<td>Confirmation</td>
<td>Naming</td>
<td>Percent Correct</td>
</tr>
<tr>
<td>68.8</td>
<td>0%</td>
<td>No</td>
<td>63.7</td>
<td>0%</td>
<td>Yes</td>
<td>47.2</td>
</tr>
<tr>
<td>67.7</td>
<td>100%</td>
<td>Yes</td>
<td>63.2</td>
<td>0%</td>
<td>No</td>
<td>14.0</td>
</tr>
<tr>
<td></td>
<td>---------</td>
<td>--------</td>
<td>---------</td>
<td>--------</td>
<td>--------</td>
<td>---------</td>
</tr>
<tr>
<td>65.1</td>
<td>0%</td>
<td>Yes</td>
<td>58.9</td>
<td>50%</td>
<td>Yes</td>
<td>42.3</td>
</tr>
<tr>
<td>64.4</td>
<td>50%</td>
<td>Yes</td>
<td>58.1</td>
<td>50%</td>
<td>No</td>
<td>39.0</td>
</tr>
<tr>
<td></td>
<td>---------</td>
<td>--------</td>
<td>---------</td>
<td>--------</td>
<td>--------</td>
<td>---------</td>
</tr>
<tr>
<td>64.4</td>
<td>50%</td>
<td>Yes</td>
<td>57.6</td>
<td>100%</td>
<td>Yes</td>
<td>39.0</td>
</tr>
<tr>
<td>63.5</td>
<td>50%</td>
<td>No</td>
<td>39.0</td>
<td>100%</td>
<td>No</td>
<td>36.6</td>
</tr>
<tr>
<td>55.9</td>
<td>100%</td>
<td>No</td>
<td></td>
<td></td>
<td></td>
<td>27.2</td>
</tr>
</tbody>
</table>

*Means that are clustered together are not significantly different from one another. The groups differ significantly (p < .05).*

Table 10 reaffirms the stimulus support effect noted previously, that the lower the stimulus support during training (here, the lower the confirmation), the better the criterion scores. This effect appeared to be heightened when combined with prior use of mnemonics (naming the rules); practice in naming rules in Experiment 1B plus low confirmation in Experiment 2 seemed to promote the best criterion performance. The effect is clearest in Part III where learning began to deteriorate with increased difficulty in the instructional materials. Here the No-Naming/Zero Confirmation Group came in first, the Naming/Zero Confirmation Group second, and so on, with the No-Naming/100% Confirmation combination representing the worst learning conditions.

Prompting/Confirmation (Exp. 1B) With Confirmation Levels (Exp. 2). The analysis of the prompting/confirmation conditions of Experiment 1B in combination with the various confirmation levels of Experiment 2 revealed no significant interactions. Examination of the individual groups did, however, suggest a type of interaction effect related to similarity of stimulus support. It appeared that the more similar the stimulus support conditions the better the performance (see Figure 8). Specifically, zero confirmation (the Prompting Group of Experiment 1B) followed by zero confirmation (in Experiment 2) resulted in better scores on criterion tests for Parts III, IV, and V than total confirmation followed by zero confirmation. This relationship also held for the zero-to-total vs. total-to-total confirmation sequences except for Part IV, where there was a reversal.

Naming/No-Naming (Exp. 1B) With Prompting Levels (Exp. 2). Analyses of the data (Table 11) reaffirmed the importance of low stimulus support (here, low prompting levels) and early practice with mnemonics (naming the rules) to criterion performance on Parts III, IV, and V. Mean scores resulting from the various sequences of treatments, Experiment 1B to Experiment 2, are shown in Table 12, grouped according to the results of a Duncan Range analysis. In general, naming followed by low prompting promoted the best performance; no-naming followed by high prompting was the worst combination.
Table 11
Analysis of Variance of the Effects of Prompting (Experiment 2) by Naming/No-Naming (Experiment 1B) on Criterion Tests for Parts III, IV, and V

<table>
<thead>
<tr>
<th>Source of Variance</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Naming-No-Naming, Exp. 1B (A)</td>
<td>1</td>
<td>1011347</td>
<td>29.2</td>
<td>.05</td>
</tr>
<tr>
<td>Prompting, Exp. 2 (B)</td>
<td>1</td>
<td>26823</td>
<td>7.9</td>
<td>.01</td>
</tr>
<tr>
<td>Replications (C)</td>
<td>2</td>
<td>442316</td>
<td>33.0</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>A</td>
<td>1</td>
<td>155902</td>
<td>9.6</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>AC</td>
<td>2</td>
<td>34593</td>
<td>2.1</td>
<td>NS</td>
</tr>
<tr>
<td>BC</td>
<td>2</td>
<td>34593</td>
<td>2.1</td>
<td>NS</td>
</tr>
<tr>
<td>A1</td>
<td>2</td>
<td>16237</td>
<td>&lt;.1</td>
<td>NS</td>
</tr>
<tr>
<td>Within Cells</td>
<td>858</td>
<td>122213</td>
<td>17.9</td>
<td>.0001</td>
</tr>
</tbody>
</table>

Table 12
Duncan Range Groupings of the Effects of Prompting (Experiment 2) - Naming/No-Naming (Experiment 1B) Combinations on Criterion Tests
for Parts III, IV, and V (N = 296)

<table>
<thead>
<tr>
<th>Part III</th>
<th></th>
<th></th>
<th>Part IV</th>
<th></th>
<th></th>
<th>Part V</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Percent Correct</td>
<td>Prompting</td>
<td>Naming</td>
<td>Percent Correct</td>
<td>Prompting</td>
<td>Naming</td>
<td>Percent Correct</td>
<td>Prompting</td>
<td>Naming</td>
</tr>
<tr>
<td>68.9</td>
<td>0%</td>
<td>No</td>
<td>66.0</td>
<td>Progressive</td>
<td>Yes</td>
<td>46.4</td>
<td>Progressive</td>
<td>Yes</td>
</tr>
<tr>
<td>66.8</td>
<td>0%</td>
<td>Yes</td>
<td>61.9</td>
<td>67%</td>
<td>Yes</td>
<td>43.4</td>
<td>0%</td>
<td>Yes</td>
</tr>
<tr>
<td>66.1</td>
<td>67%</td>
<td>Yes</td>
<td>59.4</td>
<td>0%</td>
<td>No</td>
<td>41.9</td>
<td>100%</td>
<td>Yes</td>
</tr>
<tr>
<td>66.0</td>
<td>100%</td>
<td>Yes</td>
<td>58.2</td>
<td>0%</td>
<td>Yes</td>
<td>40.3</td>
<td>100%</td>
<td>Yes</td>
</tr>
<tr>
<td>66.1</td>
<td>100%</td>
<td>Yes</td>
<td>53.8</td>
<td>33%</td>
<td>Yes</td>
<td>37.7</td>
<td>67%</td>
<td>No</td>
</tr>
<tr>
<td>62.0</td>
<td>Progressive</td>
<td>No</td>
<td>52.8</td>
<td>Progressive</td>
<td>No</td>
<td>34.6</td>
<td>33%</td>
<td>Yes</td>
</tr>
<tr>
<td>60.6</td>
<td>33%</td>
<td>No</td>
<td>51.1</td>
<td>67%</td>
<td>No</td>
<td>33.6</td>
<td>33%</td>
<td>No</td>
</tr>
<tr>
<td>58.1</td>
<td>67%</td>
<td>No</td>
<td>48.9</td>
<td>33%</td>
<td>No</td>
<td>24.1</td>
<td>100%</td>
<td>No</td>
</tr>
<tr>
<td>53.1</td>
<td>100%</td>
<td>No</td>
<td>32.9</td>
<td>100%</td>
<td>No</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Groups are separated at or beyond the .05 level.

Prompting/Confirmation (Exp. 1B) With Prompting Levels (Exp. 2). The interaction of early prompting/confirmation treatments ( Experiment 1B) with later prompting levels (Experiment 2) was highly pronounced (Table 13). The dominant factor appeared to be similarity of stimulus support, as it was in the previous discussion of prompting/confirmation followed by confirmation. Thus, as seen in Figure 9, students given total prompting in both studies performed better on Parts III, IV, and V than students given zero prompting followed by total prompting. Similarly, zero prompting in both experiments promoted better performance on all three criterion tests than total prompting followed by zero prompting.
Table 13

Analysis of Variance of the Effects of Prompting (Experiment 2) by Prompting/Confirmation (Experiment 1B) on Criterion Tests for Parts III, IV, and V

<table>
<thead>
<tr>
<th>Source of Variance</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prompting Confirmation, Exp. 1B (A)</td>
<td>1</td>
<td>228594</td>
<td>6.2</td>
<td>NS</td>
</tr>
<tr>
<td>Prompting, Exp. 2 (B)</td>
<td>1</td>
<td>164384</td>
<td>7.0</td>
<td>.05</td>
</tr>
<tr>
<td>Replications (C)</td>
<td>1</td>
<td>1297564</td>
<td>31.5</td>
<td>.01</td>
</tr>
<tr>
<td>AB</td>
<td>4</td>
<td>403593</td>
<td>3.2</td>
<td>.025</td>
</tr>
<tr>
<td>AC</td>
<td>2</td>
<td>37117</td>
<td>1</td>
<td>NS</td>
</tr>
<tr>
<td>BC</td>
<td>8</td>
<td>32834</td>
<td>0</td>
<td>NS</td>
</tr>
<tr>
<td>ABC</td>
<td>8</td>
<td>56722</td>
<td>0</td>
<td>NS</td>
</tr>
<tr>
<td>Within Cells</td>
<td>850</td>
<td>124422</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Effects of Similarity of Stimulus Support From Experiment 1B (0 or 100) to Experiment 2 (0 or 100) on Criterion Test Performance: Experiment 2

Figure 9

Naming/No-Naming (Exp. 1B) With Variety Level (Exp. 2). Analyses showed that criterion performance in Parts III, IV, and V was clearly affected by the various combinations of early naming/no-naming with later variety/no-variety (Table 14). Although the data were not entirely consistent, it appeared that performance improved as the combination approached the mix of early naming with later variety. Further, the importance of naming seemed to increase as materials became more complex (and, concomitantly, as performance dropped...
Table 14
Analysis of Variance of the Effects of Variety/No-Variety (Experiment 2) by Naming/No-Naming (Experiment 1B) on Criterion Tests for Parts III, IV, and V

<table>
<thead>
<tr>
<th>Source of Variance</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Naming No-Naming, Exp. 1B (A)</td>
<td>1</td>
<td>9072.46</td>
<td>28.2</td>
<td>&lt; .01</td>
</tr>
<tr>
<td>Variety No-Variety, Exp. 2 (B)</td>
<td>1</td>
<td>7882.97</td>
<td>1.1</td>
<td>&lt; .025</td>
</tr>
<tr>
<td>Replications (C)</td>
<td>2</td>
<td>47333.63</td>
<td>39.4</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>AB</td>
<td>1</td>
<td>16028.61</td>
<td>42.0</td>
<td>&lt; .01</td>
</tr>
<tr>
<td>AC</td>
<td>2</td>
<td>32132</td>
<td>1</td>
<td>NS</td>
</tr>
<tr>
<td>BC</td>
<td>2</td>
<td>17881.6</td>
<td>4.7</td>
<td>NS</td>
</tr>
<tr>
<td>ABC</td>
<td>2</td>
<td>38175</td>
<td>1</td>
<td>NS</td>
</tr>
<tr>
<td>Within Cells</td>
<td>876</td>
<td>121305</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

off), while the importance of variety seemed to decrease. Means of the various combinations are shown in Table 15, arranged according to the results of a Duncan Range analysis.

Prompting/Confirmation (Exp. 1B) With Variety Level (Exp. 2). No significant interactions were found.

Table 15
Duncan Range Groupings of the Effects of Variety/No-Variety (Experiment 2) - Naming/No-Naming (Experiment 1B) Combinations on Criterion Tests for Parts III, IV, and V.

<table>
<thead>
<tr>
<th>Part III</th>
<th>Part IV</th>
<th>Part V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percent Correct</td>
<td>Variety</td>
<td>Naming</td>
</tr>
<tr>
<td>70.7</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>68.0</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>63.5</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>52.5</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

*Groups are separated at or beyond the .05 level.

FACTORS RELATED TO DROPOUT

As noted earlier, about 57% of the students did not complete instruction. A series of analyses were conducted to determine the relationships between dropout and stimulus support, level of aspiration (LOA), intelligence, and performance.

Stimulus Support. The more stimulus support in training—that is, the greater the degree of prompting or confirmation—the greater was the likelihood a student would finish the course ($x^2$ trend test of proportions, $p < .05$). Figure 10, based on Part III data, shows that the prompting and confirmation factors operated alike in this regard.

Level of Aspiration. At the end of Parts I and II, students were asked to estimate how well they had performed on the previous part and how well they expected
to perform on the instruction to follow. The correlations between performance estimates on completed instruction and actual performance were quite high (.65). However, students who later dropped out expected to perform much higher on subsequent criterion tests than they did, relative to students who finished (p < .01). That is, the discrepancy between level of aspiration and performance was much higher for dropouts than for finishers. In addition, the expectations of the dropouts were significantly lower than the expectations of the finishers after Part I, and the performance of the dropouts was significantly lower.

In short, relative to the finishers, the dropouts (a) expected to perform at a lower level, (b) greatly overestimated their capability, and (c) did perform significantly worse.

Intelligence. Dropouts were characterized by significantly lower intelligence (verbal ACB scores) than finishers.

CORRELATIONS BETWEEN EXPERIMENTS 1B AND 2

Experiment 1B. The overall correlation between intelligence and criterion performance was high (Part I, $r = .69$; Part II, $r = .70$). The relationships were even higher for finishers (Part I, $r = .73$; Part II, $r = .73$).

The overall correlations between learning errors and scores on the related criterion tests were not so marked, but increased from Part I to Part II (.46 to .63). For those subjects on whom intelligence measures were not obtained, the relationship between learning and testing was even higher (.48, $N = 141$. .82, $N = 140$). Since learning errors fell within a narrow range (2%-8%), these correlations may be spuriously low.

On dividing students by intelligence into low, medium, and high, it was found that the learning-testing relationship was significant for the average and bright students who dropped out, but not for the average and bright students who finished. For low aptitude students the correlations between learning errors and criterion scores were about the same, positive but low (Table 16).

The correlation between the criterion tests for Parts I and II was high, about .7. Thus, performance on the first criterion test was a good predictor of success on the second.

Experiment 2. The partial correlations, for finishers only, between LOA (expectations), intelligence, and criterion performance are given in Table 17. The relationship between LOA and subsequent criterion performance, with intelligence scores partialled out, increased (except between Parts IV and V) as students progressed through the course. On the other hand, overall relationships between intelligence and criterion scores decreased through the instruction. The relationship between LOA (expectations) and intelligence decreased even more markedly, shrinking to almost zero (+.05) on the last criterion test.
Table 16
Correlations by Intelligence Level Between Learning and Criterion Scores of Finishers and Nonfinishers: Experiment 1B

<table>
<thead>
<tr>
<th>Intelligence</th>
<th>Part</th>
<th>Finishers</th>
<th></th>
<th>Nonfinishers</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>( r )</td>
<td>( p )</td>
<td>( r )</td>
<td>( p )</td>
</tr>
<tr>
<td>Low</td>
<td>I</td>
<td>.34</td>
<td>.01</td>
<td>.40</td>
<td>.01</td>
</tr>
<tr>
<td></td>
<td>II</td>
<td>.12</td>
<td>.01</td>
<td>.31</td>
<td>.01</td>
</tr>
<tr>
<td>Medium</td>
<td>I</td>
<td>.00</td>
<td>NS</td>
<td>.27</td>
<td>.05</td>
</tr>
<tr>
<td></td>
<td>II</td>
<td>.14</td>
<td>NS</td>
<td>.33</td>
<td>.01</td>
</tr>
<tr>
<td>High</td>
<td>I</td>
<td>.11</td>
<td>NS</td>
<td>.49</td>
<td>.01</td>
</tr>
<tr>
<td></td>
<td>II</td>
<td>.1</td>
<td>NS</td>
<td>.45</td>
<td>.01</td>
</tr>
</tbody>
</table>

Table 17
Correlations Between Expected Success, Intelligence, and Criterion Performance of Finishers, as a Function of Course Complexity: Experiment 2

<table>
<thead>
<tr>
<th>Factors Correlated</th>
<th>Part II</th>
<th>Part III</th>
<th>Part IV</th>
<th>Part V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expected Success and Criterion Performance*</td>
<td>.37</td>
<td>.50</td>
<td>.59</td>
<td>.55</td>
</tr>
<tr>
<td>Intelligence and Criterion Performance</td>
<td>.74</td>
<td>.53</td>
<td>.50</td>
<td>.48</td>
</tr>
<tr>
<td>Intelligence and Expected Success</td>
<td>.46</td>
<td>.19</td>
<td>.09</td>
<td>.05</td>
</tr>
<tr>
<td>Successive Pairs of Criterion Tests</td>
<td>.61</td>
<td>.63</td>
<td>.69</td>
<td>.34</td>
</tr>
</tbody>
</table>

*For these four correlations, intelligence was partialled out.

In short, as the finishers progressed through the course, the relation between instructional-based factors—LOA and performance—increased; however, the relationships between these factors and Intelligence, a measure taken before instruction began, decreased.
Chapter 4
DISCUSSION

The organization of the ensuing discussion will be from specific to general, and from experimental hypotheses tested in Experiments 1A and 1B to those tested in Experiment 2. Following material pertinent to the immediate findings, the implications of this type of study for future research and development in PI will be discussed. Finally, the potential utility of the secondary product of the METHOD II research, the programmed course in fundamentals of computer programming, will be indicated.

COMPARISON OF EXPERIMENTS 1A AND 1B

Evidence for Learning

The means for percent correct on the criterion tests on both Parts I and II were almost identical across studies: 87% on Part I and approximately 83% on Part II. The retention test scores for Experiment 1A are somewhat higher than for 1B; however, the test for Experiment 1A was given on the day following criterion testing, whereas in Experiment 1B a week separated criterion and retention testing.

The intelligence indicator was significantly and positively correlated with criterion scores in both studies and no interactions appeared between intelligence and treatment conditions on the principal measure, writing computer programs.

Treatment Effects

Learning Time

Unfortunately, administrative problems prevented obtaining adequate time measures in Experiment 1B. In Experiment 1A, length of learning time was negatively related to score on the criterion. Doubtless, this was due to the time spent by the Rules Group in writing out complex programming rules, a requirement which appeared to dull their terminal performance. The learning time/criterion score relationship may not generalize to other PI environments.

Criterion Scores

(1) Prompting/Confirmation Results. The tendency in Experiment 1A for the prompting/confirmation effect during learning to be reversed on testing was found even more strongly in the covariance analysis under Experiment 1B. Learning errors in the two studies were highly comparable: 3% and 3.5% for prompting, 10% and 11.5% for confirmation.

(2) Verbalization Results. With respect to the requirement of writing the names of the rules during training (mnemonics) as opposed to just writing computer programs, the suggestion in Experiment 1A of superiority of the Naming Group with the more complex materials in Part II was heightened in
Experiment 113, which involved five times as many students. Moreover, the superiority of the Naming Group (mnemonics) in the larger study was in the percent correct per se on the criterion in Part II and did not involve time-weighting the scores. That is, use of mnemonics resulted in an absolute and not just relative superiority, which carried over a two-week period, adding to the practical value of this particular finding.

Summary

Summing up the effects of the treatment conditions across both experiments, the use of mnemonics in learning the concepts in the computer programming course aided students in tests of computer programming. On the other hand, practice in writing the entire rule in the context given by the booklet hindered ability to use the rules effectively.

The confirmation and prompting comparisons are not so clear. Taken together, the two studies reveal that while confirmation led to more errors during learning, it did not lead to differences on criterion testing. If, however, one takes into account the covariate of errors during learning, then confirmation was superior to prompting (indicating that the Confirmation Group benefited from the errors made during training). Nevertheless, one cannot say that in the context of these two experiments error rate during learning was an important factor in criterion test performance.

EXPERIMENT 2

Stimulus Support

It seems clear within the context of the present research that a low degree of stimulus support (in the form of problem information), with attendant relative high degree of error during training, is desirable for achieving a high degree of proficiency on a criterion test requiring the synthesis of the materials presented during training. Variations in degree of prompting or confirmation were inversely related to criterion performance.

At the outset it was thought likely that a certain amount of error during training would result in the best criterion performance. A legitimate question is: Why did not this optimization relationship turn up?

Although the reasoning is post hoc, a good starting point is to note that the key to good instruction is transmission of information. Since error rate in the worst experimental variation of the course was still low, approximately 18%, it is proposed that all groups were either at or beyond the hypothesized optimal point relating information transmission, difficulty level, and test performance. To explore this assumption in future research, it would be worthwhile to degrade the information transmitted by decreasing the chunks of conceptual content presented at each step of training and relate these variations to end of course performance (see Seidel, 21, on the problem of units of meaning).

These findings support the proposition that complex human learning such as problem solving is of a different nature than the rote learning of isolated

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1Although the temptation may be great to treat these findings as instances of effects of knowledge of results (KR), it would be inappropriate to do so. The study does not concern KR vs. no-KR as traditionally understood, since concepts were nested in each succeeding one. True, some KR was achieved indirectly, and the subject had some self-confirmation as well. However, prompting and confirmation acted alike, and clearly a prompt, which appeared before the student attempted to answer, could not be looked upon as KR. Thus, the term "knowledge of results" seems inappropriate when generalized to include foreknowledge. More applicable here is the term "stimulus support," which treats degree of prompting or confirmation alike.
paired associates or serialized items. The latter involves training to an internal achievement criterion, as opposed to the problem-solving criterion which is external and of such a nature as to require synthesis of the concepts and the development of a strategy in a transfer test. Perhaps a good point of departure for the research reported here is Kendler's recent statement (12, p. 231):

If researchers in the field of programmed learning believe that the major response being learned is the one that the student writes in the frame, they are badly mistaken. What is being learned are concepts...what are modified are large segments of the students' verbal repertoire.

It should be noted that, when prompting or confirmation were given in the present set of experiments, they were applied not to simple stimulus-response associations (as in rote learning) but to strategies or portions thereof.

In order to be appropriately applied in the current context, Kendler's statement should be amended to include that not only are concepts being learned but strategies enabling the student to use these concepts are being learned as well. Thus, he reaches a higher level of learning called problem solving. This is in agreement with Gagné's recent distinction (13) between concept learning and problem solving."

Variety

The overall approach of the present research can be meaningfully compared to a similar study by Gagné and Bassler (23), who used a programed instructional environment to study teaching and retention of elementary non-metric geometry with sixth graders. Despite certain procedural differences, conceptually the approaches are sufficiently similar so that a detailed comparison of results should indicate some possible generalizations as well as being quite instructive for future research.

To begin with Gagné and Bassler found a moderate correlation—of the order of .62—between achievement scores immediately following learning and those of retention. In the present study, a comparable relationship (of the order of .64) was found. In the study by Gagné and Bassler, they were able to compare the subordinate learning sets immediately following learning and in retention and found a correlation of .46. Correlations in the present study for the early or subordinate criterion tasks were on the order of 1.00. Whereas Gagné and Bassler found that the correlations between the retention and the original achievement scores for the subordinate learning sets were lower than for the higher order learning sets, the data in the present study indicated no such difference.

These findings are reflected in another way by looking at retention ratios (retention score divided by original score) for the various problems. They are all just about 1.0 or fairly close to it. Differences which did appear were confined to the effects of different degrees of prompting in Parts III, IV, and V; the mean ratios for the latter are given in Table 18. The differences occurring on

"In a larger framework, the current study suggests that Kendler's admonition be extended to a theoretical level: If learning or training theorists believe that the basic unit for complex learning is the classical S-R association, they may also be badly mistaken. Scardamalia (22) arrived at the same skepticism after completing a number of studies involving the teaching of various mathematical algorithms. He proposed as an alternative to S-R associationistic theory a "set function language" (SFL) which seems to describe more precisely the conceptual and problem-solving levels of behavior. Previously, Shaw and Seidel, in a paper on informational context as a determinant of what can be learned (in preparation), showed that even with as simple an organism as the rat, associationistic principles are insufficient to account for higher order conceptual learning when such is permitted to occur. Certainly, a new alternative to associationistic theory such as Scardamalia's SFL is an interesting one and worthy of further development."
Table 18
Retention Ratios* for Prompting Treatments: Experiment 2

<table>
<thead>
<tr>
<th>Problem</th>
<th>Degree of Prompting</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0%</td>
<td>33%</td>
<td>Progressive</td>
<td>67%</td>
<td>100%</td>
</tr>
<tr>
<td>1</td>
<td>1.00</td>
<td>.99</td>
<td>.96</td>
<td>.98</td>
<td>1.00</td>
</tr>
<tr>
<td>2</td>
<td>1.06</td>
<td>1.02</td>
<td>.96</td>
<td>.98</td>
<td>1.09</td>
</tr>
<tr>
<td>3</td>
<td>1.04</td>
<td>.98</td>
<td>1.02</td>
<td>1.04</td>
<td>1.09</td>
</tr>
<tr>
<td>4</td>
<td>1.08</td>
<td>.80</td>
<td>.99</td>
<td>1.02</td>
<td>.61</td>
</tr>
<tr>
<td>5</td>
<td>.93</td>
<td>.78</td>
<td>.80</td>
<td>.98</td>
<td>.69</td>
</tr>
<tr>
<td>Total</td>
<td>1.04</td>
<td>.92</td>
<td>.97</td>
<td>1.02</td>
<td>.93</td>
</tr>
</tbody>
</table>

*Retention Score
Original Score

Problem 4 in that table and on the overall retention problems among the various prompting conditions are significant. These effects generally reflect the original effects of the stimulus support variables, showing the least stimulus support (zero prompting) yielding the maximum percent correct and the 100% stimulus support showing the least percent correct ($F = 2.96, df = 4/174, p < .05$ for Problem 4; $F = 2.73, df = 4/174, p < .05$ for overall retention comparison).

Gagné and Bassler found that "... the present evidence suggests that their [the subordinate learning sets] importance diminishes once the final task has been achieved" (23, p. 127). However, in the present study the retention results indicated this was not the case, that the subordinate concepts were retained and had the same effect as they did on the initial achievement.

Contrary to the findings of Gagné and Bassler, while the results of the present study showed the effect of Variety on immediate achievement, the effects diminished to nonsignificance on the retention test four weeks later. Their data yielded just the reverse effect, but it should be noted that in their study achievement was measured after 11 successive days of training, whereas in the current study final achievement was measured after approximately 10 weeks of study, one session per week. Retention in their investigation was measured nine weeks after the immediate achievement test, whereas in the present instance retention measures were taken four weeks following the last achievement test. Thus, it is possible that differences in the results may be due in part to the differences in the time frames for instruction and retention testing.

Mnemonics Training

Another aspect to the results of the current research relates to the value of written verbalization of rules which an individual is required to use in developing his strategies for problem solution. The data of both experiments taken together clearly indicate that "what is in a name" is important. If an individual is given mnemonics practice early in training and is required to learn these mnemonics as well as to use them in forming his strategy (writing computer programs), he is able to formulate the rules for later use with greater facility than if he is required to write the rules in the verbal context given by the instructor.

This makes good sense if one thinks about how we go about encoding our environment from day to day. If an individual is asked to recall an event, it is much easier for him to provide a sentence or two in his own words than to report
in great detail or verbatim (if the event is a poem or story). In like manner, when requiring a student to learn the conceptual rules for the use of computer commands, if he is provided with a mnemonic key with which to tag the rule as he formulates it himself, he will be able to use his own verbal repertoire to good advantage. On the other hand, if the student is required to use the instructor’s words— which may not match his own—in formulating the rule, he may indeed end up just memorizing the words without developing any understanding in the use of these rules. At least, that seems to be the inference to be made from our present study.

It is this last feature which seems to take exception to one of Gagné’s positions (13, pp. 307-308) in which he emphasized the value of recallability of “subordinate capabilities.” The present study clearly supports a distinction between recallability and availability of these subordinate abilities, the latter being the more important of the two. The Rules Group in Experiment 1A recalled the rules much better than the other groups, but they did so at the expense of being able to use these lower-order skills. On the other hand, the Naming Group was not only able to recall the rules well, but was able to have them available for use in working the computer programs.

This distinction between recallability and availability receives further support from Torrey’s recent work (24) on the teaching of Russian grammar. She found that students given contextual drill during learning were better in dealing with new material on a generalization test than were the controls. The latter students learned all the training material by a vocabulary method. It is important to note that the control subjects were periodically tested to show their ability to generate correct sentences according to the Russian grammar rules. Thus, during training they were able to generate the rule, but on the test they were not able to apply it.

The value of mnemonics as used in the present study (Naming Group) warrants further discussion. As already noted, naming practice was helpful in solving computer problems related to the course material directly involved (Part II criterion). Of perhaps greater significance were the more lasting advantages which appeared in later and more complex portions of the course. When overall proficiency dropped to a low level (Part V and final retention test), a significant interaction appeared between early naming practice (Parts I and II) and the later treatments (Parts III, IV, and V). This took the form of good early training in Experiment 1B (Naming) compensating for poorer training conditions in Experiment 2 (see Tables 10, 12, and 15).

For example, the No-Variety students who had early training with mnemonics were able to maintain as high a level of criterion proficiency in Parts IV and V as the Variety Group. In other words, the rate of loss of proficiency was not as great for the No-Variety Naming Group as it was for the Variety No-Naming Group. The compensating effect was also superimposed on the stimulus support treatment effects as seen in Tables 10 and 12.

A reasonable question which follows from these results is: What is the relationship between stage of training in which mnemonics are introduced and enhancement of criterion performance? An attempt was made in Experiment 2 to obtain some relevant data by continuing the use of mnemonics through the more complex portions of the course for three additional groups of subjects. Unfortunately, because of clerical error in the preparation of the booklets, and group attenuation because of drop-out, meaningful data were not generated. The question of timing and relative value of mnemonics, of course, remains an open and important one for future research.
Transfer Effects of General vs. Task-Specific Factors

Further discussion of the transfer effects of general vs. task-specific factors is worthwhile because the subject has special relevance to the design of instructional programs. As seen in Table 17, the initial intelligence measure is of decreasing value as a predictor of succeeding criterion performance. Conversely, the successive criterion test data and level-of-aspiration measures increased in predictive value. These findings suggest (as does Bunderson, 25) that a general intelligence (or reasoning) factor may be of greatest importance only for early stages of instruction. Thus, in constructing instructional models for optimizing a student’s path through a course, the implication is that weighting for general and task-specific factors should be differentially assigned and continually checked (to decrease the former and increase the latter) at appropriate choice-points during instruction.

PRACTICAL POTENTIAL OF THE PROGAMMED COURSE

Relationship of Content to the Parent Army Course

In order to evaluate most appropriately the practical potential of the programmed course, it would be desirable to be able to state the number and percentage of hours covered relative to that required by the total ADPS programming course presented at the Signal School. However, because the material selected was chosen to represent the basic fundamentals of computer programming and because the authors’ frame of reference for organizing did not necessarily coincide with that used by the instructors in the ongoing course, it would be extremely difficult to try to represent the finished programmed instructional product in this manner. As an alternative, it may be helpful to examine the relationship between the conceptual material presented in the programmed course and in the total ADPS course at the Signal School.

Concepts covered in the programmed course deal with internal data handling of the central processing unit (CPU). Also included is material on desk-checking and flow-charting. No input or output instructional materials were included. The number of commands included (11) represent roughly 27% of those in the parent course dealing with internal data manipulations. Viewed in terms of the proportion of such conceptual categories represented, the programmed course includes approximately 50% of those given in the ADPS course. Finally, if the basic logic of internal data handling is considered (i.e., within the CPU), the programmed course includes virtually the entire content. Thus encompassed are the simple movement of data from place to place in storage (although not without moving to an intermediate central location), arithmetic operations, comparing and sorting (general use of the loop concept), and some sophisticated programming techniques (e.g., use of index registers). All except the last category were involved in the experiments conducted with the programmed course.

Administration, Motivation, and Population Factors

Certainly the large percentage of dropouts among the volunteer subjects in Experiments 1B and 2 (57%) prevents a firm conclusion about the practical potential of the programmed course. That motivational factors as well as course difficulty might have been the cause for the number of dropouts was supported by the level-of-aspiration data (the differences in realistic expectation between those who dropped out and those who remained in the course) and the importance of the stimulus support (prompting or confirmation) factors as determinants of tendency to drop out.
A further complication to determining the course's practical potential was the fact that the administrative conditions under which the course was given were not those which obtain in the real world, whether it be in an Army school or a civilian school setting. Specifically, the students were volunteers and received no incentive in the larger study (Experiment 1B and 2) except a certificate at the end of the 14-week course indicating proficiency in the HumRRO computer programming fundamentals course. In Experiment 1A, on the other hand, the students met for three successive afternoons for a maximum of four hours per afternoon and were paid for their participation. Interestingly enough, these students performed better than did the other high school students in Experiments 1B and 2 in the comparable portion of the course.

Finally, the students in the large-scale study may not have been as intelligent as the target population of Army students (the mean ACB CL score of the high school students was 96, whereas the Army requirement for acceptance in the ADPS Course is 110).

After the large-scale experimentation, it was decided to investigate further the possible contribution of motivation, administrative procedures, and course difficulty to outcome by administering the course to a sample of enlisted personnel at Fort Gordon, Georgia (N=25). Such men presumably would be more representative of the target population for whom the course was originally constructed. The men chosen for the experiment had just finished a teletype operator's course (MOS 723) and were waiting to be shipped to their duty assignments. They were given six hours of instruction per day for five successive days. Their incentives were ball-point pens and cigarettes, allocated according to degree of proficiency. As in the large study, roughly half the students failed to complete the course, although again the general attitude on the part of the students toward the course materials was favorable. They felt that they would like this kind of course presented with the aid of an instructor. As in the larger study, the ACB CL scores of the dropouts were virtually identical to the scores of those who finished the course.

### Instructional Effectiveness

When attempting to evaluate the instructional effectiveness of the course, one must keep clearly in view the fact that the primary purpose of the overall study was to investigate a wide range of training techniques. Thus, it would be expected that only a few of the combinations would yield adequate proficiency, particularly as the training materials and criterion requirements became more complex. Thus, although the Duncan Range analysis (Table 10) appears to show very poor performance on the most complex portion of the course (Part V), the combination of lowest degree of stimulus support (especially 0% confirmation) still yielded a criterion mean close to 50% correct. The medians of the zero confirmation conditions (N=79) showed 81% correct on Part III; 73% on Part IV; and 48% on Part V. A further breakdown into variety or no-variety and degree of prompting as well as interactions with the treatments of Experiment 1B is not valuable since the number of subjects within each of these smaller groups would be much too small to yield meaningful data. Nevertheless, one can make a reasonable inference that at least some of these combinations would lower the median score for the entire 0% Confirmation Group averaged across all of these conditions.

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1 Under the current MOS structure, the teletype operator's title is Communications Center Specialist, and his MOS is 72B.
The tentative inference, then, is that the instruction was effective, but because of the overriding experimental goals of the study, coupled with the other factors noted herein, no exact statement is possible. Although no hard data are available on attitudes, it has been the impression of the course administrators and proctors that general reactions toward the programmed instructional nature of the materials were favorable.

While it seemed apparent that revision was required to simplify the course material, it was not completely clear that motivational factors could be ruled out as contributory to the resulting performance of the experimental students. One final point with regard to the contribution of administrative procedures to performance should be made. Because experimental control over student reading of the materials was of primary interest, all students were required to read one page at a time and not to turn back to previous sections whenever they were in difficulty. Obviously in a practical setting, the opportunity to review material already covered would be desirable. If in the experimental setting it would have been possible simply to measure the number of times a student returned to a previous page or, for that matter, turned ahead to other pages, it would have been perfectly acceptable to allow it. Because of the need for experimental control, however, and the impossibility of measuring the review the student might do, it could not be permitted.

**FINAL REVISION OF THE COURSE**

As a result of information obtained from the experimental situations, the materials were simplified and certain format features were added. The final version also incorporated implications from the experimental findings and the course was then completed by including a section on the use of index registers as the most complex portion of the instruction.

**Description**

In the revised course, the entire context remains oriented toward the writing of computer programs. That is, a concept is introduced and then a problem incorporating this concept is presented for the student to program. These problems were taken from actual computer programming problems encountered on the job. It is this problem-oriented approach in the course that makes it rather different from most of the other programmed booklets available.

Before each concept is presented, the student is given a preview of things to expect. Then, as he is introduced to the concept, he is given short completion questions with the answers in light type on pages opposite the questions (see Appendix C for sample pages). The problems to be programmed appear in a box-like format and the student is expected to answer the problem, whenever possible, without looking up the answer first. At the end of each section, the student is given a review and then led on to the next set of concepts.

As was noted previously, because a secondary objective of the research was to produce a programmed course available for use by the Army, the repertoire of commands and the symbolic language in which the computer programs are written have been chosen from material previously used by the Army to teach students how to program the MOBIDIC computer. The language—the FIELDATA Symbolic Language—not only represents a set of symbols interpretable by the MOBIDIC, but is sufficiently general that it largely applies to almost any other computer and to the English language (the addresses).

The Introduction to the course provides an overview of the concepts of computer programming and covers concepts of command and sample mnemonics,
address, the accumulator, memory locations, input and output, and computer functioning. There are periodic review materials and questions for the student and, finally, a short sample program.

The course proper is separated into four levels:

1. **Basic Operations** (five sections), includes an introduction to storage locations, the concept of a central work area, the movement of numbers from place to place, and simple arithmetic operations.
2. **Basic Looping** concepts are covered next (five sections), including general transfer commands, counting the loops, leaving the loops, and program preparation.
3. **Data Processing** (four sections) deals with address modification and address arithmetic (effective addressing), sorting and counting data into various categories, and multiple address modification.
4. **Advanced Techniques** for transferring data are given (five sections), including indexing.

In addition to writing many computer programs following the completion of each level, the student practices on problems within each section of the course.

**Evaluation**

The final revision of the course was administered successfully to seven college freshmen and six high school seniors. Of the college freshmen, four had scores of 90% or better on the final criterion test, two were in the high 80s, and one scored 77%. Median completion time was 26 hours, with daily sessions self-paced and lasting from 3 to 5 hours. The high school students scored slightly lower, 78% to 88%, with median course duration being 31 hours. It should be noted that the two highest scores (88%) in the high school sample were obtained by students in the bottom third of their senior class standing. Again, the general attitude of the students toward the course was favorable and they felt they had learned something that would be useful to them.

Apparently the revised version of the course was highly successful. It can be anticipated that the instruction would be successful in a military setting by virtue of the combination of experimentally effective training methods, simplified content, and administration procedures normally employed in military courses. However, no large-scale validation of the revised course to establish proficiency and failure rates in a military setting was undertaken, since this was not the principal purpose of the research.¹

**Suggested Utilization**

The ultimate question is how the revised programed course could best be utilized. The nature of the course content is such that it would be quite useful for any officer or enlisted man who needs to have some familiarity with computer programming, whether for administrative or supervisory duties or some allied operation activity.

The adequacy of the self-contained aspects of the programed instructional course has not yet been evaluated on a large scale. However, since the structure of the course is geared to actually writing computer programs—to learning by doing—it should serve both as a useful introduction to a full-scale ADPS programming course and as supplementary instruction for students who may be having difficulties with those portions of the course covered in the programed instructional version.

¹One potentially useful finding related to predictor validity was the fact that the Verbal score on the AGO correlated much higher with criterion performance ($r = .7$) than the Clerical score ($r = .25$). The Army now uses a combined CI score for course acceptance.
LITERATURE CITED
AND
APPENDICES
LITERATURE CITED


Appendix A

SAMPLES OF COURSE CONTENT AND PROBLEMS FROM EXPERIMENT 2

In these pages of sample course materials from Experiment 2, the material below and on the next two pages illustrates presentation of course content; the next three pages present three problems typical of the practice and test problems given the students, and the final three pages show the answer sheets for the three problems. These materials are from the Variety/Confirmation condition.

Data Processing: MULTIPLE CATEGORIZATION

Either TRZ or TRN can be used to sort addresses into two categories. But what if you want to sort into more than two piles? For example, suppose that each address in a series has a 1, a 2, or a 3 in it, and you want to know how many numbers there are of each type? The process is called multiple categorization. Here is a sample set of instructions for the sorting portion of data processing. Notice that it is the same type of sorting used in the subtract-sort-and-count problems, but that it includes just one additional instruction—the use of both TRZ and TRN.

CLA NUMBER
SUB TWO

(1) TRN TYPE1 If negative, the number was originally a 1
(2) TRZ TYPE2 If zero after subtraction, the number was a 2
(3) CLA TRIO If the number in the Accumulator is neither a -1
ADD ONE nor a 0, it must have been a 3 before subtraction,
STR TRIO and can be counted immediately following sorting.

In other words, clear and add the number (copy it into the Accumulator) and subtract a constant which will make it possible to branch on TRZ or TRN (2 in this example).

1. If the number was originally a 1, subtracting 2 results in a -1 in the Accumulator, which is a negative number. The TRN (Transfer if Negative) command then transfers the program down to Symbolic Location TYPE1 where the instructions which process the information coded by 1's is processed.

2. If the number was originally a 2, subtracting 2 results in a 0 in the Accumulator, a zero. The TRZ command then transfers the program to
   TYPE2.

3. If the number was originally a 3, the remainder in the Accumulator will be a -1, and instead of branching, the computer will perform the instructions next in order.
A supply depot maintains a two-word record on each vacuum tube in stock, stored in sequence relative to TUBE. The words are cost and location. The first word is coded with a 2 if the tube cost less than $5, with a 3 if it cost between $5 and $10, or with a 4 if it cost more than $10. Write a program to determine the number of tubes in each category. Store the answers in LOCOST, AVCOST, and HICOST. The total number of tubes in stock is in TOTUBE, which can be saved for the loop counter by storing in temporarily in COUNT.

Notice that data processing requires (1) subtraction of a constant, (2) sorting with both TRZ and TRN, and (3) TRU instructions to the test for completion after both types of addresses counted at the end.

Preliminary Description

Prepare COUNT
Zero LOCOST, AVCOST, and HICOST

Subtract and sort:

REPEAT CLA TUBE
SUB THREE
TRN LOW
TRZ MEDIUM

Count 1's:
add 1 to HICOST and store

LAST test COUNT for completion

modify TUBE
(add 2 to REPEAT)
TRU REPEAT

Count -0's:
MEDIUM add 1 to AVCOST and store
TRU LAST

Count -1's:
LOW add 1 to LOCOST and store
TRU LAST

STOP HLT
First we prepare the loop counter to be used later in the test for completion by checking TOTUBE to guarantee at least one tube and storing it in COUNT.

Since no other number needs to be saved for computation, we next "clean out garbage" from all locations to be used for storing answers by replacing any numbers that might be there with zeroes.

Since the word indicating the tube's location contains a 2, 3, or 4, we subtract 3 to make the numbers -1, 0, and +1. After the subtraction, a -1 remainder indicates a LOCOST tube, which the TRN command will detect and transfer the program down to Symbolic Location LOW, where these tubes are counted. Similarly, a 0 indicates an AVCOST tube, which the TRZ command will pick up.

If the number was neither a -1 nor a 0, the TRN and TRZ commands will not transfer the program. The remainder must have been a +1, indicating a HICOST tube.

TOTUBE contains the total number of tubes to be processed, but since we wanted to save that number, it was copied into COUNT, which we now use in the test for completion.

Since each tube has a two-word record, we must add 2 in address modification to get to the address containing information on cost for the next tube.

Having reached the bottom of the loop, we transfer back up to begin processing of the next tube.

The TRN command detected a -1, which means that the number was originally a 2 (before subtracting 3), and a 2 was the code number for a low cost tube.

Since the program branched out of normal order, we must transfer back up to finish out the loop.

A 3 in the word indicated an average cost tube. Subtracting 3 made it a 0, which the TRZ command detected. Having picked up an AVCOST tube, we count it here.

All tubes must be accounted for in the test for completion, whether they are counted right after the subtract-and-sort or down here at the end.

It would be a good idea to go over these two pages a few more times.
Problem 1

The Base Electronics Warehouse wants a program that will count the number of tubes used in January of last year and the number used in February. The results are to be stored in JAN and FEB.

The words for each tube are in memory starting at location VACUUM. The words are: part number, date received, shipment number, manufacturer, date tube was used, and place tube was used. TUBES contains the number of vacuum tubes in the warehouse. The month in which the tube was used is coded by number: 1 for January, 2 for February, 3 for March, and so on.

Locations CON1 and CON2 contain constants of 1 and 2, respectively. No other constants are available. Use HOLD as temporary storage for TUBES.

Use both the TRZ and TRN commands in writing this program. Write your preliminary description at the left first, paying special attention to the data processing portions.

Write the complete program below:

COMPUT

LAST

MONTH1

MONTH2

STOP

Turn to Page 32-1 for the correct answer.
Problem 2

Post Personnel wants a program that will count the number of men who have been in Alaska and the number who have been in Asia. The results are to be stored in ALASKA and ASIA.

The words for each man are in memory starting at location TROOPS. The words are: serial number, rank, dependent status, assigned unit, last overseas area, and MOS. POST contains the number of personnel on Post. The overseas area is coded by number: 1 for Alaska, 2 for Asia, 3 for Europe, and so on.

Locations K1 and K2 contain constants of 1 and 2, respectively. No other constants are available. Use SAVE as temporary storage for POST. Use both TR2 and TRN commands in writing this program.

Write your preliminary description at the left first, paying special attention to the data processing portions.

Write the complete program below:

```
MODIFY
DONE
NORTH
SOUTH
STOP
```

Turn to Page 30-2 for the correct answer. (Appendix-77)
Problem 3

A business firm wants a program that will count the number of men who scored between 91 and 100 on a screening test, and the number who scored between 81 and 90. The results are to be stored in EXCEL and GOOD.

The words for each man are in memory starting at location TEST. The words are: title, salary, dependent status, branch, test score, and health. MEN contains the number of men in the firm. Test scores are coded by number: 1 for 91-100, 2 for 81-90, 3 for 71-80, and so on.

Locations ONE and TWO contain constants of 1 and 2, respectively. No other constants are available. Use KEEP as temporary storage for MEN. Write your preliminary description at the left first, paying special attention to the data processing portions.

Write the complete program below:

```
CHANGE

OVER

FIRST

SECOND

STOP
```

Turn to Page 33-1 for the correct answer.  
(Appendix-78)
Answer to Problem 2, Page 29A

Post Personnel wants a program that will count the number of men who have been in Alaska and the number who have been in Asia. The results are to be stored in ALASKA and ASIA.

The words for each man are in memory starting at location TROOPS. The words are: serial number, rank, dependent status, assigned unit, last overseas area, and MOS. POST contains the number of personnel on Post. The overseas area is coded by number: 1 for Alaska, 2 for Asia, 3 for Europe, and so on.

Locations K1 and K2 contain constants of 1 and 2, respectively. No other constants are available. Use SAVE as temporary storage for POST. Use both the TRZ and TRN commands in writing this program. Write your preliminary description at the left first, paying special attention to the data processing portions.

This is the program:

```
CLA POST
TRZ STOP
STR SAVE
CLA ZRO
STR ALASKA
STR ASIA
MODIFY CLA TROOPS+4
SUB K2
TRN NORTH
TRZ SOUTH
DONE CLA SAVE
SUB K1
STR SAVE
TRZ STOP
CLA MODIFY
ADD K2
ADD K2
ADD K2
STR MODIFY
TRU MODIFY
NORTH CLA ALASKA
ADD K1
STR ALASKA
TRU DONE
SOUTH CLA ASIA
ADD K1
STR ASIA
TRU DONE
STOP HLT
```

Now continue your study with Page 29B. (Appendix-79)
Answer to Problem 1, Page 29

The Base Electronics Warehouse wants a program that will count the number of tubes used in January of last year, and the number used in February. The results are to be stored in JAN and FEB.

The words for each tube are in memory starting at location VACUUM. The words are: part number, date received, shipment number, manufacturer, date tube was used, and place tube was used. TUBES contains the number of vacuum tubes in the warehouse. The month in which the tube was used is coded by number: 1 for January, 2 for February, 3 for March, and so on.

Locations CON1 and CON2 contain constants of 1 and 2, respectively. No other constants are available. Use HOLD as temporary storage for TUBES. Use both the TRZ and TRN commands in writing this program.

Write your preliminary description at the left first, paying special attention to the data processing portions.

This is the program:

```
CLA TUBES
TRZ STOP
STR HOLD
CLA ZRO
STR JAN
STR FEB

COMPUT
CLA VACUUM+4
SUB CON2
TRN MONTH1
TRZ MONTH2

LAST
CLA HOLD
SUB CON1
STR HOLD
TRZ STOP
CLA COMPUT
ADD CON2
ADD CON2
ADD CON2
STR COMPUT
TRU COMPUT

MONTH1
CLA JAN
ADD CON1
STR JAN
TRU LAST

MONTH2
CLA FEB
ADD CON1
STR FEB
TRU LAST

STOP HLT
```

Now continue your study with Page 29A. (Appendix-60)
Answer to Problem 3, Page 29B

A business firm wants a program that will count the number of men who scored between 91 and 100 on a screening test, and the number who scored between 81 and 90. The results are to be stored in EXCEL and GOOD.

The words for each man are in memory starting at location TEST. The words are: title, salary, dependent status, branch, test score, and health. MEN contains the number of men in the firm. Test scores are coded by number: 1 for 91-100, 2 for 81-90, 3 for 71-80, and so on.

Locations ONE and TWO contain constants of 1 and 2, respectively. No other constants are available. Use KEEP as temporary storage for MEN.

Write your preliminary description at the left first, paying special attention to the data processing portions.

This is the program:

```
CLA MEN
TRZ STOP
STR KEEP
CLA 2RO
STR EXCEL
STR GOOD
CHANGE CLA TEST+4
SUB TWO
TRU FIRST
TRZ SECOND
OVER CLA KEEP
SUB ONE
STR KEEP
TRZ STOP
CLA CHANGE
ADD TWO
ADD TWO
ADD TWO
ADD TWO
STR CHANGE
TRU CHANGE
FIRST CLA EXCEL
ADD ONE
STR EXCEL
TRU OVER
SECOND CLA GOOD
ADD ONE
STR GOOD
TRU OVER
STOP HLT
```

Now continue your study after Page 29B. (Appendix-81)
Appendix B

LEVEL-OF-ASPIRATION SCALE

Before you continue your instruction, tell us what percentage you think you scored on the test you just completed: Make an X on the line for your estimate. The numbers are only guides. For example, if you think you scored 99%, your X would be close to the end of the line.

Now tell us what score you think you will make on the test in the next section: Remember, make an X wherever you think you will score.

DON'T FORGET YOUR NAME AT THE TOP OF THE PAGE
Appendix C

SAMPLES OF REVISED COURSE FORMAT

The samples in this appendix illustrate the content and format used in the
final revised version of the course. The first three pages are excerpts (non-
continuous) from the course, showing presentation of instructional content with
six practice problems. The following two pages are excerpts from the separate
answer booklet, showing the answers to the six problems.

Problem 1.1. There are two kinds of vacuum tubes in an
inventory, 6SN7 tubes and 6AQ6 tubes. Write a program
to compute the total value of both kinds, placing the
answer in TOTAL. The number of 6SN7 tubes is in STOCK1.
The number of 6AQ6 tubes is in STOCK2. Temporary stor-
age will be TEMP and TEMP+1. The cost of a 6SN7 is in
VALUE and the cost of a 6AQ6 is in VALUE+1. Store the
total worth of 6SN7 tubes in VALSTK and the total worth
of 6AQ6 tubes in VALSTK+1. Assume at least one tube of
each type. There is a 1 in KON. If you have to, use
COMPUT as symbolic location for the first looping pro-
gram, NEXT for the second, and SUM to get the total of
both. Use asterisks wherever possible.

Problem 1.2. This problem is like the preceding one,
except that the number of each type of tube is not known.
Instead, each tube has information on its type stored
relative to TUBE. Each location in the series has either
a 1 or a 0--a 1 to indicate a 6SN7 tube, and a 0 to mean
a 6AQ6 tube. The total number of all tubes is in STOCK,
which can be saved in TEMP. Assume at least one tube.
Use NEXT for sorting, LAST for the test for completion,
and COMPUT for computation outside the loop. Use aster-
isks wherever possible. VALSTK and VALSTK+1 will not be
needed. You can add VALUE into TOTAL in one subroutine
and VALUE+1 into TOTAL in another.

Symbolic Locations with Address Arithmetic

Tracing out a program that uses asterisks becomes a
little difficult, especially for someone else, when
the skips are much greater than 9 instructions. In
these situations, you are better off using a symbolic
location with address arithmetic.

TRU DONE+2 means, "Transfer to the instruction two
steps after symbolic location DONE."

What instruction would be performed after TRU OK-1 below?

CLA THIS
OK STR THERE
TRU OK-1
Use as few symbolic locations as possible in the following problems by (i) using the * for transfer of 9 steps or less, and (2) address arithmetic relative to a symbolic location for transfers of more steps.

Problem 1.4. There is information about the ages and ranks of enlisted men and officers starting at location INFO, in the following three-word format: enlisted man or officer, age, and rank. The first word is coded with a + to indicate an officer, or a - to indicate an enlisted personnel. Count the number of enlisted personnel in location TOTEN. The total number of personnel is in location MEN. A constant of 1 is in K1 and a constant of 3 is in K3. Use EM as symbolic location for counting. Use DATA to modify the record to be processed. (The + and - signs can be considered the same as positive and negative numbers.)

Problem 1.5. Headquarters wants to know the number of Second Lieutenants eligible for promotion to First Lieutenant at the end of this month. Eighteen months active duty in grade are required for promotion from Second Lieutenant to First Lieutenant. The data for officers are stored in 5-word records as follows: rank, serial number, months in grade on active duty, MOS, and assigned unit. Ranks for officers are coded by 1 for Second Lieutenant, 2 for First Lieutenant, and so on. The records are kept relative to RATING. PERSON contains the number of personnel. This number is not to be destroyed. Store it temporarily in HOLD. Assume at least one officer. An 18 is in TIME, a 1 is in KON, and a 5 is in KS. Store the number of eligible officers in UP. Use RANK to modify addresses referring to rank, LAST for the completion test, and SECOND for instructions referring to time in grade if the officer is a Second Lieutenant.
In effect, ADD DATA,IR2 says to copy DATA into a special temporary location (IR2) and there add to it the contents of that location (IR2). As IR2 contains the number 1, DATA+1 results. Thus, the complete instruction says the same thing as: ADD DATA+1.

Problem 2.1. Write an instruction that says the same thing as STR COST+1. Index Register 3 contains the number 1.

Problem 2.2. Write an instruction that says the same thing as STR BOOK+2. Index Register 1 contains the number 2.

The Comma

Why the comma?

It is needed to separate two address fields, the one that we have been using all along and a new one that is used in indexing.

Up to now, you have been working with symbolic location fields, operational codes (the commands), and a single address field. For example:

<table>
<thead>
<tr>
<th>Symbolic Location</th>
<th>Op. Code</th>
<th>Address Field</th>
</tr>
</thead>
<tbody>
<tr>
<td>REPEAT</td>
<td>ADD</td>
<td>COST</td>
</tr>
</tbody>
</table>

The address field you have been using is called the First Address Field. All addresses that we have used previously appeared in the First Address Field.

Indexing uses another address field, known as the Second Address Field. And, thus, the comma. Anytime more than one address field is used, a comma is required to keep them separated. Hence, the comma:

ADD DATA,IR2

What is the address field for DATA in the instruction above? IR2?
ANSWERS TO PROBLEMS OF PHASE III: DATA PROCESSING

Problem 1.1.

CLA REPEAT
ADD ONE
STR REPEAT

Problem 1.2.

CLA HUBERT
ADD DIGIT
STR HUBERT

Problem 1.4.

CLA ZRO
STR FINAL

REPEAT
CLA VALUE
ADD FINAL
STR FINAL

CLA REPEAT
ADD K
STR REPEAT
TRU REPEAT

Problem 1.5.

CLA ZRO
STR EVERY

AGAIN
CLA COST
ADD EVERY
STR EVERY

CLA AGAIN
ADD TWD
STR AGAIN
TRU AGAIN

Change VALUE to VALUE+1 so that on the next loop VALUE+1 will be added into FINAL.

COST is modified to COST+2 for the next loop.
Problem 2.1.

CLA ZRO
STR BONUS

CHECK CLA PUSH
TRZ TEST
CLA BONUS
ADD UNIT
STR BONUS

TEST CLA MEN
SUB UNIT
STR MEN
TRZ STDP

CLA CHECK
ADD UNIT
STR CHECK

TRU CHECK
Looping.

STDP HLT

Problem 2.2.

CLA MEDICS
STR TEMP

CLA ZRO
STR CALLS

AGAIN CLA DOCTOR
TRZ OUT

CLA CALLS
ADD ONE
STR CALLS

OUT CLA TEMP
SUB ONE
STR TEMP
TRZ STOP

CLA AGAIN
ADD ONE
STR AGAIN

TRU AGAIN

STDP HLT

Copy in a number.
If it's a zero, skip to the test for completion.
If it's not zero, count the salesman here; he must have made at least one sale.

Test for completion.

Address modification.

Looping.
in continuing research into the technology of training, a study was undertaken to devise guidelines for applying programed instruction to training courses that involve the learning of principles and rules for use in problem solving. As the research vehicle, a portion of the material in the Army’s ADPS Programing Specialist Course was programed to explore several different factors in using automated instruction to teach computer programming. Experimental versions of the course were administered to over 900 subjects in various experimental groupings. Criterion and retention tests based on actual job problems were used to measure subjects' performance, along with in-training measures. Results in a series of prompting/confirmation variations indicated that giving subjects extensive stimulus support during training helps motivate them and improves scores during training, but hampers them in using what they have learned. Requiring subjects to fully write out rules during training hindered them in developing problem-solving skills applying these rules; however, using mnemonics (writing only the names of the rules) during training aided subjects in retaining what they had learned, particularly for more complex material. Working with a variety of practice problems facilitated the learning of problem-solving skills.
<table>
<thead>
<tr>
<th>KEY WORDS</th>
<th>LINK A</th>
<th>LINK B</th>
<th>LINK C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computer Programming</td>
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<td>Problem Solving</td>
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<td>Programmed Instruction</td>
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<td>Variety of Practice</td>
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<td>Verbalization</td>
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DISTRIBUTION LIST

1. SPEC HAFORD SC FT DRAG ON AFT
2. USL SVC HAFORD SC FT MCLUSKEY FT MERRELL
3. ARMY SIG FT SC FT HOPFNER FT LIND FT DUD
4. COMUS USA ARMY SC FT FORD
5. SECUS USA ARMY SC FT HENDERSON.ARN
6. COMUS WORKING ARMY COMUS SC FT MCCLELLAN
7. ARMY AVOCATIONAL FT MCCURDY FT MCMILLIAN
8. COMUS ARMY SC FT MELTON FT MEDEN
9. ARMY BP SC FT MEYERS FT MCMURRY
10. COMUS ARMY SC FT MILTON FT MCMURRY
11. ARMY BP SC FT MILLER FT MCMURRY
12. COMUS ARMY SC FT MILTON FT MCMURRY
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