THE INTERACTION OF ASSOCIATIVE MEMORY AND GENERAL REASONING WITH AVAILABILITY AND COMPLEXITY OF EXAMPLES IN A COMPUTER-ASSISTED INSTRUCTION TASK

C. Victor Bunderson
Joe B. Hansen

TECHNICAL REPORT NO. 6

August 1971

PROJECT ON COGNITIVE ABILITIES AND LEARNING
Sponsored By
Advanced Research Projects Agency
ARPA Order No. 1261
Contract N00014-67-A-0126-0006
Program Code No.: NR 154-282/8-13-68 Code 458

This research was sponsored by the Personnel and Training Research Programs, Psychological Sciences Division, Office of Naval Research, Washington, D. C.

Co-Principal Investigators:
C. V. Bunderson and J. L. Dunham

THE UNIVERSITY OF TEXAS AT AUSTIN
Computer-Assisted Instruction Laboratory
Austin, Texas 78712

Unclassified
Security Classification

DOCUMENT CONTROL DATA - R & D

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

1. ORIGINATING ACTIVITY (Corporate author) Advanced Research Projects Agency Washington, D. C. 20301	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP

3. REPORT TITLE
THE INTERACTION OF ASSOCIATIVE MEMORY AND GENERAL REASONING WITH AVAILABILITY AND COMPLEXITY OF EXAMPLES IN A COMPUTER-ASSISTED INSTRUCTION TASK

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)
Technical Report No. 6, August 1971

5. AUTHOR(S) (First name, middle initial, last name)
C. Victor Bunderson, and Joe B. Hansen

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
August 1971	18	11

8a. CONTRACT OR GRANT NO. N00014-67-A-0126-0006 b. PROJECT NO. NR 154-282/8-13-68 Code 458 c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report) Technical Report No. 6

10. DISTRIBUTION STATEMENT
This document has been approved for public release and sale; its distribution is unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	U.S. Department of the Navy Office of Naval Research Washington, D.C. 20301

13. ABSTRACT

In an attempt to produce an ability by treatment interaction (ATI) between associative memory and the complexity and availability of examples, 110 undergraduate Ss were randomly assigned to four treatment groups for a computer-assisted instruction task. The groups consisted of a double classification on availability and complexity of examples. (U)

All Ss were given six ability tests measuring the factors of general reasoning and associative memory. The hypothesized ATI was observed but failed to reach significance, possibly due to inadequate control of example availability. Both availability and complexity increased the demand for reasoning ability. Further studies were suggested. (U)

I

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Associative Memory						
General Reasoning						
Availability of Examples						
Complexity of Examples						
Computer-Assisted Instruction						
Ability by Treatment Interaction.						
Ability Measures						
The Science of the Xenograde System						
Factor Analysis						
Two-Factor Varimax Solution						

II

THE INTERACTION OF ASSOCIATIVE MEMORY AND GENERAL REASONING WITH AVAILABILITY AND COMPLEXITY OF EXAMPLES IN A COMPUTER-ASSISTED INSTRUCTION TASK

The results of a series of ability by treatment interaction (ATI) studies at The University of Texas at Austin (Bunderson, 1969a, 1969b; Dunham & Bunderson, 1969; Merrill, 1970) have suggested that the ATI phenomenon can be brought under experimental control, thereby enabling researchers to produce ATI's through the revision and alteration of available instructional treatments. This study is the fourth in a series of studies which have attempted to examine the relationship of two separate aptitude factors, Associative Memory (Ma) and Reasoning (R), to various performance criteria in a hierarchical learning task utilizing computer-assisted instruction (CAI).

In the first study in this series a significant disordinal interaction was produced by the two instructional treatments comprising "expository" and "discovery" approaches and the regression of number of examples required to learn the material on Associative Memory factor scores. All Ss in this study had access to previous examples throughout the task. For the discovery group the slope of the regression line was positive, while for the expository group, it was negative. Following a task revision in which examples used were simplified, two further studies were conducted.

In the second and third studies, previously displayed examples were not available to Ss. In both of these studies the regression of number of examples on Ma factor scores produced a negative slope, indicating greater learning efficiency for high Ma Ss than for low Ma Ss. Previous studies (Blaine, Dunham, & Pyle, 1968) indicated that Memory load in a concept attainment task could be reduced by having past instances available. It was reasoned, therefore, that the removal of previous instance availability in revising the task may have had a similar effect. Before task revision, Ss of low Ma may have been aided by having access to previous examples, while those high on Ma may have been led to adopt inappropriate strategies, resulting in less efficient strategies for high than for low Ma Ss. This strategy selection hypothesis was suggested by Bunderson (1967) and is consistent with the findings of Wicklegren and Cohen (1962). These investigators found that Ss who used a smaller external Memory device solved multidimensional concept problems faster and with a greater rate of success than those using a much larger external memory, the larger Memory capacity having led Ss to employ highly inefficient strategies.

The present study was an attempt to replicate the previous regression slope reversal under controlled conditions. Since the task revision following the first study included simplifying the examples used, as well as eliminating the availability factor, example complexity was included as a dimension of this study. It was included as a control variable only and no *a priori* hypotheses were made regarding its effects. Specifically, it was hypothesized that when previous examples were available, Ss with high Ma scores would persist longer in an inappropriate strategy than would Ss low on Ma, leading to a negative regression of performance on Ma, while in the non-available group, Ma ability would show a strong positive relationship to performance, thus producing a significant ATI.

Method

Subjects. The Ss in this study were 110 undergraduate education majors from The University of Texas at Austin.

Materials and apparatus. The task, a CAI program on an imaginary science called "The Science of Xenograde Systems," is comprised of 10 rules that govern the relationship between a nucleus and an orbiting satellite in a closed, oscillating system. The task was programmed in Coursewriter II and was presented on the IBM 1500 instructional system, using IBM 1510 cathode ray tube (CRT) display units.

The Ss were randomly assigned to four treatment groups, each group employing an inductive approach. Group I (n = 26) was the "simple display--no previous examples available" group. The examples presented on the CRT for this group were simplified to contain no redundancies or irrelevancies, providing just enough information to illustrate the rule being taught. Group II (n = 18), the "simple display--plus availability" group, received the same examples as Group I, but received additional instructions to copy all relevant data from each example as it was displayed, using a special display recording form provided for this purpose. Group III (n = 32), the "complex display--not available" group, was the same as Group I except that the examples displayed contained additional, irrelevant information beyond that which was minimally necessary for learning the rules. Group IV (n = 34), the "complex display--plus availability" group, received the complex examples and the recording forms with instructions the same as those given Group II. The four groups together formed a 2 x 2 factorial design.

Procedure. The study was conducted in three phases. In Phase I, all Ss were given a battery of six ability tests, consisting of two markers each for the three factors of Associative Memory (Ma), Induction (I), and General Reasoning (R). One of the tests for each factor was taken from the Kit of Reference Tests for Cognitive Factors (French, Ekstrom, & Price, 1963). The other three measures were task relevant process measures developed to measure processes inherent in the Xenograde task and are described in detail by Merrill (1970).

Phase II consisted of presentation of the learning task, followed by a 60-item paper-and-pencil posttest. In the learning task each S was presented with a tabular display (example) on the CRT screen, representing a Xenograde system at each of several increments in time. From each display, S was to infer the rule exemplified by it. Following each example, S was presented with three completion-type questions on the CRT, requiring application of the rule. Answering two of these three questions correctly resulted in S's being advanced to the next rule. Failure to reach this criterion caused the presentation of a new example of the same rule, followed by three more questions. This procedure was repeated for each rule until S either met the criterion of two out of three correct or received the maximum of five examples and their corresponding test items for a given rule.

In the first three studies the posttest was administered on-line while the S was still seated at the terminal. Some corrective feedback was necessary in order to prevent cumulative errors from adversely affecting performance as S proceeded further through the test. No significant ATI effects were obtained on posttest results on any of these earlier studies. Since it was desirable to have a measure of amount learned as well as learning efficiency, the posttest was revised for this study to a paper-and-pencil test, redesigned to eliminate the need for corrective feedback.

Phase III consisted of the retention and transfer tests. The retention test constituted a parallel form of the posttest, while the transfer test required S to infer three new higher order rules for the Xenograde science from two examples provided. The test contained 24 constructed response test items requiring application of the three new rules.

Results

A factor analysis of the ability scores resulted in a two-factor Varimax solution, yielding the factors of Ma and R, the I factor failing to separate. Factor scores for each test were used in a multiple-linear regression analysis to test the main hypothesis and to explore other interesting aspects of the data. The analysis was based on procedures described by Bottenberg and Ward (1963).

The hypothesized interaction of Ma with Availability using number of examples as the criterion was observed but failed to reach statistical significance. However, the regression lines for Groups I and II do cross near the center of the factor score range and the slopes are in the predicted directions. This finding is illustrated in Figure 1.

A significant ($p < .05$) Pearson product moment correlation of .44 was obtained between number of examples and Ma factor scores for Group I. Group II produced an $R = -.11$ for these measures. Taken together, these correlations indicate that availability of past examples reduces the memory requirement for Ss who receive simple examples.

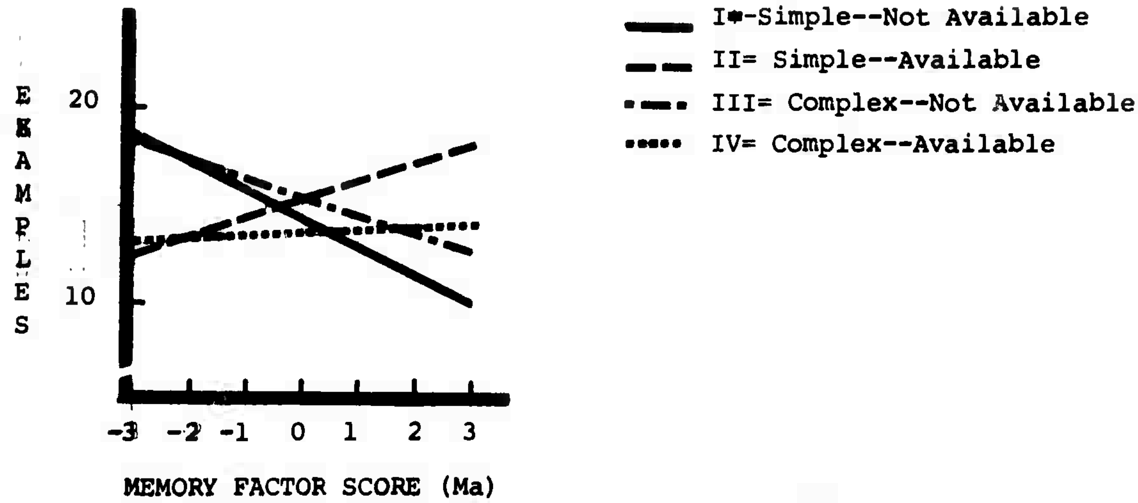

Figure 1.--Regression of number of examples required to learn the science on memory factor scores, by group.

In a test for parallel slopes, a significant _F_ ratio was obtained for the regression of number of examples on R factor scores, $F(3,102) = 4.30$, $p < .01$. Further analysis revealed the slope of the regression line for Group II to be significantly steeper than the others, $F(1,104) = 10.33$, $p < .002$. These findings are illustrated in Figure 2.

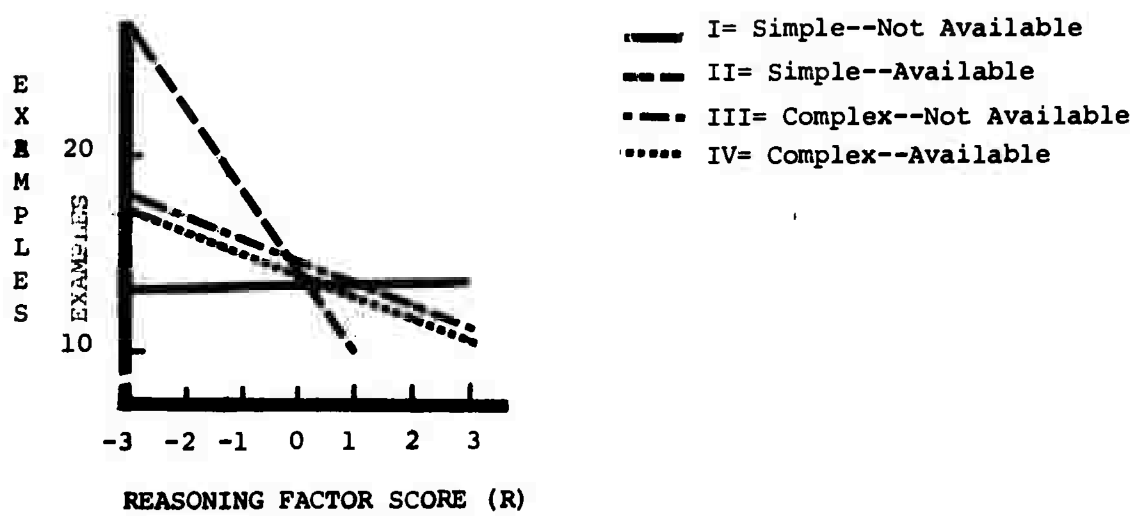

Figure 2.--Regression of number of examples required to learn the science on reasoning factor scores, by group.

For Ss in Group II, reasoning score was a better predictor of the number of examples required to learn the science than for any other groups. The availability of previous examples seemed to facilitate performance for Ss with high R scores, while it generally impeded performance for Ss low on R. In the simple non-availability group, R scores were not related to performance. The effect of example complexity was slightly detrimental to performance for Ss low on reasoning ability without impairing performance for high ability Ss. The high reasoning ability Ss did rather well, irrespective of treatment condition. The regression of posttest raw scores on R factor scores produced a significant disordinal ATI, $F(3,102) = 3.54$, $p < .02$. Figure 3 illustrates this finding.

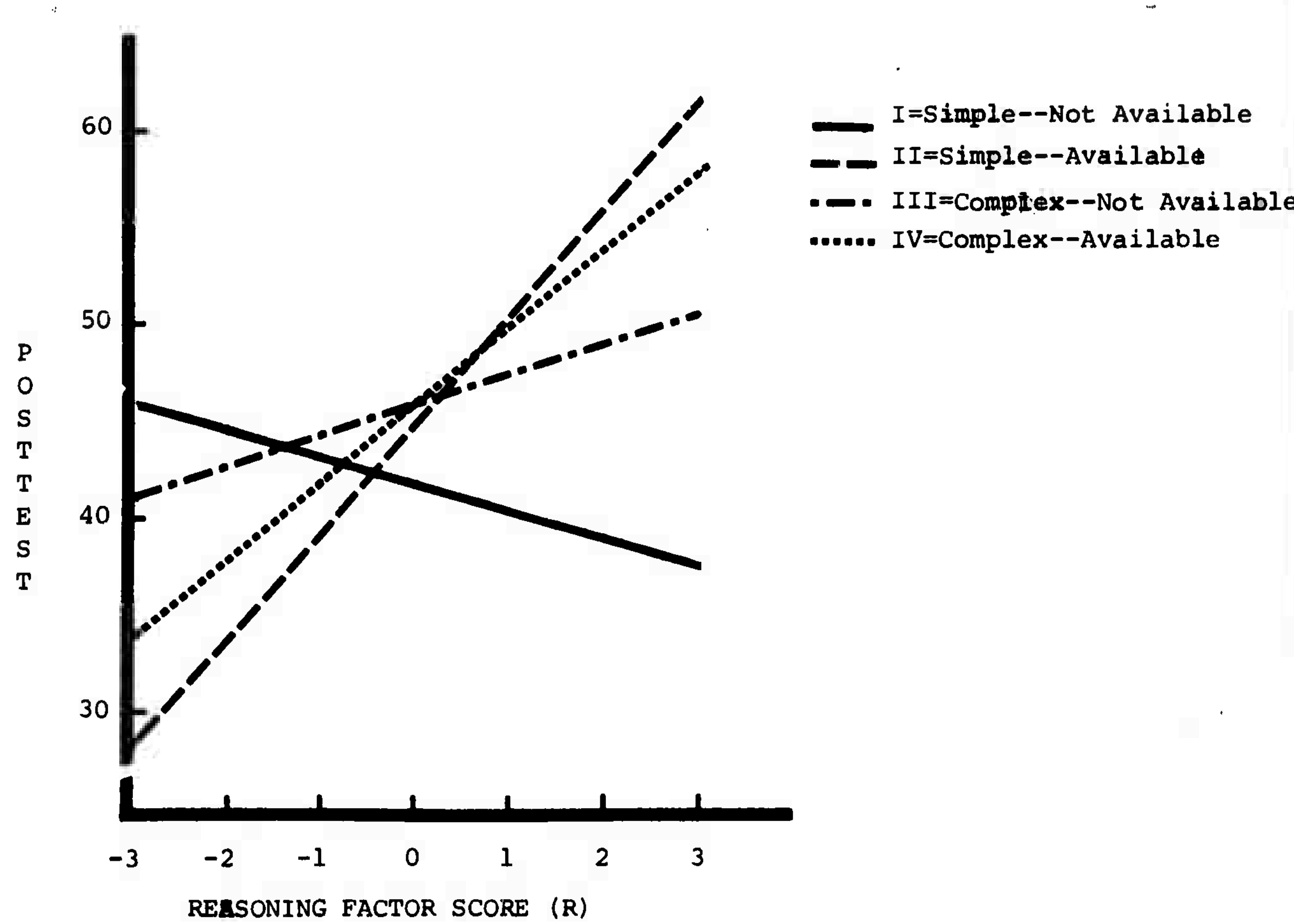

Figure 3.--Regression of posttest raw score on reasoning factor scores, by group.

As is shown in Figure 3, the regression slope for Group I is negative and differs significantly from the other slopes which are essentially parallel to one another and all positive. The possession of high Reasoning ability for Ss in all groups except Group I facilitated learning. For Group I, a high score on this ability was associated with decreased performance.

A significant interaction, $F(1,106) = 4.16$, $p < .05$, was obtained for mean number of examples, with the simple--not-available group and the complex--available group completing the task with fewer examples than the simple--available and complex--not-available groups. Table 1 shows the means and standard deviations for number of examples for each group disregarding abilities.

Table 1

Means and Standard Deviations for Each Group on Number of Examples Required to Learn the Science

Complexity of Examples	Available			Not Available		
	N	Mean	SD	N	Mean	SD
Simple	18	15.44	6.92	26	13.54	2.42
Complex	34	13.47	3.08	32	15.00	3.59

The retention and transfer phase was largely exploratory and produced few striking results. The relationship between retention test scores and Reasoning ability closely approximated the posttest by Reasoning data for all groups except the simple--available group. For the Ss in this group, Reasoning ability had no effect on retention scores at any level of R, as can be seen in Figure 4.

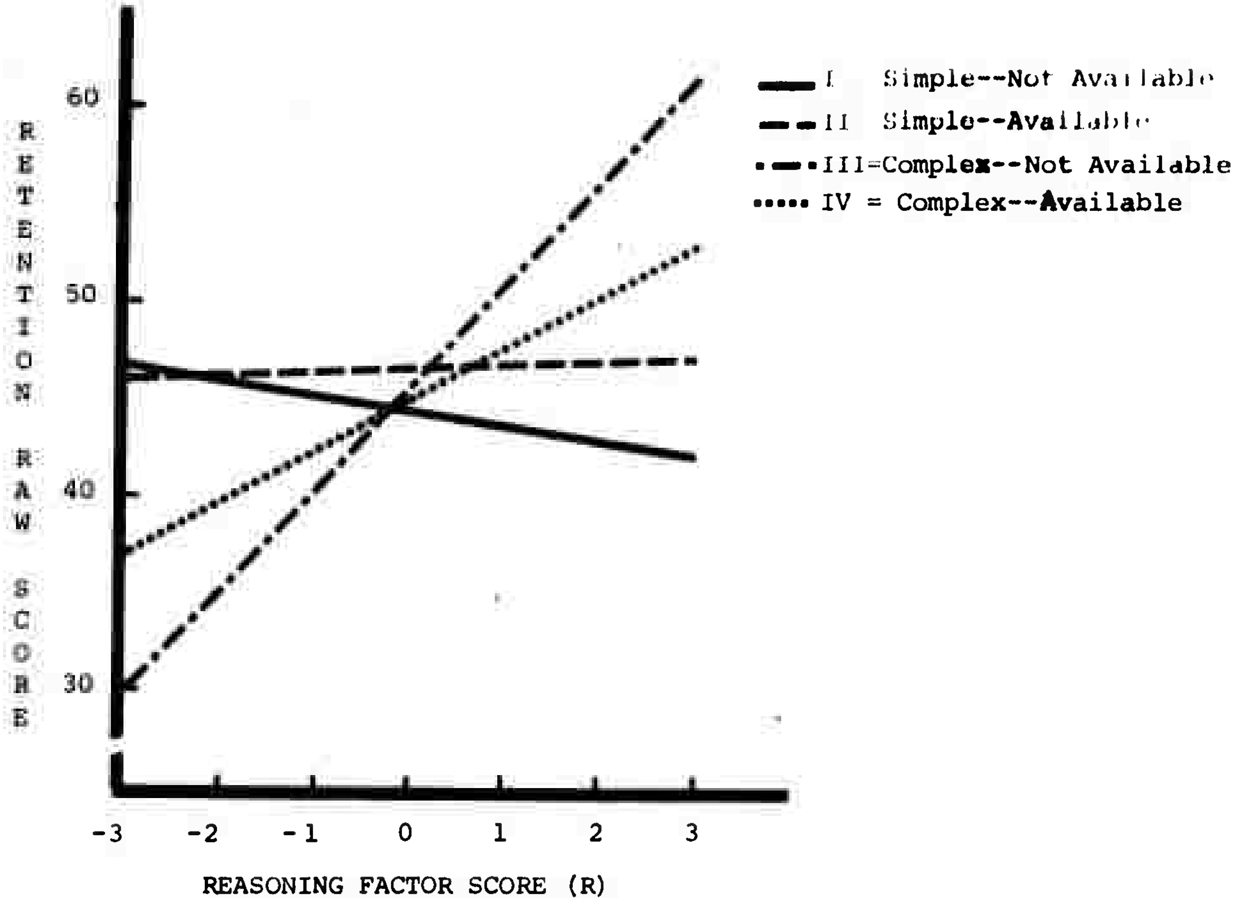

Figure 4.--Regression of Betention on reasoning factor, by group.

For Ss of low R ability, the simple example-available treatment resulted in an improvement of performance on retention as compared with posttest scores, while those Ss of higher R ability showed a decrease from posttest to retention. Low R Ss in the simple-available group required a greater number of examples than high R's in the same condition. It is possible that the additional exposure to examples enabled the low R Ss to learn from the posttest, thereby producing an improvement in performance on the parallel form retention test.

Despite the decreased efficiency of learning for low Ma Ss without availability, there was no significant difference between groups on posttest nor on retention test results. The regression slopes for all groups were essentially parallel on each of these criteria.

The Ma by Transfer interaction observed in Figure 5 failed to reach significance at an acceptable level. Availability produced negatively-sloped regression lines, and non-availability produced positive slopes, the two pairs of lines crossing near the midpoint of the factor range. Availability seemed to be a greater asset to low Ma Ss on the transfer task than on the retention test.

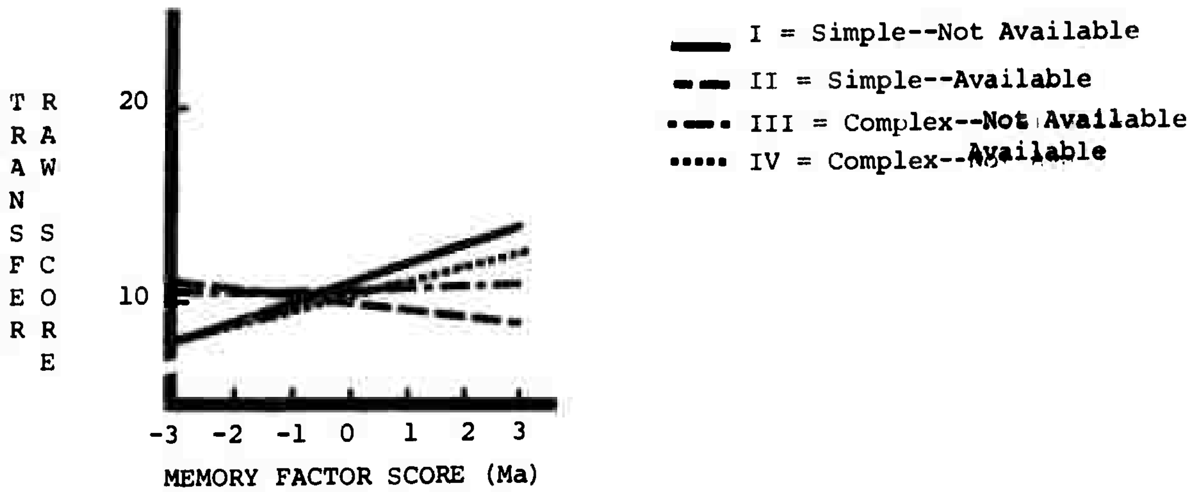

Figure 5.--Regression of transfer test raw scores on memory factor scores, by group.

A slight moderate positive relationship can be observed between R and transfer scores for all groups, with the simple--available group again distinguishing itself from the others. These data are plotted in Figure 6. This positive relationship between R and transfer scores, while seemingly understandable, represents a reversal of the observed trend from posttest to retention for this group. While the posttest-retention shift in regression slope for this group might be explained in terms of posttest learning for low R Ss, it seems more likely that the stronger slope here indicates an increased need for reasoning skills on the transfer task.

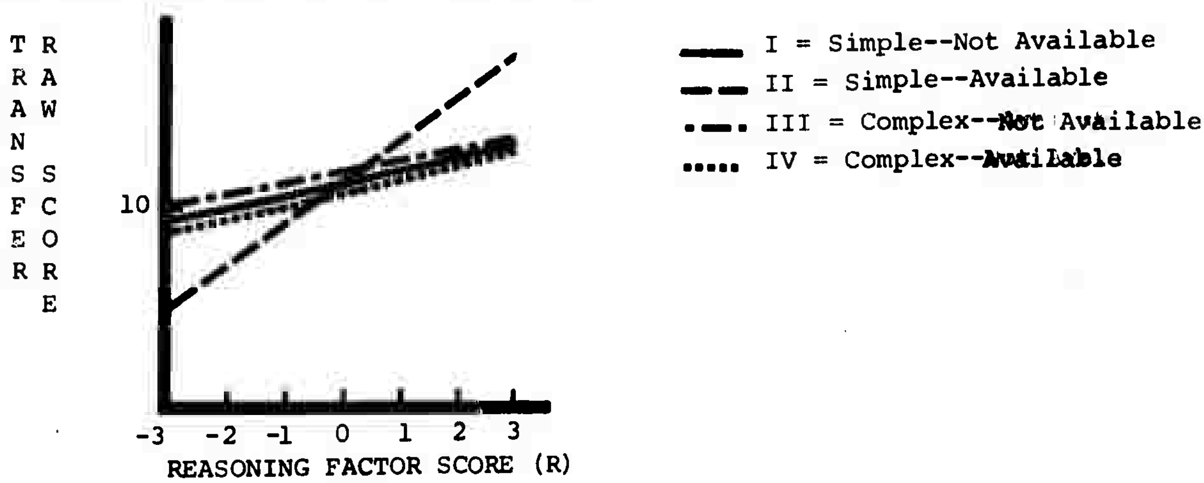

Figure 6.--Regression of transfer scores on reasoning factor scores, by group.

Discussion

The significant correlation between number of examples and Ma scores for Group I, when compared with the very low nonsignificant corresponding correlation for Group II, provides support for the findings of previous concept-learning studies (Blaine, Dunham, & Pyle, 1968; Bourne, Goldstein, & Link, 1964; Pishkin & Wolfgang, 1965). These studies have suggested that past instance availability reduces the short-term memory load, thus facilitating performance for Ss on the lower end of the Memory ability range.

It is well to note that while ability measures assume an underlying psychological continuum, adherence to such an assumption poses serious difficulties in interpreting data such as these. It may be more reasonable to assume that abilities differ somewhat at different extremes of their scales and that different explanations may be required for the effects of low ability on performance than for the effects of high ability on performance. The results of this study are therefore interpreted from this point of view.

The effect of availability on low Ma may be viewed as facilitative in that it leads to more efficient performance while non-availability is superior for high Ma Ss. This differential efficiency could be attributed to the selection of different learning strategies. Such an explanation is consistent with the findings of Wicklegren and Cohen (1962). Complexity of examples had no effect on the learning efficiency of low Ma Ss, but seemed to reduce the availability effect for Ss of high Ma ability. Availability of examples during learning adversely affected both learning efficiency and mastery for Ss of low Reasoning ability. High R ability Ss, however, benefited from availability.

These data suggested the need for further analysis in which Reasoning and Memory factor scores could be covaried simultaneously in an attempt to determine whether varying combinations of these two abilities would result in differential utilization of the availability and complexity dimensions. Bunderson (1967) found that Ss who were either high or low on both Inductive Reasoning ability and memory span were better at solving complex problems using positive instances than were Ss who were high on either one of these factors and low on the other. This line of reasoning led to the tentative hypothesis that high Memory ability might be of little or no value in problem solving unless one also possesses sufficiently high reasoning ability to enable him to select and implement an effective strategy for utilization of stored information. Additional analysis failed to provide support for this, however.

The effect of complexity of examples was that of facilitating both efficiency of performance and amount learned for Ss with high R ability and of impairing performance and learning for Ss low on R ability, while moderating the effect of availability. Perhaps complex examples during learning increased the interest value of the task for high reasoning types, with this increased interest carrying over to the posttest as a motivational factor.

This interest hypothesis might also help to explain the poorer performance for the Group I Ss with high R ability. Perhaps the examples they received were so simple as to be noninteresting to them, thus adversely affecting their performance both during learning and later during the posttest.

Failure to obtain an acceptably high level of significance for the availability effect may be partly attributable to the manner in which recording forms were used. Individual Ss revealed a large amount of idiosyncratic behavior with respect to the use of these forms. Some Ss used the forms to record complete displays, some Ss recorded only parts of displays, while others used the forms for note-taking and data summarization. This diversity of recording behaviors might be a result of some ambiguity in the instructions given the availability groups. The instructions were:

> *As you proceed through the course, you will find it necessary to recall certain information from previous displays. You should therefore use the accompanying recording forms to record all relevant data from each display as it is presented on the CRT screen.*

These instructions may have allowed for considerable variability in behavior depending upon S's interpretation of them. Perhaps stronger instructions defining the desired recording behaviors more explicitly would have resulted in greater uniformity in the use of the recording forms, thereby reducing the amount of variance on the dependent variable for the availability groups.

An alternate approach to the problem of example availability might be to have the examples recorded on 16mm film and displayed via the image projector. Such an approach would insure that S would receive a complete example and would obviate the need for S to record any data, thus promoting increased concentration while studying the example.

Throughout these data, complexity seems to have been acting as a moderator of the availability effect. For the regression of both posttest and retention on R scores, complex examples produced relatively steep positive slopes, indicating greater demand for Reasoning ability. Since these explanations of complexity effects and all observations on posttest performance are based primarily on post-hoc reasoning, further studies are recommended to confirm them.

References

Blaine, D. D., Dunham, J. L., & Pyle, T. W. Type and amount of available past instances in concept learning. *Psychonomic Science*, 1968, 12(4), 159-160.

Bottenberg, R. A., & Ward, J. H., Jr. *Applied multiple linear regression.* Technical Documentary Report, PRL-TDR-63-6, 1963, Lackland AFB, Texas, 1963.

Bourne, L. E., Jr., Goldstein, S., & Link, W. E. Concept learning as a function of availability of previously presented information. *Journal of Experimental Psychology*, 1964, 67, 439-448.

Bunderson, C. V. Transfer of mental abilities at different stages of practice in the solution of concept problems. Research Bulletin (RB-67-20). Princeton, N.J.: Educational Testing Service, 1967.

Bunderson, C. V. Ability by treatment interaction in designing instruction for a hierarchical learning task. Paper presented at the annual meeting of the American Educational Research Association, Los Angeles, February, 1969a.

Bunderson, C. V. Aptitude by treatment interaction: of what use to the instructional designer? Paper presented at the annual meeting of the American Psychological Association, Washington, D. C., September, 1969b.

Dunham, J. L., & Bunderson, C. V. Effect of decision-rule instruction upon the relationship of cognitive abilities to performance in multiple-category concept problems. *Journal of Educational Psychology*, 1969, 60(2), 121-125.

French, J. W., Ekstrom, R. B., & Price, L. A. Kit of reference tests for cognitive factors. Princeton, N. J.: Educational Testing Service, 1963.

Merrill, P. F. Interaction of cognitive abilities with availability of behavioral objectives in learning a hierarchical task by computer-assisted instruction. Technical Report No. 5, Advanced Research Projects Agency Contract No. N00014-67-A-0126-0006, Austin, Texas: Computer-Assisted Instruction Laboratory, The University of Texas at Austin, 1970.

Pishkin, V., & Wolfgang, A. Number and type of available instances in concept learning. *Journal of Experimental Psychology*, 1965, 69, 5-8.

Wickelgren, W., & Cohen, D. H. An artificial language and memory approach to concept attainment. *Psychological Reports*, 1962, 11, 815-827.