INTERACTION OF COGNITIVE ABILITIES WITH AVAILABILITY OF BEHAVIORAL OBJECTIVES IN LEARNING A HIERARCHICAL TASK BY COMPUTER-ASSISTED INSTRUCTION

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13. ABSTRACT

The purpose of this study was to investigate what effects the availability of behaviorally stated objectives would have on the learning process. It was hypothesized that objectives would serve as orienting stimuli which dispose the student to attend to, process, and organize relevant aspects of displayed information in accordance with the stated objectives. Therefore, the presentation of objectives was expected to reduce the number of examples and amount of time required to learn the task, facilitate performance on transfer retrieval criterion measures, and reduce the requirements for memory and reasoning abilities.

The learning task consisted of a hierarchical imaginary science called the Science of Xenograde Systems which was presented by an IBM 1500/1800 Computer-Assisted Instruction System to 130 introductory educational psychology and science education students.

Before learning the task, all Ss were given a battery of six cognitive ability tests comprised of three existing published tests and three task-relevant tests developed for this study. The tests were selected to measure abilities postulated to have specific relationships to task performance.

The Ss were randomly assigned to an Example-Only group, an Objective-Example group, a Rule-Example group, and an Objective-Rule-Example group. All Ss were required to meet a minimum criterion performance at each level of the task before proceeding to the next level.

14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Objectives						
Transfer						
Rule Learning						
Discovery						
Regression Analysis						
Computer-Assisted Instruction						
Hierarchical Task						
Cognitive Abilities						

13. Abstract (cont'd)

A significant rule effect was found on the number of examples and the total time required to complete the task with the rule groups needing less time and fewer examples than the no-rule groups. Objectives significantly reduced the number of examples required to learn the task, but they did not reduce total latency. An analysis of the component latency measures revealed that objectives either increased or had no effect on display latency but significantly reduced test-item-response latency. Apparently the objective treatments affected the efficiency and effectiveness of the S's information processing and thereby facilitated his performance on the criterion-test items based on the objectives.

No significant differences were found between treatments on the post or retention tests, but a significant rule effect in favor of the rule groups was found on the transfer test.

The battery of cognitive tests was factor analyzed, and a two-factor varimax solution was obtained yielding the factors of reasoning and associative memory. Regression analyses of the individual ability test scores, factor scores, and the criterion measures were conducted. Significant ability by treatment interactions were obtained using test-item-response latency as criterion and reasoning factor scores, plus individual reasoning tests as covariables. Reasoning had a high negative relationship to test-item-response latency for Ss in the Example-Only group, but this relationship was significantly smaller for Ss in the remaining groups. Therefore, the presentation of objectives and/or rules effected a reduction in the requirement for reasoning ability.

On the basis of the results of this study it was concluded that objectives have orienting and organizing effects which dispose students to attend to, process, and structure relevant information in accordance with the given objectives.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Statement of the Problem

It seems that even though educational psychologists (Bobbitt, 1924; Tyler, 1951; Bloom, 1956) had been stressing the need for precise statements of instructional objectives for many years, it was not until Mager (1961) published his book on preparing objectives that the educational community started to take instructional objectives seriously. Since Mager's book many people have mounted the bandwagon and filled the literature with articles extolling the virtues of instructional objectives. However, it is disappointing to find that most of these articles merely rehash what Mager had previously stated. A few have made additional contributions. Gagné and his collegues (Gagné, 1962; Gagné & Paradise, 1961) have proposed a method of hierarchical task analysis based upon the precise statement of instructional objectives while Popam (1969) has set up a national clearing house for behaviorally stated objectives at UCLA. There are also those (Eisner, 1967a; Ebel, 1967; Kliebard, 1968; Jackson & Belford, 1965) who question the value of objectives and feel they might actually be a hindrance to the design of instruction. After an interchange of views in the literature, Eisner (1967b) responded to his critics by pointing out that the contribution of educational objectives to curriculum construction, teaching, and learning is an empirical problem, while most articles that have been written are merely logical arguments. He further claims that the little research that has been done is at best inconclusive.

The purpose of this study was to investigate what effects the presentation of behavioral objectives would have on the learning process. Specifically, this study was conducted to further clarify: 1) how the presentation of objectives would affect Ss' performance on criteria measures, 2) how other task characteristics would vary the effects of presenting objectives, and 3) how individual aptitudes interact with the presentation or non-presentation of objectives.

The literature relevant to these issues incorporates the overlapping areas of behavior objectives, task analysis, and aptitude by treatment interactions.

The Effect of the Presentation of Objectives

Most of the studies which investigated the effects of objectives were concerned with the specification of objectives to aid the instructional designer or the teacher. Only those studies which have investigated the effects of presenting objectives to the students as part of their instruction will be reviewed here. Mager and McCann (1961) conducted a study using engineers in an industrial training situation. One group of Ss were given a specific statement of the training objectives and then allowed to instruct themselves by any means or sequence they desired. The second group of Ss were allowed to select the content in accordance with a self assigned sequence. The third group of Ss received a sequence of content controlled by the instructor. The results of this study showed that the training time for the group given the objectives and allowed to instruct themselves was reduced by as much as 65 percent without a loss in performance. Because of the lack of careful control of conditions in this study, it is not possible to conclude that this dramatic effect was solely due to the presentation of objectives to the students. However the results do suggest that the presentation of objectives may be a great tool for the individualization of instruction.

Mager and Clark (1963) cited a study (Allen & McDonald, 1963) where Ss were taught how to play a game by one of two instructional methods. One group was taught by a linear program while the second group was given a list of objectives and allowed to ask the instructor questions. The group given the objectives and allowed to ask questions learned the game in half the time required by the linearly sequenced group. However, the linear program group's terminal performance was slightly better than that of the objective group. The effect of objectives found in this study is also confounded because the objective group was not given the same sequence of content as the linear program group.

Task Analysis

It cannot be assumed that any effect found by presenting objectives to students learning one task will be replicated on different tasks. It is, of course, impossible in any single study to replicate an effect on all possible tasks. A more economical approach would be to analyse a given type of task in an attempt to hypothesize what different effects would be expected from differences in task characteristics. Given a learning task which contains objectives as part of the task, one can ask how the availability of the objectives will affect the student's learning activities or information processing? It was hypothesized that objectives, presented to the student before the material to be learned, would serve as orienting stimuli which dispose the student to attend to and process, relevant aspects of the material. Thus objectives were hypothesized to result in some of those behaviors termed by Rothkopf (1965) as "mathemagenic behaviors.". Much research has been done concerning the effects of other orienting stimuli such as formal prompts (Anderson & Faust, 1967) and questions (Frase, 1969). However, in addition to having a selective or focusing effect analogous to that found with pre-questions (Frase, 1969), it was further hypothesized that objectives would also affect the way the learner organizes the material to which he attends. This organization should affect the way the material is stored and its availability for different types of retrieval. Guilford (1968) distinguishes between two types of retrieval: retention retrieval and transfer retrieval. Retention retrieval is merely a playback of what is currently in storage while transfer retrieval is the selection of relevant material that will assist in the solution of a problem in a different context. It was hypothesized that objectives could affect S's cognitive organization of information so as to aid retention retrieval and/or transfer retrieval depending on how the objective was formulated. For example the objective: (Given the value of the Force Field, Alphon Count of the Nucleus and the distance of the satellite from the nucleus, the student should be able to predict the distance at the next time) should not only focus the student's attention on the relevant information but should also affect the way this information is organized or processed so that it can be used in a new or transfer situation to make predictions. However, the mere statement of a rule: (The decrease in distance between each time is equal to the product of the Force Field and Alphon Count of the Nucleus) does not give the student a clue as to how the material will be used or should be organized to facilitate its use. Thus, properly stated objectives may affect the student's information processing and give him a transfer and/or retention set.

Based on the above argument, it was hypothesized that the presentation of objectives to the student would first dispose the student to attend to the material related to the objective, and therefore reduce the total time and number of examples required to meet the objective, and second, give the student a transfer set which would enable him to score higher on transfer retrieval criterion measures.

These effects, however, would be tempered or interact with the other properties of a given task. If objectives are inserted in a task which otherwise has minimal orienting or organizing stimuli, then the above hypothesized effects should be very evident. On the other hand, if objectives are inserted in a task which has other effective orienting stimuli, such as rules or pre-questions, then the objectives would be somewhat redundant and have a more subtle effect. However, the organizing effect of objectives should be evident even when other orienting stimuli are available.

Relationship of Cognitive Abilities to Task Performance

Recently many investigators have found a study of the relationship between cognitive abilities and learning performance to be very helpful in understanding the effect of task variables on the learning process. Ferguson (1954; 1956) was one of the first to propose a rationale behind this approach. He assumed that abilities were patterns of behavior which had become relatively invariant because of overlearning. He further suggested that abilities may transfer differentially and exert their effects on learning tasks differentially. This approach received further emphasis when Cronbach (1957) recommended that investigators narrow the gap between correlational and experimental psychology and study the interaction between abilities and treatments. Bunderson (1967) conducted a study to investigate the relationship between abilities and performance in a concept learning task at different stages of practice. By analysing the task, Bunderson developed a conceptual model involving information-processing constructs and postulated three higher-order processes: a problem analysis process, a search process, and an organization process. Thirty mental tests were chosen for their relevance to the model and were administered to the Ss. The test scores were factor analyzed, and ten factors were interpreted. The performance scores at different stages of practice on the concept-attainment tasks were located within the factor structure by a factor extension procedure. The results revealed that the abilities did transfer at different stages of practice, giving support to the assumption that the abilities related to those processes required at a given stage would transfer at that stage of practice.

Dunham and Bunderson (1969) carried the approach one step further to discover if the relationship between cognitive abilities and performance in a concept learning task could be altered by manipulating a task variable. They argued that if measures of a cognitive ability tap an underlying intellectual process then the relationship between the ability and task performance must be due to an aspect of the task which requires that ability. Thus, if a task variable is manipulated, the relationship between the ability and performance on the task may be changed. To test for a shift in ability relationships one group of Ss was given the decision rules for solving the concept problems, while a second group was not given the decision rules. Performance scores on the concept problems were extended into the factor space of six cognitive abilities considered to be relevant to the task. The results showed that the two conditions required the use of different abilities. A discriminant analysis of solvers from non-solvers revealed that Ss with one ability succeeded under one condition, while Ss with a different ability succeeded under the other condition. Thus, it was argued that "...the manipulation of the instructional variable resulted in a change in the nature of the information processing which occurred in the two groups."

In an attempt to bridge the gap between the laboratory and the classroom Bunderson, Olivier, and Merrill (1970b) used an imaginary science called the Science of Xenograde as a hierarchical learning task to study the relationship of cognitive abilities to the manipulation of a task variable. Before learning the task, all Ss were given a battery of cognitive tests. The Ss were then randomly assigned to two groups. Group I received a rule plus example instructional treatment while Group II received an example-only instructional treatment. All Ss received additional examples of a rule until they were able to pass constructed response test items on the rule. The battery of cognitive tests were factor analyzed and regression analysis of the factor scores and the criterion, number of examples, were conducted. The results showed that memory and reasoning were related to the number of examples required by the example-only group but not related to the number of examples required by the rule-example group. Thus, by manipulating a task variable it was possible to vary the nature of the learning process such that the constraints of memory and reasoning abilities were minimized.

Studies, such as those cited above, which investigate the relationship of abilities to task performance have other important implications besides helping to understand the effect of task variables on the learning process. The relationships between abilities and performance also have important implications to the design of instruction. Snow (1969) argued that if we seek to individualize instruction so that each individual's performance is maximized on a given set of criteria, then we must search for evidence that it is worthwhile to instruct students differentially and discover those variables which will allow us to make classification decisions that will lead to improved instructional outcomes.

Based on the results of the studies cited above it was hypothesized that a manipulation of the presentation of objectives to the students would exert an effect on the relationship between cognitive abilities and task performance. Analysis of such ability by treatment interactions would further reveal the actual effect of objectives on the learning process.

An analysis of the information processing required to learn the task used in this study suggested that the following hypothesized processes would be required by <u>S</u>s who receive only examples:

1. Formation of a hypothesis as to what parts of an example are relevant;
2. Inference of a rule which determines the relevant relationships in the example;

3. Application of the inferred rule to predict entries in a new example;
4. Recall past instances or examples of a rule; and
5. Conjuntivė utilization of several inferred rules to make correct predictions.

On the basis of the above analysis it was hypothesized that the abilities or processes of induction, associative memory, and general reasoning would be highly related to task performance for Ss in an example-only treatment group.

It was hypothesized that the presentation of objectives in addition to examples would allow Ss to focus on the relevant parts of an example, thus facilitating the inference process and reducing its relationship to task performance. This focusing effect would also reduce the importance of associative memory since fewer parts of an example would need to be recalled when studying future examples of the same rule. The organizing effect of objectives would also reduce the requirement for general reasoning.

If rules plus examples are presented to the Ss, it was hypothesized that the role of induction and associative memory would be reduced since the rule would eliminate the need to infer a rule or recall past examples. The role of general reasoning would also be reduced because of the additional structure provided by the precise statement of the rule governing the relationships demonstrated by the example.

If both objectives and rules are presented to Ss, it was expected that the relationships between task performance and the abilities of induction, associative memory, and general reasoning would be reduced as when only objectives or rules are included in the task. There may even be an additive reduction in the role of these abilities, although such an effect is not expected to be significant.

Role of Objectives in the Learning by Discovery Issue

In a very well known article Bruner (1961) hypothesized that learning by discovery allowed the student to organize those things which he learned in such a way that memory processing and transfer retrieval would be facilitated. The research which has been done (Wittrock, 1966) in an attempt to prove or disprove this hypothesis has produced conflicting results. Most of this research has suffered from problems in design and the assumptions that all students learn best by one method and that the said method is best no matter what task is to be learned. Ausubel (1964) argued that these assumptions are not plausible, and that few students are sufficiently brilliant to discover every thing they need to know. He further claimed that the miracle of culture is made possible only because it is so much less time consuming to communicate and explain an idea meaningfully to others than to require them to rediscover it by themselves.

In addition to the results cited in the previous section, Bunderson et al., (1970) found that when both groups (rule-example vs. example-only) learned the hierarchical task equally well, the example-only group took significantly more examples to reach criterion than the rule-example group, and that there was no significant difference between the groups performance on either a retention test or a transfer test.

Therefore, even with more examples, the example-only group did not show superior performance. However a significant interaction ($p < .01$) of reasoning factor scores with rule-example vs. example-only treatments was found using number of examples as criterion. These results indicate that some students with high reasoning ability performed better under the example-only treatment than under the rule-example treatment. In as much as the regression lines crossed at the high end of the range of reasoning abilities, the contention by Ausubel (1964), that we should not attempt to structure the learning environment of the non-exceptional child in terms of the educational objectives and teaching methods that are appropriate for a few, is supported.

Even though the study cited above suggests that, for most students, learning by discovery not only does not produce superior performance on retention and transfer, but is also more time consuming than rule instruction, the question remains whether these results would be changed by the presentation of objectives to the student. Most educators would agree in principle with Ausubel (1964) that before students can discover concepts and generalizations with reasonable efficiency, they must be given problems which are structured and organized in such a way as to make discovery possible. Few students would be able to make sense out of masses of raw data. Based on the argument that objectives have a focusing and organizing effect, it was hypothesized that if specific objectives were given to a student learning by discovery, they would reduce his search time and allow him to organize relevant information in such a way as to enable him to have greater transfer retrieval. As argued in the previous section, the presentation of objectives would also reduce the strain which learning by discovery places on the processes of induction and general reasoning.

Statement of Hypotheses

In the above sections several hypotheses were stated concerning the possible effects the presentation of objectives would have on the learning process. The following is a summary of the hypotheses made in this study.

1. No differences were expected between groups on the posttest since all Ss received additional examples until a minimum criterion performance was reached.
2. It was expected that the significant reduction in the number of examples required by a rule group as compared to an example-only group in earlier studies would be replicated.
3. In as much as the total time required to complete the task was expected to have a high positive correlation with the number of examples required to finish the task, it was further hypothesized that those groups who received statements of the rules would require significantly less time to learn the task than those groups who did not receive rules.
4. It was hypothesized that the presentation of objectives would significantly reduce the number of examples and the amount of time required to complete the task. It was hypothesized that this reduction in time and examples would be greater when objectives were added to a task with no other orienting stimuli than it would be when objectives were added to a task with other orienting stimuli such as rules.

5. It was expected that the non-significant differences between a rule group and an example-only group on transfer test scores found in earlier studies would be replicated.
6. It was hypothesized that a treatment group which received objectives in addition to examples would score significantly higher on both retention and transfer tests than treatments groups which received only examples or rules plus examples.
7. It was hypothesized that the presentation of objectives and/or rules in addition to examples would significantly reduce the relationship between task performance and scores on memory, induction, and general reasoning cognitive ability tests.

METHOD

Subjects

The 160 Ss who participated in this study were taken from four sections of an introductory educational psychology course and three sections of a science education course at The University of Texas at Austin. All Ss were required to participate as a class assignment. Only 131 of the original Ss completed all three phases of the study; however, the data reported in this paper are based on only 130 Ss. During the original data analyses, it became apparent that the data for one S were highly discrepant from those of all other Ss. Her scores on the ability measures were consistently low, and she required 14 more examples and twice as much time to complete the task as any other S. Her scores on the post, retention, and transfer tests were also very low. Because of the highly discrepant nature of this S's data, they were excluded from the final data analyses. Without the exclusion of this outlier, the results would have been spurious.

Ability Measures

The studies reviewed in a previous section (Bunderson, 1967; Bunderson & Dunham, 1969; Bunderson et al., 1970b) were conducted to investigate the relationships of cognitive abilities to task performance. In these studies the learning tasks were analyzed to establish what cognitive processes were required to perform the tasks, and existing published tests were analyzed in order to select those which supposedly measured these cognitive processes. However, Bunderson (1969b) has argued that it may be more profitable to define and develop new measures which are more task relevant to assess the actual processes required by a given task. In this study, an effort was made to investigate further the validity of Bunderson's argument by comparing the predictive power of three new task relevant tests developed by this author to that of three additional ones selected from existing published tests. The three published tests were selected from the Kit of Reference Tests for Cognitive Factors (French, Ekstrom, & Price, 1963). The First and Last Names Test was selected to measure associative memory; the Letter Sets Test was selected to measure induction; and the Ship Destination Test was selected to measure general reasoning.

As mentioned above, three new tests were developed for this study in order to assess directly the actual processes required by the task. Each of these new tests required the Ss to process the same type of information as must be processed in the learning task, while the published tests required similar processes on information not related to the task. The First and Last Names test required the memorization of names, while the learning task and the new memory test (Memory of Number Series Test) both required the memorization of number series. The learning task and the new induction test (Bi-Column Number Series Test) both required the inference of rules from related columns of numbers while the Letter Sets Test required the inference of rules based on sets of letter combinations. The new general reasoning test (Tote Mobile Test) required the structuring and application of rules which were isomorphic to those found in the learning task. The instructions and sample items from the new task relevant tests may be found in Appendix G.

Experimental Task and Materials

The hierarchical learning task used in this study was an imaginary science called the Science of Xenograde Systems. The use of an imaginary science assured that none of the Ss had any previous experience with the task and eliminated the necessity of pretesting and discarding Ss due to prior knowledge of the task. Since the structure and content of the Science was similar to that of formal science topics, the generality of the results was increased. The initial version of the Science was developed by Carl Bereiter at the Training Research Laboratory, University of Illinois, for use in studying group interaction problems. This skeleton version was further expanded and developed by David Merrill (1964). Merrill's version of the Science was simplified,and an instructional program for presenting the task on the IBM 1500/1800 Computer-Assisted Instruction System was designed by this author and William Olivier according to an instructional design model developed by Bunderson (1969).

In the current version of the Science, a Xenograde System consists of a nucleus with an orbiting satellite. The satellite is composed of small particles called alphons which may also reside in the nucleus. Under certain conditions, a satellite may collide with the nucleus. When such a collision occurs, a "blip" is said to have occurred, and the satellite may exchange alphons with the nucleus. The subject matter of the Science deals with the principles or rules by which the activity of satellites and alphons may be predicted.

The terminal objective of the task required that Ss predict and record the state of the alphons and satellite of a Xenograde System at successive time intervals given the initial state of the System at time zero. The sub-objectives and hierarchical sequence for presenting the principles or rules of the Science were determined by an analysis of an efficient information processing algorithm for performing the terminal behavior. This analysis entailed the determination of a series of ordered steps comprising an algorithm which S would use to perform the terminal behavior. The next step of the analysis entailed the specification of the exact information which would be required by S in order to make a correct response at each succeeding step of the algorithm. The sub-objectives of the task were then developed to correspond with the steps of the algorithm, and the sequence for presenting the principles or rules (information) required to perform the sub-behaviors was made to correspond with the order of the steps.

The instructional program consisted of ten modules corresponding to the ten steps of the algorithm. The materials for each module included a statement of a sub-objective, a statement of a rule, five examples of the rule, and five short constructed response tests. The examples were in the form of partial Xenograde tables which showed the activity and relationships of a Xenograde System at several points in time. The latter part of Appendix B contains a sample Xenograde table with an explanation of how it is to be interpreted. A sample test can be found in Appendix C, and a statement of the sub-objectives and rules of the Science are found in Appendix A. A printed instruction booklet was also provided which contained an introduction to the Science, the purpose and justification of the course, instructions on reading Xenograde tables, and a treatment-specific explanation of the procedure for learning the task. A sample booklet is found in Appendix B. The method used for presenting these materials is discussed in the procedure section. A more complete description of the task and copies of the examples and test items may be found in Bunderson, Olivier, and Merrill (1970a).

Dependent Measures

Posttest--Retention Test. In previous studies (Bunderson et al., 1970b; Olivier, 1970) using this task, the posttest was designed to provide corrective feedback to the Ss while taking the test. This was done to prevent cumulative errors. Since Olivier (1970) found that this feedback had an instructional effect, a new posttest and retention test were developed. The posttest and retention test in this study were parallel forms with constructed response test items which required Ss to predict the successive state of the alphons and satellite of a Xenograde System by making entries in a Xenograde Table. These entries could be determined by using the rules of the Science and the given previous entries of the table. The items were sequenced so as to simulate the processing of a continuous algorithm, but each item was independent to avoid the necessity of providing corrective feedback. Appendix D contains examples of instructions and items for the post and retention tests.

Transfer Test. The transfer task consisted of a booklet containing two Xenograde Tables and 24 constructed response test items. The Ss were required to infer three higher-order rules of the Science from the tables and made predictions based on the inferred rules. The transfer test score was the total number of correct predictions made by S. Instructions and sample items for the transfer test are found in Appendix E.

Equipment

The instructional program was written in the Coursewriter II language and presented to the Ss by the IBM 1500/1800 Computer-Assisted Instruction System. The rules and objectives of the Science were displayed on the IBM 1512 random access image projector, while the examples of the rules were displayed on the cathode ray tube of the IBM 1510 instructional terminal. The use of a computer-assisted instruction system to present the instructional material made it possible to run up to seven Ss at one time while maintaining tight control over the variable stimulus events for each S and simultaneously recording accurate latencies and responses.

Procedure

The six ability tests were administered to all Ss in several group sessions. Immediately preceding the testing, a short lecture was given to the Ss to explain the value of their participation in the study and give an introduction to computer-assisted instruction. The Ss were randomly assigned to four groups: an Example-Only group (n=32), an Objective-Example group (n=33), a Rule-Example group (n=32), and an Objective-Rule-Example group (n=33). Fig. 1 is a graphical representation of the 2 x 2 factorial design formed by these groups. Following the testing session all Ss made individual appointments for two sessions, separated by two weeks, at the Computer-Assisted Instruction Laboratory.

OBJECTIVES	RULES	
	NO	YES
NO	EXAMPLE ONLY "X" (n = 32)	RULE EXAMPLE "R" (n = 32)
YES	OBJECTIVE EXAMPLE "O" (n = 33)	OBJECTIVE RULE EXAMPLE "RO" (n = 33)

Figure 1.--2 x 2 Factorial design used in this study.

During the first session, all Ss first received a printed instruction booklet corresponding to their group assignment and were instructed and tested on the use of the terminal. Next, the Ss learned the Science and took the posttest.

In learning the Science, Ss in the Example-Only group received an example of the first rule of the Science displayed on a cathode ray tube. After studying the example each S responded to a three item constructed response test where he was required to predict certain values using the rule inferred from the example. If the S responded correctly to two out of the three test items he was given an example of the next rule in the sequence; otherwise, he was given another example of the same rule followed by another three item test. This sequence of new examples followed by a test continued until the S responded correctly to two out of the three items or received five examples. The task was completed after all 10 rules of the Science were learned to the required criterion.

The Ss in the other three groups learned the science by the same basic procedure except for the following treatment differences: The Objective-Example group was shown a statement of a sub-objective on the image projector while the corresponding example was displayed on the cathode ray tube; the Rule-Example group was displayed a statement of the rule corresponding to each example; and the Objective-Rule-Example group received both the objective and the rule in addition to the example.

Two weeks after their first session, all Ss returned to the laboratory and took the retention and transfer tests.

RESULTS

Descriptive Statistics

In addition to total scores on the six cognitive ability tests, posttest, retention test, and transfer test mentioned in the previous section, data were obtained for each S on the following criteria: total number of examples required to learn the Science, display latency, test-item-response latency, and total latency. Display latency was the total time S spent studying the examples, and depending upon S's treatment group, the corresponding rules and/or objectives. Test-item-response latency was the total time required by S to respond to the three-item tests following each example display. Total latency was merely the sum of the display and test-item-response latencies. Display and total latency data for three Ss were lost. Therefore, all analyses on these criteria are based on a n = 30 for the Example-Only group and a n = 31 for the Objective-Example group. An intercorrelation matrix of all criterion variables is found in Table 23 of Appendix H.

The descriptive statistics and reliabilities of the ability tests are found in Table 1. Time constraints made it impossible to administer parallel forms of these tests. The reliabilities were therefore estimated using the Kuder-Richardson formula 20 (KR-20). These were not pure speeded tests, but they were timed, and all Ss were not able to attempt all items in the time allowed. Since the reliabilities estimated by KR-20 may in some cases be higher than would have been obtained from alternative forms, the communality is reported as a lower-bound estimated of the reliability.

The reliabilities of the posttest, retention test, and transfer test are presented in Table 2. These reliabilities were also estimated using the Kuder Richardson formula 20; however, none of the criterion tests were timed. The correlation between the posttest and retention test, which were parallel forms administered two weeks apart, was .82.

The battery of cognitive ability tests were factor analyzed, but consistent with previous findings (Bunderson et al., 1970b), it was not possible to separate out the three factors of associative memory, induction, and general reasoning. Therefore, a two-factor varimax solution which yielded the factors of reasoning and associative memory is presented in Table 3. The reasoning factor is marked by the two induction and the two general reasoning tests. An intercorrelation matrix of the six ability tests is found in Table 4. The correlations between the ability covariables and the criterion measures within each treatment groups may be found in Table 24 of Appendix H.

Table 5 contains, by treatment group, the squared multiple correlations between three different subsets of the battery of cognitive abilities and each of the seven criterion measures used in the present study. The first row of each part contains the squared multiple correlations between the full battery of tests and each criterion based on the Ss in each respective treatment group. The second row of each part contains the squared multiple correlations between the three published tests and each criterion while the third row of each part contains the squared multiple correlations between the three new task relevant tests developed for this study and each criterion. In general, the subset containing the task relevant tests correlates higher on most of the criteria than does the subset of published tests for all treatment groups except the Rule-Example group. For the Rule-Example group, the correlations between the criteria and the published tests are generally higher than those between the criteria and the task relevant tests.

Table 1

Descriptive Statistics of Ability Measures

Tests	Number of Items	Means	SD	Reliability (KR-20)	Communality
Memory of Number Series (MA)	15	6.8	3.0	.69	.73
First and Last Names (MA)	15	11.6	3.4	.83	.72
Bi-Column Number Series (I)	15	4.1	1.7	.53	.37
Letter Sets (I)	15	10.4	2.1	.57	.53
Tote Mobile (R)	15	6.4	2.2	.73	.58
Ship Destination (R)	24	13.6	4.1	.85	.68

Table 2

Reliabilities of Post, Retention, and Transfer Tests

	Post	Retention	Transfer
Reliability (KR-20)	.92	.93	.80

Table 3

Varimax Rotation Factor Matrix[a]

Tests	Factor Loadings	
	Reasoning Factor	Associative Memory Factor
Memory of Number Series	1877	8336
First and Last Names Test	0078	8465
Bi-Column Number Series	6001	0802
Letter Sets	7006	1954
Tote Mobile	7458	1607
Ship Destination	8191	-1103

[a]Decimal points are omitted.

Table 4

Intercorrelations of Six Cognitive Ability Tests[a,b]

Tests	1	2	3	4	5	6
1. Memory Number Series (MA)	1.00	45**	12	31**	23**	07
2. First and Last Names (MA)		1.00	12	07	14*	02
3. Bi-Column Number Series (I)			1.00	28**	28**	34**
4. Letter Sets (I)				1.00	39**	41**
5. Tote Mobile (R)					1.00	49**
6. Ship Destination (R)						1.00

[a]Decimal points are omitted.

[b]$n = 208$. The additional 78 Ss tested were from the same population, but participated in another study.

*$p < .05$

**$p < .01$

Table 5

Squared Multiple Correlations Between Subsets of Ability Test Battery and Criterion Measures[a]

Test Subset	Posttest	Retention Test	Transfer Test	Number of Examples	Display Latency	Test Latency	Total Latency
Example-Only Group							
All	27	48	36	42	35	51	47
Published	21	16	22	39	24	30	27
Task Relevant	23	44	29	26	29	46	40
Objective-Example Group							
All	21	20	24	27	25	21	22
Published	07	06	16	20	20	11	12
Task Relevant	21	18	16	16	24	10	17
Rule-Example Group							
All	24	17	31	35	51	45	52
Published	24	16	30	18	40	38	42
Task Relevant	11	06	13	29	33	22	30
Objective-Rule-Example Group							
All	31	39	36	51	47	41	50
Published	15	29	18	14	32	30	36
Task Relevant	25	24	20	39	41	36	44

[a]Decimal points omitted.

Analysis of Ability by Treatment Interactions

In order to investigate the hypothesized ability by treatment interactions, the relationships between the abilities and task performance was operationalized in terms of the slope (amount of change in the criterion per unit change in the covariable) of the regression lines for each of the treatment groups. Thus, the hypothesis that the relationship between performance and a given ability would be reduced by the availability of objectives and/or rules was accepted if the slopes of the regression lines for the objective and/or rule groups were significantly less than the slope of the regression line for the Example-Only group. Linear regression analysis (Bottenberg & Ward, 1963) was used to test for differences in the slopes of treatment group regression lines.

The following series of comparisons were made using the reasoning and memory factors plus the six individual ability tests as covariables with each of the seven criteria:

1. The error sums of squares of the residual vector of a full model which allowed the slopes for all regression lines to be different (Model 1) was compared with the corresponding error sums of squares of a restricted model (Model 2) which assumed equality of slopes for all regression lines. The resulting *F* statistic is labeled in the regression analyses tables as F_1.
2. If F_1 was significant, then the ability by treatment interaction was further analyzed by comparing the error sums of squares of the full model (Model 1) with the error sums of

the squares of a second restricted model (Model 3). Model 3 assumed that the regression lines for the Objective-Example group, the Rule-Example group, and the Objective-Rule-Example group were all mutually parallel but allowed the slope of the regression line for the Example-Only group to be different. The resulting F statistic is labeled F_2.

3. If F_2 was non-significant, then Model 3 was concluded to be true and was used as a full model to compare with the restricted model (Model 2) which assumed equality of slopes for all regression lines. If the resulting F statistic, F_3 was significant, then it was concluded that the slope for the Example-Only group was significantly different from the slopes of the regression lines for the other three treatment groups.

The models described above are defined mathematically in Appendix G. The results of these analyses will be reported in the appropriate sections which follow.

Treatment Effects on Posttest and Retention Test Scores

Since the experimental procedure required all Ss to perform at a minimum criterion level on each rule before proceeding to the next, no group mean differences were expected on the posttest. This expectation was confirmed by a non-significant F from a random groups analysis of variance. Table 6 contains the group means and standard deviations for the posttest.

There also were no significant differences between the treatment groups on retention test scores. The retention test group means and standard deviations are given in Table 7.

No significant ability by treatment interactions were found using either posttest scores or retention test scores as criterion and individual ability test scores or factor scores as covariables.

Treatment Effects on Transfer

Table 8 presents means and standard deviations for the transfer test. These data were evaluated by a 2 x 2 factorial analysis of variance which is summarized in Table 9. It should be noted that the significant rule effect is in favor of the groups which received a statement of the rules and not in favor of the no-rule groups as would be expected by advocates of the discovery hypothesis. The objective effect did not reach significance at an acceptable level, but it did approach significance, $F(1, 126) = 3.1$, $p < .10$, with the objective groups obtaining higher mean transfer scores than the no-objective groups. There were no significant ability by treatment interactions using the transfer test scores as criterion.

Table 6

Posttest Group Means and Standard Deviations

Objectives	Rules			
	No		Yes	
	Means	SD	Means	SD
No	45.4	4.9	45.1	12.9
Yes	44.3	11.7	47.8	12.2

Table 7

Retention Test Group Means and Standard Deviations

Objectives	Rules			
	No		Yes	
	Means	SD	Means	SD
No	44.2	7.2	43.6	14.2
Yes	43.3	13.9	46.2	12.2

Table 8

Transfer Test Group Means and Standard Deviations

Objectives	Rules			
	No		Yes	
	Means	SD	Means	SD
No	11.0	2.8	14.1	5.6
Yes	13.2	4.4	14.7	5.0

Table 9

Analysis of Variance Summary for Transfer Test Score

Source	df	MS	F
Between	3	85.6	
Objectives (A)	1	67.2	3.1
Rules (B)	1	170.2	7.8**
A X B	1	19.4	0.9
Within	126	21.9	
Total	129	23.4	

**$p < .01$

Treatment Effects on Number of Examples

The treatment effects on the number of examples required to learn the task is graphically portrayed by the group frequency distributions given in Fig. 2. The corresponding means and standard deviations are presented in Table 10, while the 2 x 2 analysis of variance results are reported in Table 11. The significant rule effect replicates the findings of earlier studies (Bunderson et al., 1970b) which revealed that the presentation of rules significantly reduces the number of examples required to learn the task. The significant objective effect shows that the presentation of objectives also reduces the number of examples required, but this reduction is not nearly as marked as the reduction caused by the presentation of the rules.

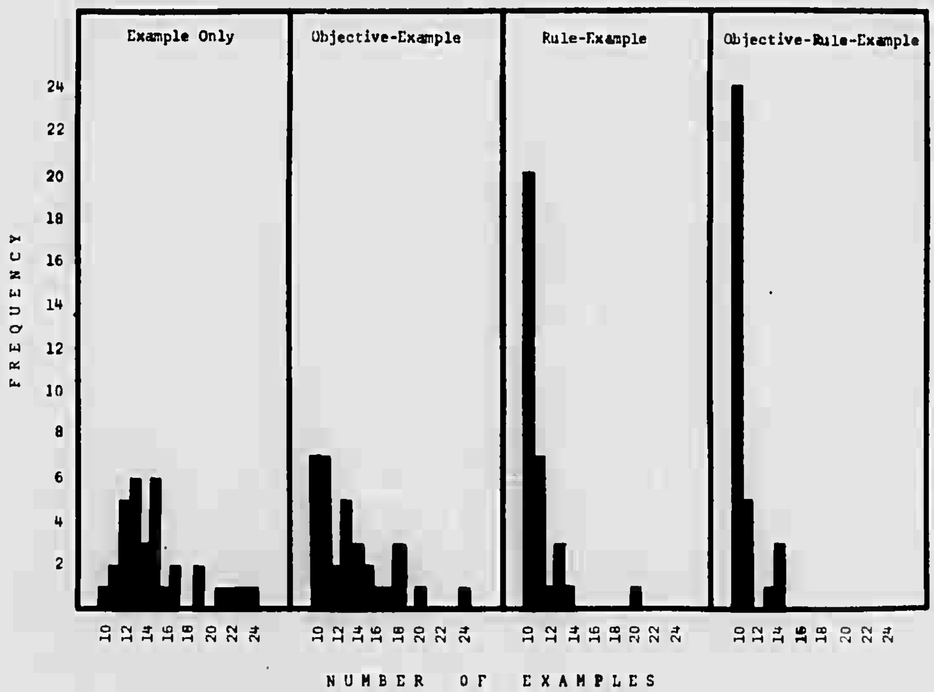


Figure 2.--Frequency Distribution by Treatment Group of the Number of Examples Received.

Table 10

Group Means and Standard Deviations of the Number of Examples Required to Learn the Task

Objectives	Rules			
	No		Yes	
	Means	SD	Means	SD
No	15.0	3.6	11.0	2.0
Yes	13.3	3.4	10.6	1.2

Table 11

Analysis of Variance Summary for Number of Examples

Source	df	MS	F
Between	3	137.9	
Objectives (A)	1	35.9	4.7*
Rules (B)	1	364.3	48.7***
A X B	1	13.8	1.8
Within	126	7.5	
Total	129	10.5	

*$p < .05$

***$p < .001$

Although there were no ability by treatment interactions which reached the .05 level of significance using number of examples as criterion, the regression analysis using reasoning and memory factor scores as covariables are reported in order to give the reader a better feel for the actual relationships between the abilities and treatments. A summary of the regression analysis of reasoning factor scores as the covariable and number of examples as the criterion is presented in Table 12. (Since F_1 was not significant, F_2 and F_3 are not reported.) The equations for the treatment group regression lines, the criterion and covariable group means, and the ranges of scores on the criterion and the covariable are also reported in Table 12. The corresponding regression lines are plotted in Fig. 3. The results of the regression analysis using memory factor scores as the covariable are presented in Table 13, while the regression lines are plotted in Fig. 4.

From Fig. 4, it should be noted that the slopes of the regression lines for all treatments were very close to zero, which indicates that there was very little relationship between S's task performance and his memory factor scores. In contrast, the interaction of reasoning factor scores with the instructional treatments (Fig. 3) approaches significance, $F(3, 122) = 2.18$, $p < .10$, with the slopes of the Example-Only and Objective group regression lines being somewhat steeper than those of the Rule and Objective-Rule groups.

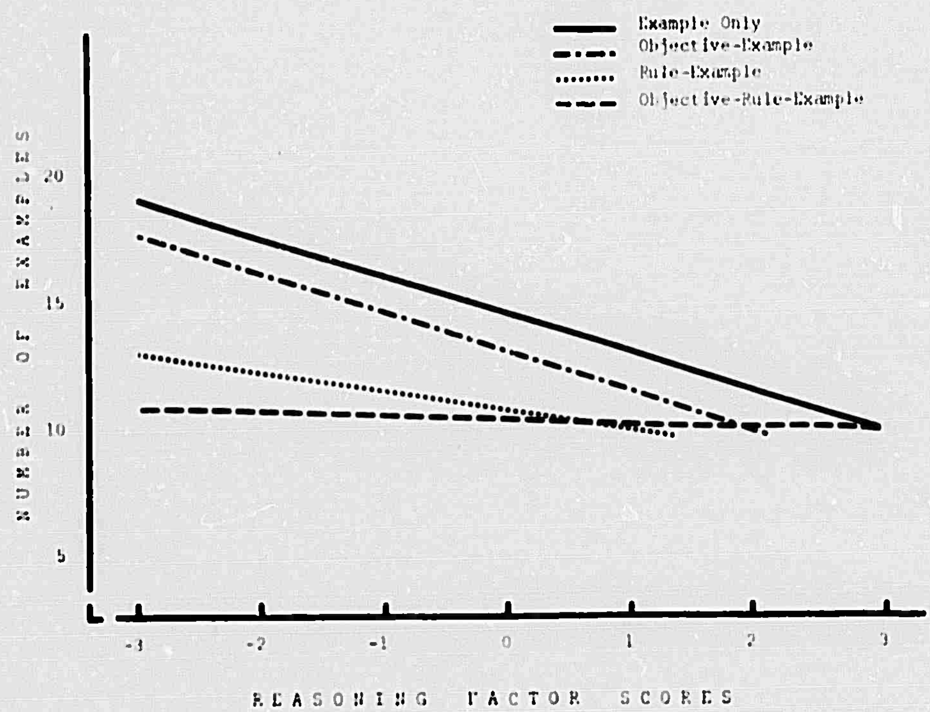


Figure 3.--Interaction of Reasoning Factor Scores and Treatments with Number of Examples as Criterion.

Table 12

Regression Analysis Summary for Number of Examples with Reasoning Factor Scores as Covariable

Group	Means		Range		Equations for Group Regression Lines
	Criterion	Covariable	Criterion	Covariable	
Example-Only	15.00	-.215	10 to 24	-2.9 to 2.2	X = -1.48A + 14.69
Objective-Example	13.30	.046	10 to 24	-2.0 to 1.6	O = -1.51A + 13.37
Rule-Example	11.00	-.146	10 to 20	-3.1 to 1.9	R = -0.75A + 10.89
Objective-Rule-Example	10.61	.257	10 to 14	-1.9 to 2.2	RO = -0.20A + 10.66

Comparison[a]	**df_1**	**df_2**	**RSQ_F**	**RSQ_R**	**F**
F_1	3	122	.4434	.4136	2.18

[a]Comparisons are described under section titled Analysis of Ability by Treatment Interactions. The mathematical definitions of the linear regression models are found in Appendix G.

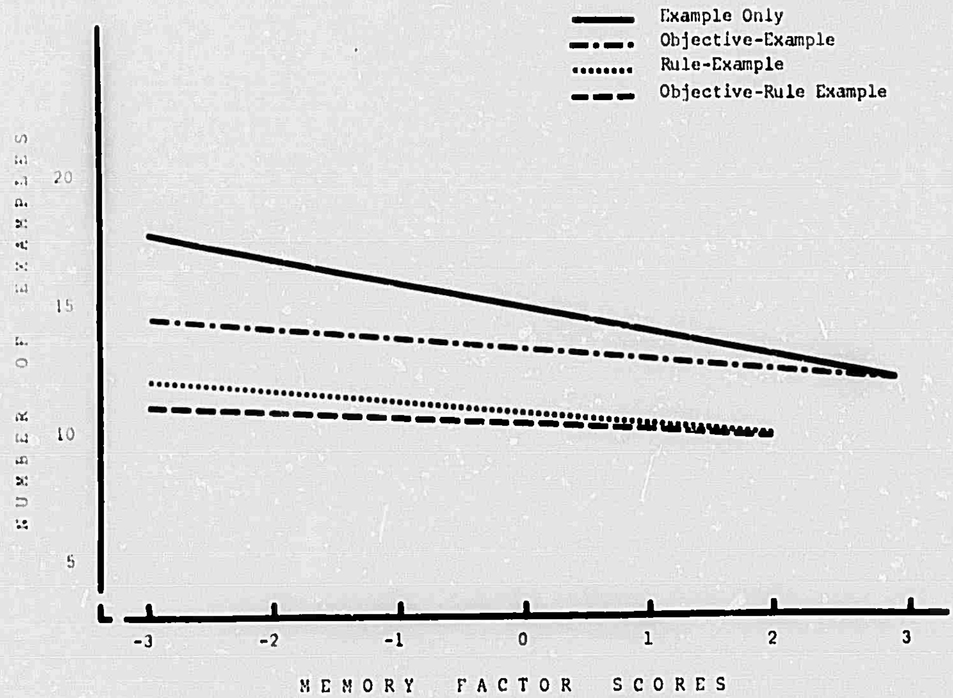


Figure 4.-- Interaction of Memory Factor Scores and Treatments with Number of Examples as Criterion.

Table 13

Regression Analysis Summary for Number of Examples with Memory Factor Scores as Covariable

Group	Means		Range		Equations for Group Regression Lines
	Criterion	Covariable	Criterion	Covariable	
Example-Only	15.00	.057	10 to 24	-1.9 to 1.6	X = -.94A + 15.15
Objective-Example	13.30	.109	10 to 24	-2.2 to 1.9	O = -.40A + 13.44
Rule-Example	11.00	-.242	10 to 20	-2.2 to 2.1	R = -.40A + 10.90
Objective-Rule-Example	10.61	-.131	10 to 14	-2.0 to 2.0	RO = -.24A + 10.57

Comparison[a]	df_1	df_2	RSQ_F	RSQ_R	F
F_1	3	122	.3331	.3259	.44

[a]Comparisons are described under section titled Analysis of Ability by Treatment Interactions. The mathematical definitions of the linear regression models are found in Appendix G.

Treatment Effects on Latency

Table 14 contains the means and standard deviations for each group on the three latency measures while Table 15, 16, and 17 give the corresponding results of the analyses of variance of the data using 2 x 2 factorial designs. There was a significant rule effect on all three measures with the rule groups taking considerably less time to study the displays and respond to the criterion test items. The objective effect is significant only on test-item-response latency. The groups which received objectives required less time to respond to the test items than the groups which were not presented the objectives. There also was a significant interaction (Table 14) with test-response latency as the criterion. This interaction indicates that the objectives have a greater effect in reducing response latency when added to a task which has no other focusing or organizing stimuli than they do when added to a task which has other effective orienting stimuli such as rules. In other words, the difference in response latency between the Example-only and Objective groups is greater than the corresponding difference between the Rule and Objective-Rule groups.

In contrast to the objective effect on test-item-response latency where objectives reduced response time, the effect of presenting objectives was in the opposite direction on display latency. Even though this effect did not reach an acceptable level of significance, the contrast between the order of the display latency means and the test-item-response latency means has theoretical significance which will be presented in the Discussion Section. In as much as objectives had opposite effects on the two component latencies, the combined total latency objective effect was non-significant (Table 17).

Table 14

Group Means and Standard Deviations for Display Latency, Test-Item-Response Latency, and Total Latency

Group	Latency					
	Display		Test-Item-Response		Total	
	Means	SD	Means	SD	Means	SD
Example-Only	821.2	379.8	923.3	430.7	1772.8	771.7
Objective-Example	865.8	377.5	749.3	253.9	1513.5	569.5
Rule-Example	[illegible]	208.6	493.7	211.7	1037.6	399.1
Objective-Rule-Example	634.3	218.2	419.8	126.2	1053.5	321.2

Table 15

Analysis of Variance Summary for Display Latency

Source	df	MS	F
Between	3	7377.8	
Objectives (A)	1	1445.3	1.5
Rules (B)	1	20521.5	21.9***
A X B	1	166.6	.2
Within	123	932.9	
Total	126	1086.3	

$^{***}p < .001$

Table 16

Analysis of Variance Summary for Test-Item-Response Latency

Source	df	MS	F
Between	3	16152.3	
Objectives (A)	1	9865.2	12.8***
Rules (B)	1	35360.8	45.8***
A X B	1	3230.9	4.2*
Within	126	772.2	
Total	129	1129.9	

$^{*}p < .05$

$^{***}p < .001$

Table 17

Analysis of Variance Summary for Total Latency

Source	df	MS	F
Between	3	41315.2	
Objectives (A)	1	4696.1	1.6
Rules (B)	1	113245.9	39.2***
A X B	1	6003.7	2.1
Within	123	2891.4	
Total	126	3906.3	

$^{***}p < .001$

Several significant ability by treatment interactions were found using latency as the criterion measure. Tables 18 through 21 report the results of the regression analyses using test-item-response latency as the criterion measure, while Figures 5 through 8 show the corresponding plots of the regression lines.

Fig. 5 dramatically shows that test-item-response latency has a high negative relationship to reasoning, as defined by the reasoning factor scores, for Ss in the Example-Only group. However, the regression analysis (Table 18) shows that the corresponding relationship between reasoning factor scores and test-item-response latency is significantly reduced for Ss in the other three treatments. Similar results were obtained using the Tote Mobile Test scores (Table 19 and Fig. 6), the Ship Destination Test scores (Table 20 and Fig. 7), and the Letter Sets Test Scores (Table 21 and Fig. 8) as the covariables

There were no significant interactions using display latency as the criterion measure; however, one significant interaction was obtained using total latency as criterion. The regression analysis results are reported in Table 22 with the regression lines plotted in Fig. 9. As can be seen from Fig. 9, the ability by treatment interaction found with total latency as criterion is generally the same as that found using test-item-response latency as the criterion and Letter Sets Test scores as the covariable (Table 21 and Fig. 8). In both cases, the slope of the Example-Only treatment group regression line was found to be significantly greater than the slopes of the regression lines for the other three treatment groups.

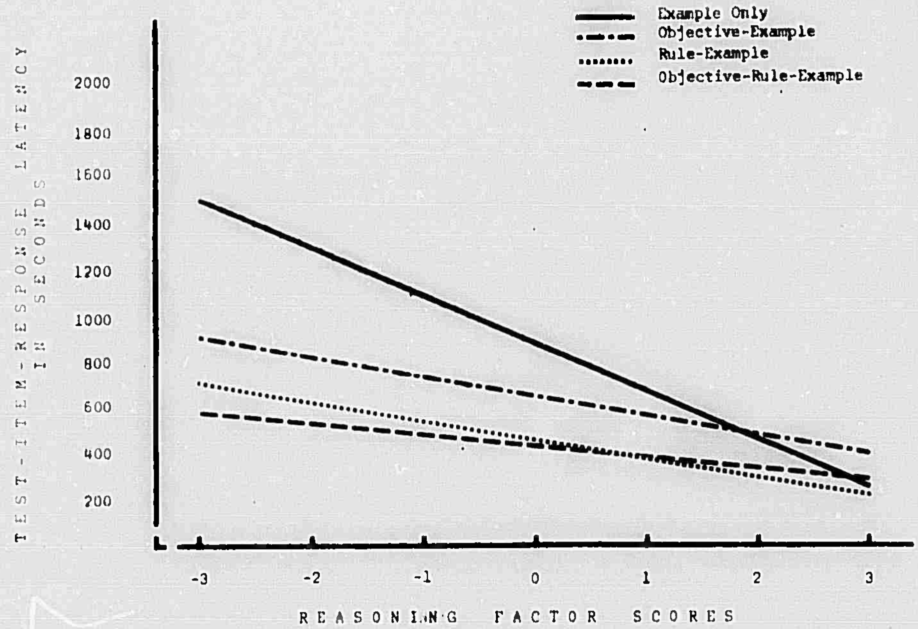


Figure 5.--Interaction of Reasoning Factor Scores and Treatments with Test-Item-Response Latency as Criterion.

Table 18

Regression Analysis Summary for Test-Item-Response Latency[a] with Reasoning Factor Scores as Covariable

Group	Means		Range		Equations for Group Regression Lines
	Criterion	Covariable	Criterion	Covariable	
Example-Only	923.31	-.215	372 to 2025	-2.9 to 2.2	X = -203.5A + 879.5
Objective-Example	649.34	.046	274 to 1224	-2.0 to 1.6	O = - 80.7A + 652.8
Rule-Example	493.70	-.146	285 to 1494	-3.1 to 1.9	R = - 86.3A + 481.2
Objective-Rule-Example	419.17	.257	230 to 848	-1.9 to 2.2	RO = - 55.1A + 433.3

Comparison[b]	df_1	df_2	RSQ_F	RSQ_R	F
F_1	3	122	.5078	.4696	3.16*
F_2	2	122	.5078	.5065	.16
F_3	1	124	.5065	.4696	9.28**

[a]Latency reported in seconds.

[b]Comparisons are described under section titled Analysis of Ability by Treatment Interactions. The mathematical definitions of the linear regression models are found in Appendix G.

*$p < .05$

**$p < .01$

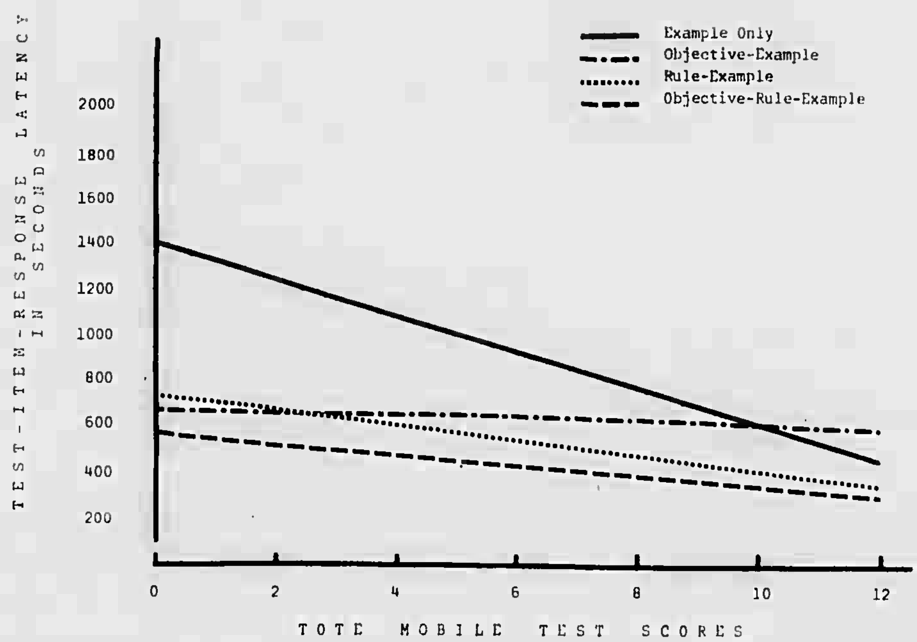


Figure 6.--Interactions Between Tote Mobile Test Scores and Treatments with Test-Item-Response Latency as Criterion.

Table 19

Regression Analysis Summary for Test-Item-Response Latency[a] with Tote Mobile Test Scores as Covariable

Group	Means		Range		Equations for Group Regression Lines
	Criterion	Covariable	Criterion	Covariable	
Example-Only	923.31	6.09	372 to 2025	0 to 12	X = -78.5A + 1401.6
Objective-Example	649.34	6.36	274 to 1224	3 to 10	O = - 4.1A + 675.8
Rule-Example	493.70	6.50	285 to 1494	2 to 11	R = -32.5A + 704.8
Objective-Rule-Example	419.17	6.52	230 to 848	2 to 11	RO = -24.5A + 579.4

Comparison[b]	df_1	df_2	RSQ_F	RSQ_R	F
Γ_1	3	122	.4618	.4220	3.00*
Γ_2	2	122	.4618	.4578	.45
Γ_3	1	124	.4578	.4220	8.19**

[a]Latency reported in seconds.

[b]Comparisons are described under section titled Analysis of Ability by Treatment Interactions. The mathematical definitions of the linear regression models are found in Appendix G.

*$p < .05$

**$p < .01$

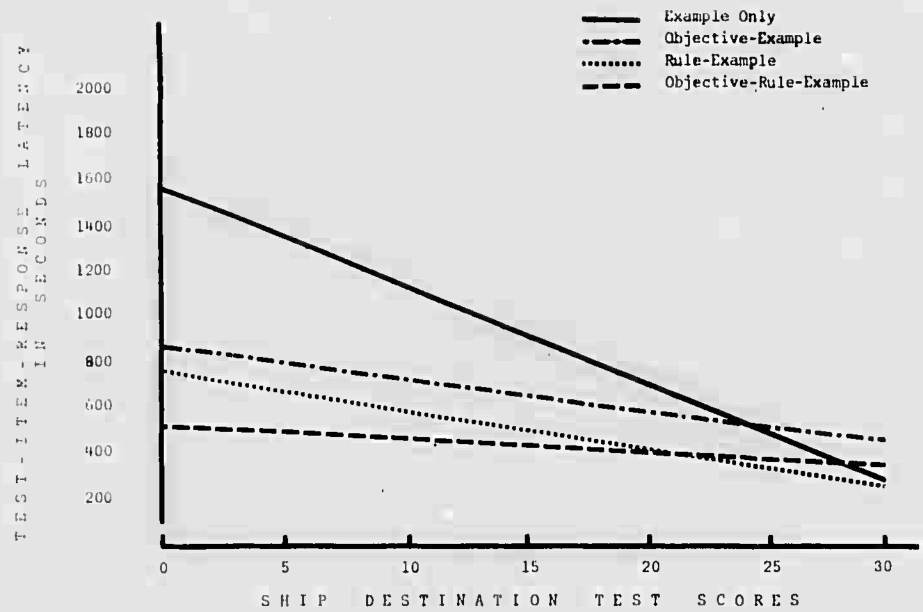


Figure 7.--Interaction of Ship Destination Test Scores and Treatments with Test-Item-Response Latency as Criterion.

Table 20

Regression Analysis Summary for Test-Item-Response Latency[a] with Ship Destination Test Scores as Covariable

Group	Means		Range		Equations for Group Regression Lines
	Criterion	Covariable	Criterion	Covariable	
Example-Only	923.31	12.81	372 to 2025	2 to 19	X = -49.9A + 1562.5
Objective-Example	649.34	13.24	274 to 1224	4 to 18	O = -19.2A + 903.0
Rule-Example	493.70	13.56	285 to 1494	2 to 19	R = -21.2A + 781.4
Objective-Rule-Example	419.17	15.33	230 to 848	7 to 20	RO = - 7.3A + 531.8

Comparison[b]	df_1	df_2	RSQ_F	RSQ_R	F
F_1	3	122	.4757	.4396	2.80*
F_2	2	122	.4757	.4724	.38
F_3	1	124	.4724	.4396	7.71**

[a]Latency reported in seconds.

[b]Comparisons are described under section titled Analysis of Ability by Treatment Interactions. The mathematical definitions of the linear regression models are found in Appendix G.

*$p < .05$

**$p < .01$

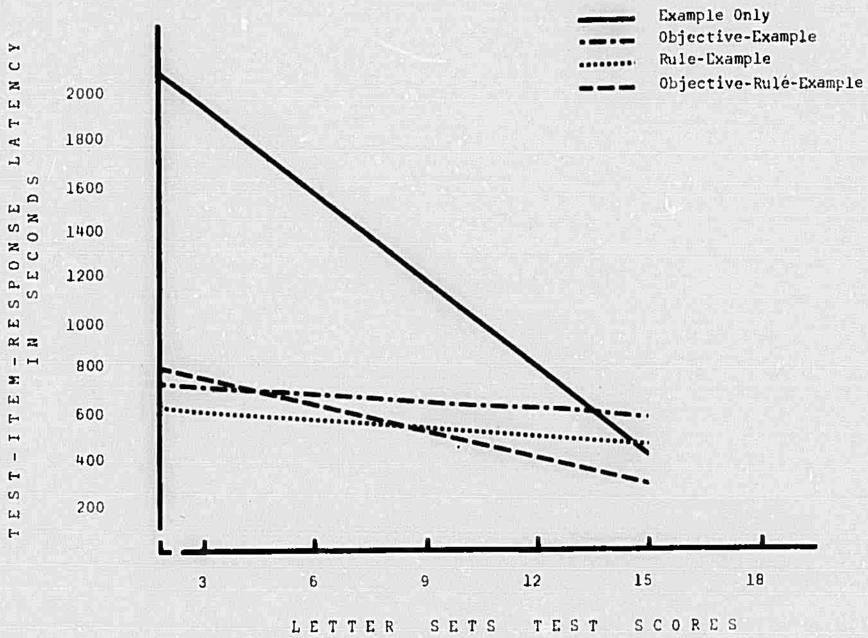


Figure 8.--Interactions Between Letter Sets Test Scores and Treatments with Test-Item-Response Latency as Criterion.

Table 21

Regression Analysis Summary for Test-Item-Response Latency[a] with Letter Sets Test Scores as Covariable

Group	Means		Range		Equations for Group Regression Lines
	Criterion	Covariable	Criterion	Covariable	
Example-Only	923.31	10.25	372 to 2025	6 to 14	X = -111.16A + 2062.82
Objective-Example	649.34	10.55	274 to 1224	6 to 14	O = - 10.29A + 756.70
Rule-Example	493.70	9.62	285 to 1494	0 to 15	R = - 14.05A + 628.96
Objective-Rule-Example	419.17	10.73	230 to 848	6 to 15	RO = - 34.97A + 794.32

Comparison[b]	df_1	df_2	RSQ_F	RSQ_R	F
F_1	3	122	.4741	.4035	5.47**
F_2	2	122	.4741	.4710	.37
F_3	1	124	.4710	.4035	15.83***

[a]Latency reported in seconds.

[b]Comparisons are described under section titled Analysis of Ability by Treatment Interactions. The mathematical definitions of the linear regression models are found in Appendix G.

**p < .01

***p < .001

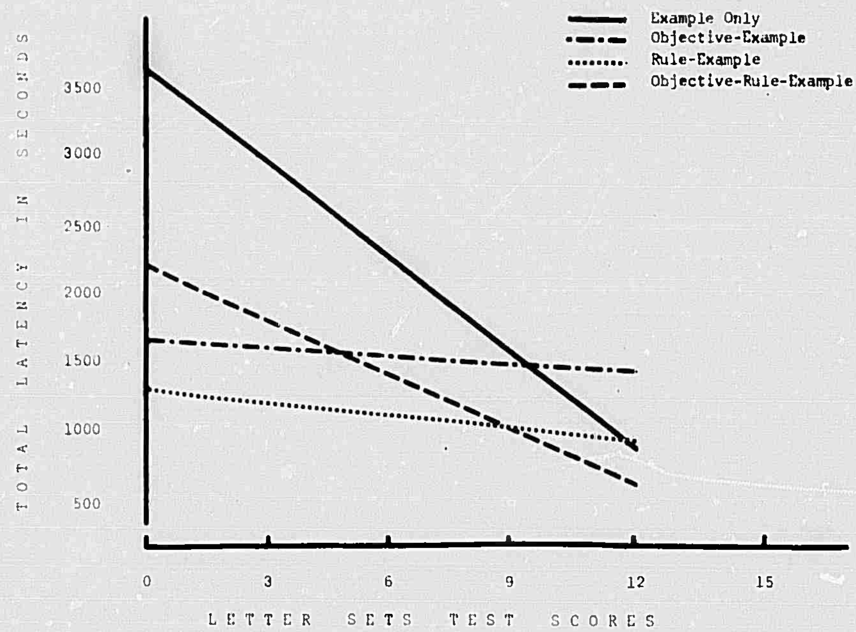


Figure 9.--Interaction of Letter Sets Test Scores and Treatments with Total Latency as Criterion.

Table 22

Regression Analysis Summary for Total Latency[a] with Letter Sets Test Scores as Covariable

Group	Means		Range		Equations for Group Regression Lines
	Criterion	Covariable	Criterion	Covariable	
Example-Only	1772.76	10.25	711 to 3442	6 to 14	X = -183.37A + 3637.23
Objective-Example	1513.47	10.55	673 to 2859	6 to 14	O = - 11.71A + 1636.66
Rule-Example	1037.58	9.62	566 to 2687	0 to 15	R = - 28.87A + 1315.46
Objective-Rule-Example	1053.48	10.73	547 to 2097	6 to 15	RO = -106.65A + 2197.45

Comparison[b]	df_1	df_2	RSQ_F	RSQ_R	F
F_1	3	119	.3936	.3345	3.85*
F_2	2	119	.3936	.3800	1.33
F_3	1	121	.3800	.3348	8.83**

[a]Latency reported in seconds.

[b]Comparisons are described under section titled Analysis of Ability by Treatment Interactions. The mathematical definitions of the linear regression models are found in Appendix G.

*$p < .05$

**$p < .01$

DISCUSSION

In the introductory section of this paper it was proposed that objectives would serve as orienting and/or organizing stimuli which dispose Ss to attend to and organize relevant aspects of given information so as to facilitate attainment of the objectives. Therefore, it was hypothesized that the orienting effect of objectives would reduce the number of examples and amount of time required to complete the task, while the organizing effect of objectives would improve performance on transfer retrieval measures. It was also hypothesized that the orienting effect of objectives would compensate for low associative memory and induction abilities while the organizing effect of objectives would compensate for low reasoning ability Thus the relationship between these abilities, assumed to be required by the task, and task performance would be reduced.

It was further expected that the effects of inserting objectives in a task without other orienting or organizing stimuli would be greater than the effects of inserting objectives in a task with other orienting stimuli such as rules. The effects of rules found in previous studies (Bunderson et al., 1970b) were expected to be replicated in this study; i.e., rules would reduce the number of examples required to complete the task and reduce the requirement for general reasoning.

The design of the present study was such that all Ss were required to reach a minimum criterion performance at each level of the task before they were allowed to go on to the next level. This procedure was used to assure that all treatment groups would perform at the same level on the posttest. Unless all groups learned the original task equally well, differential performance on retention or transfer measures could not be interpreted in terms of the organization or structure provided by an instructional treatment. The results confirmed the expectation of non-significant group differences on posttest performance. Therefore, it was concluded that all groups had learned the task equally well.

The hypothesis that the Objective-Example group would perform significantly higher on the retention and transfer tests than other treatment groups was not supported. Since there was a negligible decrement in performance between the posttest and retention test for all treatment groups, the retention interval of two weeks may have been too short for the treatments to have had an affect on retention. However, there were significant treatment effects on transfer performance. Even though the rule groups received significantly fewer examples and took significantly less time to learn the task, their performance on the transfer test was significantly higher than that of the no-rule groups. If we compare the objective groups and the no-objective groups, the same type of result is obtained even though the differential performance on the transfer test only approaches significance.

As mentioned in the previous section, the significant rule effect in favor of the rule groups on the transfer measure does not support the learning by discovery hypothesis, nor does it replicate the Bunderson et al., (1970b) findings of no significant differences between rule and no-rule treatments. This lack of replication may be due to the fact that the transfer test used in this study had twice as many items as the test used in the earlier study. In the section in which the learning by discovery issue was discussed it was suggested that presenting objectives would allow Ss to organize relevant information so as to facilitate transfer to a new task. Even though there was a weak trend in favor of the objective groups, it seems that precisely stated rules have a greater effect on transfer retrieval than objectives. The weak objective effect may have been due to the fact that the objectives only specified that transfer retrieval would be required to solve new problems using previously demonstrated relationships. Objectives did have a significant effect on transfer retrieval (number of examples & test item response latency) where the criterion items were constructed according to the original objectives.

The significant rule effect on number of examples found in this study replicates the results of previous studies (Bunderson et al., 1970b), and the significant objective effect supports the hypothesis that objectives would reduce the number of examples required to meet criterion by helping the S to focus on the relevant stimuli in the displays. The frequency distributions (Figure 2) show that the presentation of rules enabled most Ss to learn the science in a minimum number (10) of trials and therefore with nearly zero errors. Objectives had a similar but less pronounced effect. Since the rule treatments brought such a high percentage of Ss to perfect performance in terms of the number of examples required, the full impact of these treatments using number of examples as criterion is indeterminate. However, the within group variance was not similarly restricted in the latency criterion measures.

The hypothesis that presentation of rules would significantly reduce the amount of time required to learn the task was supported by significant rule effects on all three latency measures. Although a floor effect was not observed in the rule groups using latency measures as criteria, the rule treatments seemed to effect a substantial decrease in latency within group variance.

The presentation of objectives did not have the hypothesized effect of reducing the total time required to complete the task. This result would seem to contradict the argument that objectives have a focusing effect if it were not for the reduction in the number of examples required by the objective groups. A comparison of the component latency measures, display and test-item-response latency, revealed that objectives either increased or had no effect on display latency but significantly reduced test-item-response latency. Apparently the presentation of objectives affected the efficiency and effectiveness of the S's information processing and thereby facilitated his performance on the criterion test items.

The hypothesis that objectives and/or rules would reduce the relationship between certain cognitive abilities and task performance was only partially supported. Apparently the assumption that task performance would be related to associative memory was not valid. Therefore, a reduction in the requirement for associative memory for Ss who received rules and/or objectives could not be detected. There are at least two possible explanations for the lack of relationship between task performance and memory. First, the task may have required only a certain minimum level of memory ability possessed by all Ss, and second, the task may have required some other type of memory ability such as memory span instead of associative memory. The interaction between reasoning factor scores and the treatments with number of examples as criterion only approached significance. The difference between the regression line slopes for the Rule-Example and Example-Only groups was similar to that found in earlier studies (Bunderson et al., 1970b), but the Objective-Example-treatment did not effect a reduction in the slope with number of examples as criterion. However, the presentation of objectives and/or rules did significantly reduce the relationship between reasoning factor scores and test-item-response latency. There was a similar significant reduction in the relationships between Letter Sets Test scores and total latency for Ss who received rules and/or objectives. Why the treatments interacted with reasoning abilities using test-item-response latency and total latency as criteria and did not interact significantly with display latency and number of examples as criteria is not clear. Apparently reasoning abilities are more crucial during the stages of the task when Ss respond to the criterion test items, and therefore the objectives and/or rule treatments compensation for these abilities is more evident during those stages. No ability by treatment interaction hypotheses were formulated concerning the post, retention and transfer criterion measures. It was not assumed that the same abilities which would be required to learn the task would also be required to perform the terminal behavior of the task. Therefore, the regression analyses using post, retention, and transfer test scores were only conducted for exploratory purposes. However, no significant ability by treatment interactions were found using the post-task criterion measures.

The hypothesis that objective effects would be greater between the Example-Only and Objective groups than between the Rule and Rule-Objective groups was only supported significantly by the interaction found with test-item-response latency as criterion. However, an examination of the means for the other criterion measures shows that the corresponding differences between the means of the other criteria are consistent with the hypothesis. Thus it is impossible to make broad general statements about the effect of objectives on the learning process without taking into account the other stimulus properties of the task.

The purpose of this study was to investigate what effects the presentation of behavioral objectives would have on the learning process. On the basis of the results of this study it was concluded that objectives have orienting and organizing effects which dispose students to attend to and organize relevant information and thus facilitate performance on criterion test items constructed in accordance with the objectives. The organizing effect of objectives also compensates for reasoning abilities required to respond accurately to the test items based on the objectives. Objectives have a greater effect when added to a task without other orienting or organizing stimuli than when they are added to a task with other organizing stimuli such as rules. Rules have similar but somewhat more pronounced effects than objectives. Contrary to the learning by discovery hypothesis, the presentation of rules facilitates performance on a transfer task where higher order rules must be inferred from examples. However, the presentation of objectives for one task does not necessarily facilitate performance on a transfer task with different, though similar, objectives. Objectives and rules seem to perform different functions since there is an apparent additive effect when they are presented together.

The data of the present study have several methodological implications. One of the major implications seems to be that latnecy data may be of greater value than has been previously supposed. Even though total latency is probably of greater practical importance in terms of the differential costs required to use various instructional treatments, it may be of greater psychological importance to examine latency in terms of its different components as was done in the present study.

Second, even though none of the ability by treatment interactions found in this study are of great practical importance in terms of individualizing instruction by using ability profiles, they are of theoretical importance since they facilitate analysis of the effects various treatments have on the learning process of Ss with different ability strengths. Thus, the results of this study further support Dunham and Bunderson's (1969) contention that it is possible to vary the nature of the cognitive processes in learning by manipulating a task variable.

Third, a comparison of the difference between the squared multiple correlations of the criterion measures and the task relevant versus the published ability tests suggests that the use of task relevant tests in ability by treatment interaction studies should receive continued consideration. Through further revision and testing of the task relevant tests it should be possible to increase their reliability and multiple correlation with criteria. It is of further interest to note that the predictive effectiveness of task specific tests may vary depending upon the type of instructional treatment the sample receives. (For the Rule-Example group the published tests correlated higher with criterion measures than did the task relevant tests.)

In conclusion, the reader is cautioned against over-generalization of the results of this study. It should be remembered that the learning task was a highly symbolic imaginary science presented by computer-assisted instruction, and that Ss were required to participate as a class requirement. Thus it is dangerous to generalize to highly different tasks, methods of presentation, and/or populations of Ss. Nevertheless, the implications of this study and its methodology are such that it would be valuable to attempt to replicate the major findings using other tasks and populations. Future research on objectives needs to be conducted to investigate what effects objectives would have on terminal behavior criterion measures if the number of examples and amount of time allowed for each treatment is controlled. Since Ss in the no-objective groups of the present study could have inferred the objectives from the criterion test items presented after each example, the full effect of objectives could not be determined. Therefore, future research on objectives should also examine the differential effects of verbally stated objectives and test items based on objectives.

SUMMARY

The purpose of this study was to investigate what effects the availability of behaviorally stated objectives would have on the learning process. It was hypothesized that objectives would serve as orienting stimuli which dispose the student to attend to, process, and organize relevant aspects of displayed information in accordance with the stated objectives. Therefore, the presentation of objectives was expected to reduce the number of examples and amount of time required to learn the task, facilitate performance on transfer retrieval criterion measures, and reduce the requirements for memory and reasoning abilities.

The learning task consisted of a hierarchical imaginary science called the Science of Xenograde Systems which was presented by an IBM 1500/1800 Computer-Assisted Instruction System to 130 introductory educational psychology and science education students.

Before learning the task, all <u>Ss</u> were given a battery of six cognitive ability tests comprised of three existing published tests and three task-relevant tests developed for this study. The tests were selected to measure abilities postulated to have specific relationships to task performance.

The <u>Ss</u> were randomly assigned to an Example-Only group, an Objective-Example group, a Rule-Example group, and an Objective-Rule-Example group. All <u>Ss</u> were required to meet a minimum criterion performance at each level of the task before proceeding to the next level.

A significant rule effect was found on the number of examples and the total time required to complete the task with the rule groups needing less

time and fewer examples than the no-rule groups. Objectives significantly reduced the number of examples required to learn the task, but they did not reduce total latency. An analysis of the component latency measures revealed that objectives either increased or had no effect on display latency but significantly reduced test-item-response latency. Apparently the objective treatments affected the efficiency and effectiveness of the S's information processing and thereby facilitated his performance on the criterion-test items based on the objectives.

No significant differences were found between treatments on the post or retention tests, but a significant rule effect in favor of the rule groups was found on the transfer test.

The battery of cognitive tests was factor analyzed, and a two-factor varimax solution was obtained yielding the factors of reasoning and associative memory. Regression analyses of the individual ability test scores, factor scores, and the criterion measures were conducted. Significant ability by treatment interactions were obtained using test-item-response latency as criterion and reasoning factor scores, plus individual reasoning tests as covariables. Reasoning had a high negative relationship to test-item-response latency for Ss in the Example-Only group, but this relationship was significantly smaller for Ss in the remaining groups. Therefore, the presentation of objectives and/or rules effected a reduction in the requirement for reasoning ability.

On the basis of the results of this study it was concluded that objectives have orienting and organizing effects which dispose students to attend to, process, and structure relevant information in accordance with the given objectives.

APPENDICES

APPENDIX A

Sub-Objectives and Rules

APPENDIX A

Sub-Objectives for the Science of Xenograde Systems

1. Given that F.F. = 1, and the values of ACS and the previous distance, predict the value of the next distance.

2. Given that ACS = 1, and the values of F.F. and the previous distance, predict the value of the next distance.

3. Given the values of F.F., ACS and the previous distance, predict the value of the next distance.

4. Given the previous values of ACN and ACS, and that no blip has occurred, predict the next values of ACN and ACS.

5. Given the value of the time and that a blip has occured, predict the blip time and the value of the distance at that time.

6. Given the previous values of ACN and ACS, and that the blip time is even, predict the next values of ACN and ACS.

7. Given the previous values of ACN and ACS, and that the blip time is odd, predict the next values of ACN and ACS.

8. Given the previous value of ACS, that the blip time is even, and that ACN was zero on the previous line, predict the next values of ACN and ACS.

9. Given the values of F.F., ACS, and that a blip has occurred, predict the next distance.

10. Given the distance at time zero, predict the maximum value the distance will reach.

Rules for the Science of Xenograde Systems

1. If F.F. = 1, the decrease in distance between each time is equal to ACS.
2. If ACS = 1, the decrease in distance between each time is equal to F.F.
3. The decrease in distance between each time is equal to the value of F.F. x ACS.
4. ACN and ACS cannot change unless a blip occurs.
5. When the distance becomes zero a blip is recorded whose value is equal to the value of the time.
6. When the blip time is even, ACN decreases by one while ACS increases by one.
7. When the blip time is odd, ACN increases by one while ACS decreases by one.
8. If the blip time is even and ACN was zero on the previous line, ACN and ACS do not change.
9. After a blip occurs, the distance begins to increase each time by the value of F.F. x ACS.
10. After a blip, the distance increases to its value at time zero then begins to decrease again.

APPENDIX B

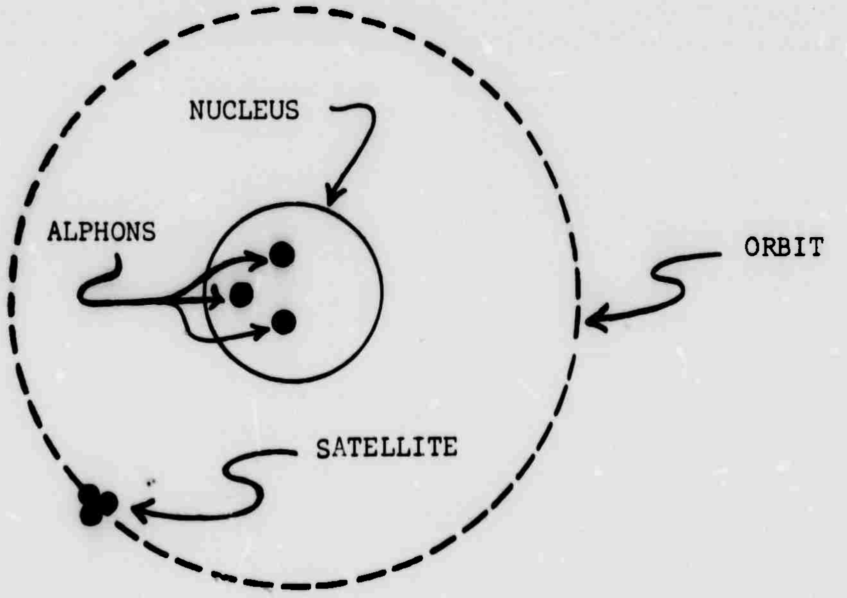
Instruction Booklet with Xenograde Table

APPENDIX B

Student Instruction Booklet

The instructional program concerns an imaginary science called the Science of Xenograde Systems. A Xenograde System consists of a nucleus with an orbiting satellite. The satellite is composed of small particles called alphons which may also reside in the nucleus. Under certain conditions, a satellite may collide with the nucleus. When such a collision occurs, a "blip" is said to have occurred, and the satellite may exchange alphons with the nucleus. The science deals with the laws by which the activity of satellites and alphons may be predicted.

The following diagram is one way of conceptualizing a Xenograde System:



Justifications

Your participation in the study of Xenograde Systems will enable the research staff of this laboratory to study how people learn a science and how they form and test hypotheses.

The time you spend will not give you an encyclopedia of facts useful outside this course, but it may improve your skills of observation, inference, prediction, formulating hypotheses, controlling and manipulating variables, interpreting data, formulating models, and a better way of approaching scientific problems. The study you are about to undertake has the challenge of a complex game and should be interesting in its own right.

The interaction with the materials in this study will give you some idea of the potential of computer-assisted instruction in simulation of a science and testing. Later you may want to sample some demonstration programs showing other uses of computer-assisted instruction.

Instructions for Reading the Displays

In taking this course, you will need to be able to read a tabular display on the CRT which records the activity of the particles making up a Xenograde System.

Figure 1 is a sample display.

FF = 2

System Time	ACN	Blip Time	Satellite Distance	ACS
0	2		24	3
1	2		18	3
2	2		12	3
3	2		6	3
4	1	4	0	4
5	1		8	4
6	1		16	4

Figure 1. Sample display of a Xenograde table.

The symbols stand for the following.

F.F.- Force field - Physically this can be thought of as an area in space, which if entered by an Xenograde system, will exert certain predictable effects on the system. The strength of the force field can be measured and given numerical values. The effect of the force field on the Xenograde System is based on the strength of the force field.

Time- This column serves as a clock which provides a basis for presenting the state of the system at small sequential intervals of time. It is increased by a value of 1 (one) with each reading. Notice that time always starts at time 0 (zero).

ACN- Alphon Count of the Nucleus. As the name suggests, the numerical values in the column under ACN refer to the number of alphons that are located in the nucleus at any given time. For example, in the figure the number of alphons in the nucleus at time 2 is 2 while the number of alphons on the nucleus at time 6 is 1.

BLIP TIME- In the column under this heading are recorded the values of the time clock when a blip occurs, that is when a satellite collides with the nucleus. In Figure 2 you will notice that such a collision occurred at time 4.

SATELLITE DISTANCE- The values recorded in the column under this heading refer to the number of units of distance between the satellite and the nucleus. From Figure 2 you will notice that the satellite is 24 units from the nucleus at time 0 while it is only 6 units from the nucleus at time 3.

ACS- Alphon count of the Satellite. The values recorded in the column under this heading refer to the number of alphons which make up the satellite at any given time. For example, in the Figure, the number of alphons in the satellite at time 2 is 3 while there are 4 alphons in the satellite at time 5.

⋮ - A series of three dots in any column refer to a series of values that have been skipped. For example, if the time column starts with three dots followed by the number 24, then all the values from time 0 to time 24 have been skipped.

Instructions for Group 6 (X)

Follow these instructions in taking the course.

1. After the proctor signs you on the terminal you will be instructed in how to use the terminal and given time to practice typing in numbers and correcting errors.
2. When you begin the course a Xenograde display table will appear on the Cathode Ray Tube (CRT). Your task will be to study each table as it is presented and try to discover a rule which determines how the values in the tables change.
3. After you have studied the table, type the letter "c" to continue.
4. Next you will then be given a series of 3 test items. These test items will consist of partial tables with missing values represented by a shaded box. You will be asked to predict the missing values by using the rule you have discovered. After typing in your answer and performing the ENTER Function, you will automatically be given the next item. After taking the three test items, you will be told how many you answered correctly.
5. If you miss more than one out of three test items, you will be shown another table based on the same rule followed by another series of three test items. You may receive up to five tables followed by test items for each rule.
6. If you answer at least 2 out of 3 test items correctly, a new table will be displayed based on the next rule.

7. You will follow the above procedures repeatedly until the 10 rules of the science have been learned.

8. After learning all the rules of the science, you will take a posttest. The posttest will assess your ability to predict entries in a table of Xenograde readings line by line given the initial conditions. Since the scores you make in learning this course will not affect your grade, but will be used to answer research questions in education, we would appreciate it very much if you would refrain from discussing the details of the science and posttest with fellow class mates who have not yet taken the course. Prior knowledge of the details of the course may confound the results and make the time you have spent in vain.

Please make no notes of any of the instructional material. Paper and pencil are not allowed to be used during any of the instruction at the computer terminal. One goal of this research is to investigate your ability to remember without using notes or any reference materials.

PLEASE NOTE: If you run into difficulty, it will be very helpful for you to refer back to this booklet. Try to relate the numbers in the tables to the physical diagram and the explanation found on the first page of this booklet.

APPENDIX C

Sample Intra-Task Test

APPENDIX C

Sample Intra-Task Test

After studying each example in the task, the Ss respond to a three item constructed response test. The following are sample items taken from one of these tests.

---

1. F.F. = 3

SYSTEM TIME	ACN	BLIP TIME	SATELLITE DISTANCE	ACS
0			45	5
1			?	5

What is the value of the distance at time 1? ________

---

2. F.F. = 4

SYSTEM TIME	ACN	BLIP TIME	SATELLITE DISTANCE	ACS
0			32	2
1			?	2

What is the value of the distance at time 1? ________

---

3. F.F. = 4

SYSTEM TIME	ACN	BLIP TIME	SATELLITE DISTANCE	ACS
0			24	3
1			?	3

What is the value of the distance at time 1? ________

APPENDIX D

Post and Retention Test Instructions

and Sample Items

APPENDIX D

Post and Retention Test Instructions and Sample Items

The purpose of this test is to assess your ability to use all the rules you have learned to predict entries in Xenograde Tables given certain previous conditions.

For each item you will be asked to fill in an entire line of a Xenograde Table. Thus you will make four predictions for each item. Write your predictions in the spaces provided on the last line of each table.

In some of the items, there may be cases where no entry should be made in a column. When this occurs leave the appropriate space blank.

Sample Items from Posttest

1. F.F. = 2

SYSTEM TIME	ACN	BLIP TIME	SATELLITE DISTANCE	ACS
0	3		40	2
1	___	___	___	___

2. F.F. = 1

SYSTEM TIME	ACN	BLIP TIME	SATELLITE DISTANCE	ACS
0	.	.	28	.
1	4		25	3
2	___	___	___	___

3. F.F. = 3

SYSTEM TIME	ACN	BLIP TIME	SATELLITE DISTANCE	ACS
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
14	0		18	3
15	0		9	3
16	___	___	___	___

4. F.F. = 2

SYSTEM TIME	ACN	BLIP TIME	SATELLITE DISTANCE	ACS
0			32	
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
4	0	4	0	5
5	___	___	___	___

APPENDIX E

Transfer Test Instructions

and Sample Items

APPENDIX E

Transfer Test Instructions and Sample Items

Instructions for Transfer Task

For the transfer task you will be given two Xenograde tables which will serve as examples for three new rules of the Science. Your task will be to study these tables in order to discover the additional rules.

When you feel you have discovered the rules, go to the test items where you will be asked to use the rules to predict:

1. What effect a negative force field will have upon alphon activity.
2. When a satellite will disappear.
3. What the next distance will be if the distance increment would take the satellite past its original orbit.

Example 1

FF = -2

System Time	ACN	Blip	Satellite Distance	ACS
0	2		12	3
1	2		6	3
2	3	2	0	2
3	3		4	2
4	3		8	2
5	3		12	2
6	3		8	2
7	3		4	2
8	4	8	0	1
9	4		2	1
10	4		4	1
11	4		6	1
12	4		8	1
13	4		10	1
14	4		12	1
15	4		10	1
16	4		8	1
17	4		6	1
18	4		4	1
19	4		2	1
20	5	20	0	0

The Satellite disappeared at time 20.

Example 2

FF = 2

System Time	ACN	Blip	Satellite Distance	ACS
0	2		12	3
1	2		6	3
2	1	2	0	4
3	1		8	4
4	1		8	4
5	2	5	0	3
6	2		6	3
7	2		12	3
8	2		6	3
9	3	9	0	2
10	3		4	2
11	3		8	2
12	3		12	2
13	3		8	2
14	3		4	2
15	4	15	0	1
16	4		2	1
17	4		4	1
18	4		6	1
19	4		8	1
20	4		10	1
21	4		12	1
22	4		10	1
23	4		8	1
24	4		6	1
25	4		4	1
26	4		2	1
27	5	27	0	0

The Satellite disappeared at time 27.

Sample Transfer Test Items

1. F.F. = 6

SYSTEM TIME	ACN	BLIP TIME	SATELLITE DISTANCE	ACS
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
57	8		12	1
58	8		6	1
59	?	59	0	?

Will the satellite disappear at time 59? ________ (yes or no)

2. F.F. = -5

SYSTEM TIME	ACN	BLIP TIME	SATELLITE DISTANCE	ACS
0			25	
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
5	2		0	2
6	2		10	2
7	2		20	2
8	2		?	2

At time 8 the value of the distance is ________.

3. F.F. = -3

SYSTEM TIME	ACN	BLIP TIME	SATELLITE DISTANCE	ACS
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
13	3		24	4
14	3		12	4
15	?	15	0	?

At time 15 the value of ACN = ________ and ACS = ________.

APPENDIX F

Task Relevant Test Instructions and Sample Items

APPENDIX F

MEMORY OF NUMBER SERIES TEST

Instructions and Sample Items

This is a test of your ability to learn combinations of letters and a series of numbers. Your task will be to study a page of 15 pairings of letters with number series. After studying the page showing both the letters and the corresponding number series you will turn to the next page showing only the letters in the same order. You will be asked to write down the number series which goes with each letter.

Here is a practice list of letter-number series pairs. Study this list until you are asked to go to the next page. (one minute)

F - 9 0 9 0

K - 2 2 2 6

R - 1 2 3 4

M - 4 5 4 3

G - 8 8 8 8

DO NOT TURN THIS PAGE UNTIL ASKED TO DO SO

Practice Test Page

The correct number series which corresponds to the letter F has been entered. Write all the other number series which correspond to the given letters that you can remember.

F - 9 0 9 0

K - ______

R - ______

M - ______

G - ______

Your score will be the number marked correctly. Even if you are not sure of the correct answer to a question, it will be to your advantage to guess.

There are two pages to the test. The first of these is a memory page which you are to study for 4 minutes.

The second is a test page on which you are to write the numbers series that go with the letters. You will have two minutes to write.

DO NOT TURN THIS PAGE UNTIL ASKED TO DO SO

BI-COLUMN NUMBER SERIES TEST

Instructions and Sample Items

Each problem in this test has four sets of numbers arranged in two columns each. The first three sets demonstrate a rule governing the relationship between the two columns. Your task will be to discover the rule and then to use it to predict a value in the second column of the fourth set. A different rule will be used for each problem. You are to indicate your answer by writing the predicted value on the answer line provided in the extreme right hand column.

Please study the following example carefully.

Example A:

a	b	a	b	a	b	a	b
4	32	3	45	8	18	3	16
5	30	4	43	3	14	3	13
10	28	6	41	6	10	3	
	26		39		6		

In Example A the correct answer is 13. This answer is marked for you in the space provided in the right hand column. The answer is arrived at by the following rule: Multiply the first two numbers in column a together, then divide their product by the third number in column a. Column b will decrease by the quotient of this division.

Now try to derive the rule and the answer for Example B.

Example B:

a	b	a	b	a	b	a	b
7	65	9	45	16	58	10	58
6	52	6	30	12	30	8	
5	43	3	27	8	18	6	___
4	34	0	24	4	6	4	

In Example B, the values in column b decrease once by an amount equal to the sum of the first two values in column a. Then column b decreases twice by the sum of the last two values in column a. The correct answer is 30. Notice that the answer required for Example B is in the third row, while the answer for Example A is in the second row.

Some of the remaining items in this test will be easier than the examples above, while others will be more difficult. You should expect to find any kind of rule or operation governing the relationship between the two columns. You will have 8 minutes in which to complete the test.

DO NOT TURN THIS PAGE UNTIL ASKED TO DO SO

TOTE MOBILE TEST

Instructions and Sample Items

The accompanying diagram represents the course for a TOTE MOBILE. The TOTE MOBILE may travel up and down or from side to side, but may not travel diagonally. Each square has a label corresponding to the intersection of the numbered columns and lettered rows. As examples, note squares C6, D4 and D8 in the diagram. The vertical lines are labeled with numbers in parentheses while the horizontal lines are labeled with small letters.

REFER TO THE ACCOMPANYING DIAGRAM FOR ALL THE FOLLOWING PROBLEMS.

Below is a chart showing the course of the TOTE MOBILE:

	Start				
Location	D4	D5	D6	D7	D8

Thus, the TOTE MOBILE traveled from D4 to the right for four squares to D8.

Your task will be to predict the final destination (END SQUARE) of the TOTE MOBILE based on the following given conditions.

Condition I. Tote Mobiles begin traveling to the right.
Condition II. Tote Mobiles travel one square for each cup of fuel.

Look at these two sample items:

1) FUEL = 5

	Start					
Location	G1	G2	G3	G4	G5	G6

END SQUARE = G6

2) FUEL = 6

	Start						
Location	H4	H5	H6	H7	H8	H9	H10

END SQUARE = H10

In item 1 the TOTE MOBILE started in square G1 and traveled to the right (condition I) for 5 squares (condition II). Thus its final destination (G6) is entered in the space provided after END SQUARE =.

In item 2 the TOTE MOBILE traveled six squares to the right since it had 6 cups of fuel.

You may use the empty spaces provided to keep track of the MOBILE's course, however only the value recorded in the blank provided for the END SQUARE will be scored.

For practice, predict the END SQUARE for the following TOTE MOBILES based on the above conditions and the following condition:

Condition III. If a border (line 11, 1, a or k) is reached the TOTE MOBILE will reverse direction.

3) FUEL = 4

Start

Location F8 ______

END SQUARE = ____

4) FUEL = 4

Start

Location C7 ______

END SQUARE = ____

For item number 3 you should have entered F8 in the space provided after END SQUARE and for item 4 you should have entered C9.

You will have 8 minutes for this test and will be told when 3 minutes remain. If you have any questions ask them now.

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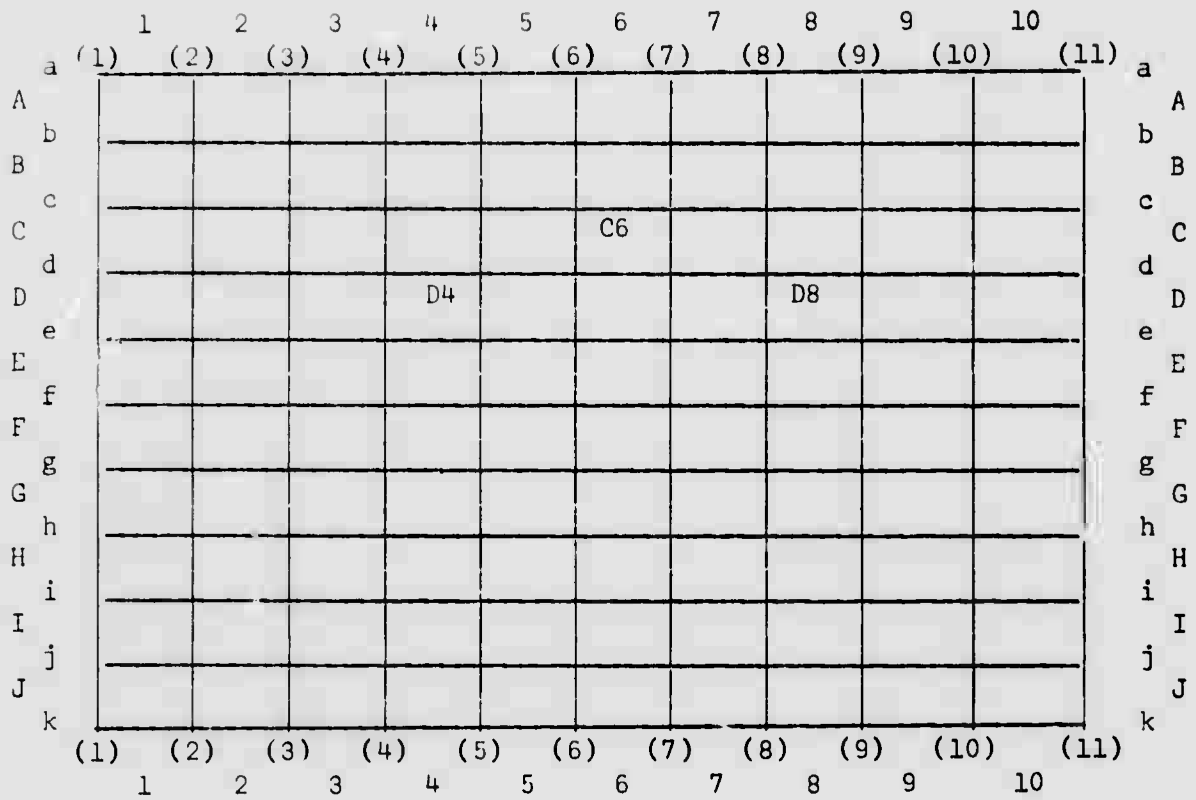
Tote Mobile Test Diagram



REFER TO THIS DIAGRAM TO SOLVE THE TOTE MOBILE PROBLEMS.

APPENDIX G

Linear Regression Models

APPENDIX G

Linear Regression Models

In order to test the ability by treatment interaction hypotheses made in this study, analyses of linear regression models were conducted. A computer program prepared by Jennings (1968) entitled Program Linear was used for the analyses.

The models which were discussed in the section entitled Analysis of Ability by Treatment Interactions are defined mathematically as follows:

Model 1

$$Y = a_1X + a_2O + a_3R + a_4RO + b_1(X*A) + b_2(O*A) + b_3(R*A) + b_4(RO*A) + E_1$$

Where

Y = vector containing the criterion score for each S.

X = vector in which the element is a 1 if the corresponding element in Y is a score for a S in the Example-Only group, zero otherwise.

O = vector in which the element is a 1 if the corresponding element in Y is a score for a S in the Objective-Example group, zero otherwise.

R = vector in which the element is a 1 if the corresponding element in Y is a score for a S in the Rule-Example group, zero otherwise.

RO = vector in which the element is a 1 if the corresponding element in Y is a score for a S in the Objective-Rule-Example group, zero otherwise.

A = ability score of a S whose corresponding criterion score is an element of vector Y.

X*A, O*A, R*A, and RO*A are direct product vectors which are obtained by multiplying each element of the first vector by its corresponding element in the second vector. Thus X*A is a vector containing ability scores for Ss in the Example-Only group, and zero otherwise.

$a_1, a_2, a_3, a_4, b_1, b_2, b_3, b_4$ = unknown coefficients, or weights, associated with their corresponding vectors. These weights are estimated by a least-squares procedure.

E = residual vector in which elements are the differences between the observed and estimated values in the criterion vector Y.

The above and following models assume that for each unit of change in ability score there is an equal change on the criterion. This assumption is commonly referred to as the assumption of linearity.

In effect, the estimated values for b_1, b_2, b_3, and b_4 are the slopes of the treatment group regression lines. Thus, the above model allows the four slopes to be different.

To test the null-hypothesis that the slopes are all parallel, the following restrictions are imposed on the slope coefficients of Model 1:

$$b_1 = b_2 = b_3 = b_4 = bo \text{ (a common weight)}$$

giving the following restricted model:

Model 2

$$Y = a_1X + a_2O + a_3R + a_4RO + boA + E_2$$

where the vectors are defined as under Model 1 above.

To test the null-hypothesis that the regression lines' slopes for the Objective-Example group, the Rule-Example group, and the Objective-Rule-Example groups are all mutually parallel, and the slope of the Example-Only group regression line is allowed to be different, the following restrictions are imposed on the coefficients of Model 1:

$$b_2 = b_3 = b_4 = c_o \text{ (a common weight)}$$

giving the following restricted model:

Model 3

$$Y = a_1X + a_2O + a_3R + a_4RO + b_1(X*A) + c_oZ + E_3$$

Where

Z = (O*A) + (R*A) + (RO*A) = vector containing ability scores for Ss in the Objective-Example, Rule-Example, and Objective-Rule-Example groups, and zero otherwise.

APPENDIX H

Correlation Matrices

APPENDIX H

Table 23

Intercorrelation of Criterion Variables for All Groups[a,b]

Variable Number	1	2	3	4	5	6	7
1. Post	100	82**	60**	-35**	-27**	-24**	-28**
2. Retention		100	60**	-35**	-25**	-20*	-24**
3. Transfer			100	-43**	-31**	-35**	-36**
4. No. of Examples				100	60**	73**	73**
5. Display Latency					100	70**	92**
6. Test-Item-Response Latency						100	92**
7. Total Latency							100

[a]Decimal points omitted.

[b]n = 127 for display and total latency;
n = 130 for all other criteria.

*p < .05
**p < .01

Table 24

Correlations of Criterion Variables with Cognitive Ability Covariables[a]

Covariables	Post	Retention	Transfer	No. of Examples	Display Latency	Test-Item Response Latency	Total Latency
Example-Only Group[b]							
Memory of Number Series (MA)	31	31	42*	-36*	-21	-28	-27
First & Last Names (MA)	27	11	23	-27	-26	-25	-26
Bi-Column Number Series (I)	14	19	12	-21	-21	-26	-21
Letter Sets (I)	32	23	11	-45**	-45	-57**	-54**
Tote Mobile (R)	43*	33	34	-46**	-48**	-53**	-51**
Ship Destination (R)	35*	63**	43*	-52**	-36*	-53**	-46**
Reasoning Factor	39*	46**	32	-52**	-47**	-59**	-54**
Memory Factor	27	11	27	-26	-22	-22	-23
Objective-Example Group[c]							
Memory of Number Series (MA)	10	-01	06	-15	-22	-15	-22
First & Last Names (MA)	05	-02	00	-16	-34	06	-19
Bi-Column Number Series (I)	08	17	21	-38*	-22	-32	-29
Letter Sets (I)	15	21	11	-17	00	-08	-04
Tote Mobile (R)	26	16	35*	-15	-19	-03	-14
Ship Destination (R)	45**	42*	40*	-42*	-33	-31	-35*
Reasoning Factor	36*	37*	40*	-40*	-24	-28	[illegible]
Memory Factor	01	-09	-03	-11	-28	01	-17
Rule-Example Group[d]							
Memory of Number Series (MA)	18	04	07	-34	-28	-28	-29
First & Last Names (MA)	07	02	02	-22	-08	-10	-09
Bi-Column Number Series (I)	20	20	08	-38*	-39*	-50**	-47**
Letter Sets (I)	17	10	22	-26	-20	-19	-21
Tote Mobile (R)	45**	38*	54**	-31	-51**	-37*	-46**
Ship Destination (R)	32*	22	35*	-42*	-53**	-44*	-51**
Reasoning Factor	37*	29	41*	-44*	-53**	-47**	-52**
Memory Factor	10	00	-02	-20	-12	-14	-14
Objective-Rule-Example Group[e]							
Memory of Number Series (MA)	02	08	32*	-14	-27	-34	-32
First & Last Names (MA)	11	23	41*	-24	-10	-32	-20
Bi-Column Number Series (I)	24	38*	09	22	-22	-14	-22
Letter Sets (I)	16	31	04	-30	-64**	-54**	-65**
Tote Mobile (R)	37*	50**	35*	-44*	-54**	-48**	-56**
Ship Destination (R)	45**	38*	07	00	-26	-18	-25
Reasoning Factor	41*	51**	15	-16	-54**	-42*	-54**
Memory Factor	02	13	40*	-23	-21	-37*	-20

[a]Decimal points omitted.
[b]$\underline{n}$ = 30 for display and total latency; $\underline{n}$ = 32 for all other criteria.
[c]$\underline{n}$ = 32 for display and total latency; $\underline{n}$ = 33 for all other criteria.
[d]$\underline{n}$ = 32
[e]$\underline{n}$ = 33
*$\underline{p}$ < .05
**$\underline{p}$ < .01

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