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INDIVIDUAL DIFFERENCES IN LEARNING FROM VERBAL AND FIGURAL MATE--ETC

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N00014-75-C-0882

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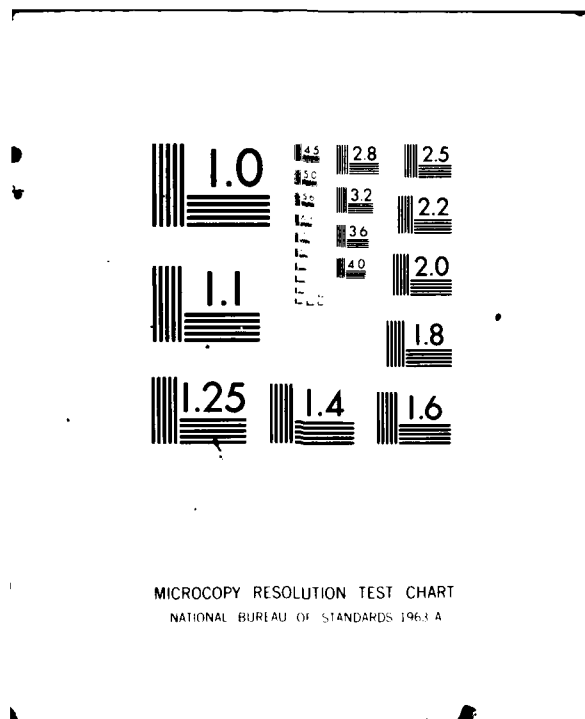
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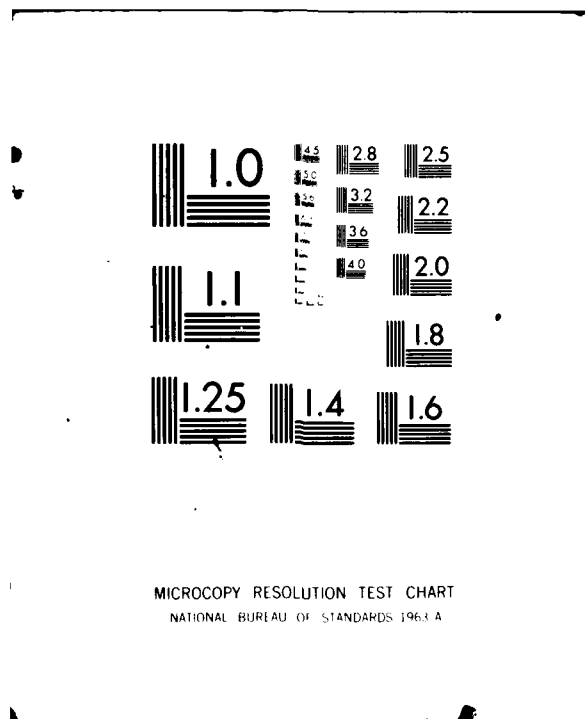
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LEVEL II

INDIVIDUAL DIFFERENCES IN LEARNING
FROM VERBAL AND FIGURAL MATERIALS

ELANNA YALOW

TECHNICAL REPORT NO. 12
APTITUDE RESEARCH PROJECT
SCHOOL OF EDUCATION
STANFORD UNIVERSITY

Sponsored by
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Psychological Sciences Division
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and
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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER 12	2. GOVT ACCESSION NO. AD-A098	3. RECIPIENT'S CATALOG NUMBER 317
4. TITLE (and Subtitle) Individual Differences in Learning From Verbal and Figural Materials		5. TYPE OF REPORT & PERIOD COVERED Technical Report
		6. PERFORMING ORG. REPORT NUMBER 12
7. AUTHOR(s) Elanna Yalow		8. CONTRACT OR GRANT NUMBER(s) N00014-75-C-0882
9. PERFORMING ORGANIZATION NAME AND ADDRESS School of Education Stanford University Stanford, California 94305		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS NR 154-376
11. CONTROLLING OFFICE NAME AND ADDRESS Personnel and Training Research Program Psychological Sciences Division, ONR, 458		12. REPORT DATE September 1980
		13. NUMBER OF PAGES 44
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report) UNLIMITED		
DISTRIBUTION STATEMENT A Approved for public release; Distribution Unlimited		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report) UNLIMITED		
18. SUPPLEMENTARY NOTES This research was jointly sponsored by the Office of Naval Research and the Defense Advanced Research Projects Agency.		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Aptitudes, aptitude-instructional treatment interaction, cognitive abilities, learning, verbal vs. figural materials in instruction, elaboration of instruction.		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) The effects of supplementary verbal and figural instructional materials on students of different abilities are not fully understood. Findings in this area have been inconclusive and inconsistent. Rarely have treatment or aptitude specifications been sufficiently precise to relate outcome to particular instructional components. The present study attempted to improve on some of these shortcomings. Of primary interest in this study was the effect of general ability on learning. It was hypothesized that students higher in general ability would		

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obtain higher posttest scores on the average than lower ability students. It was further hypothesized that verbal and figural explanatory supplements to minimal instructional materials would reduce the regression of general ability on outcome. That is, the difference between low and high ability students was expected to be smallest when instruction was supplemented with explanatory verbal or figural displays.

This study further explored the differential impact of crystallized-verbal ability (Gc) and fluid-spatial-visualization ability (Gfv). As before, it was expected that students with higher aptitude scores would obtain higher posttest scores. Furthermore, it was hypothesized that Gc and Gfv might moderate the relations between instruction and outcome differently. Thus, verbal supplements were expected to be particularly useful to students low in Gc; figural supplements were expected to be particularly useful to students low in Gfv.

This study also explored the effects of a more task-specific aptitude, graph processing, on outcome, and involved both immediate and delayed learning outcome measures.

A 2-week course in Economics was presented to high-school students using one of three sets of instructional materials. Before the course, participants took a 3-hour aptitude battery and were randomly assigned to treatment. Posttests were administered at the end of the course and two weeks later.

The basic treatment covered the theory of market price. Treatments varied in the explanatory displays and the difficulty of the processing demands. One treatment (MIN) presented the information with little redundancy, few examples, and limited explanations. Another (VE) covered the same material as MIN, with additional verbal expansion material. A third (FE) covered the material of MIN, with additional graphs and diagrams as figural expansion.

Generalized regression analysis was used to assess the effects of aptitudes, treatments, and their interactions (ATI). On the immediate posttest, students in VE and FE did better than students in MIN, suggesting that the elaboration provided in these conditions helped students learn. Significant ATIs suggested that the elaboration was particularly useful to low ability students. High ability students did as well or better in MIN. Thus, the regression of achievement on general ability was steepest in MIN and reduced in VE and FE.

Partitioning the total test score by posttest item type indicated that VE was particularly helpful on verbal items and FE was particularly helpful on figural items. Again, significant ATI indicated that these treatments were particularly helpful to low ability students. Hence, the regression of verbal items on general ability was least steep in VE; the regression of figural items on general ability was least steep in FE.

Examination of learning outcomes on retention, however, led to strikingly different conclusions. While students in MIN were worse on average achievement on the immediate posttest, they performed the best on retention. Losses from immediate to delayed posttest were greatest when the assistance was most direct. That is, losses on verbal items were greatest in VE; losses on figural items were greatest in FE. No significant main effects or ATI were associated with the differential between Gc and Gfv on either posttest.

In summary, this study provided evidence that neither aptitude nor instructional treatment alone can fully describe learning outcomes. Interactions between them exist and were demonstrated. Further, instructional supplements, whether verbal or figural, can be effective in filling-in for student weaknesses and reducing differences between high and low ability students.

Such supplements, however, must be used with caution. Reducing the difficulty of instructional materials may, indeed, enhance immediate learning, but these advantages may be short-lived.

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PREFACE

The investigation reported herein is part of an ongoing research project aimed at understanding the nature and importance of individual differences in aptitude for learning. Requests for information regarding this project and for copies of this or other technical reports should be addresses to:

Professor Richard E. Snow, Principal Investigator
Aptitude Research Project
School of Education
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CHAPTER 1

INTRODUCTION

In the past two decades, research on individual differences in aptitude in relation to instructional variables has increased substantially (Cronbach, 1957; Cronbach and Snow, 1977). A large body of literature now demonstrates that relations between learner aptitudes and learning outcomes vary with instructional conditions. Thus, aptitude-treatment interactions (ATI) clearly exist. However, ATI findings have often been inconsistent and not readily applicable to real world instructional practice (Snow, 1977). Hence, there is a need for research that can provide a deeper understanding of aptitudes, instructional treatments, and their interactions.

Background

The concept of general mental ability is central to most current models of intelligence and ability organization, and has been regarded as the most important aptitude for learning from instruction. Measures of general ability also seem to show the strongest and most consistent ATI. This is, then, the logical place for new ATI research to start.

The bulk of prior evidence is consistent with the following hypothesis: When instruction places heavy information processing burdens on learners, the regression of learning outcomes onto general ability differences is relatively steep; able students do well and less able students do poorly. In contrast, when an instructional treatment is designed to relieve some of the information processing burdens on learners by simplifying, structuring, or elaborating the learning task, the regression of outcome on general ability is relatively shallow; less able students

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benefit, more able students sometimes do less well than they might have done without help (Snow, 1976).

A second, popular ATI hypothesis has arisen from the contrast of verbal and non-verbal ability. This is the major distinction beneath general ability in a hierarchical view of ability organization. The non-verbal side has usually been thought of as spatial (Butcher, 1968; Vernon, 1950) or figural and symbolic (Guilford, 1967) ability, or as fluid-analytic intelligence (Cattell, 1963; 1971). Factor analytic studies often separate verbal-crystallized ability (Gc) from fluid-analytic and visualization ability (see, e.g., Snow, Marshalek, Lohman, Yalow and Webb, 1977). But the further distinction between fluid ability and spatial visualization has often been difficult to make (Lohman, 1979a; Snow, in press). In the present discussion, Gfv is used to denote a combined fluid-analytic-visualization dimension.

This second, differential, hypothesis suggests that matching the medium of instruction (verbal vs. figural, symbolic, or spatial) to the relative strength and weakness of Gfv and Gc in learners should be beneficial, and isolated studies based on this hypothesis have reported ATI. But two different and opposing kinds of matching are possible, and both have been found; matching to the learner's strength might be beneficial in some ways, but matching to the learner's weakness might have compensatory benefits. In one typical study, for example, Peterson and Hancock (1974) taught students the mathematics of network tracing using either verbal, symbolic, or figural materials. Aptitude measures were selected from Guilford's (1967) system to represent these three content areas. Posttests were administered immediately after instruction, and again

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The results of other studies investigating relations between verbal and spatial ability in instruction have also been inconsistent. Allison (1960) provided instruction on concept attainment tasks using either verbal stimuli and semantic solution rules or geometric stimuli and classification solution rules. Verbal and spatial aptitude measures were used. Those higher in verbal ability did better with verbal content; there was no effect for spatial ability. Bracht (1970) taught addition of signed numbers using figural or verbal programmed texts. Numerical, verbal and spatial aptitudes were measured. There were no significant ATI. Markle (1969) taught crystallography using programmed texts composed either entirely of words or emphasizing diagrams. The pattern of correlations of outcome with verbal and spatial measures was similar in both treatments. In a series of studies by Carry (1967), Webb (1971), and Eastman (1972), students were taught quadratic inequalities using materials designed to capitalize on spatial-visualization. After reviewing this series, Cronbach and Snow (1977) concluded, "The three studies together provide only negative evidence on the possible relevance of visualization to a presentation that uses graphs" (p.285).

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On the basis of these and other mixed results, Cronbach and Snow (1977) rejected "the conclusion that spatial treatments demand spatial ability and that differentiated Guilford abilities will interact with treatments of the same name" (p. 293). They did not rule out the possibility of positive findings in the future, however, given more powerful and penetrating analyses.

Gustafsson (1974; 1976) also obtained conflicting results in a series of studies exploring the verbal vs. figural contrast. Two of these studies used a text on polar lights as a verbal treatment; the pictorial treatment was a slightly reduced text supplemented with illustrations. Aptitude measures included a vocabulary test, a reasoning test, and a spatial-visualization test. Learning was measured by a short answer test and an essay test. Results on the essay test were not consistent across the two studies. On the short-answer tests in both studies, the slope of the regression on verbal ability was steeper in the verbal treatment than in the pictorial treatment; students low in Gc did best with pictures, especially if they were also high on Gv. Students in the third study were taught about the heart and the blood circulation system using either illustrated or unillustrated materials. Immediate and delayed outcome measures included items assessing verbal, pictorial, and spatial criteria. Aptitude measures represented Gc and Gv. There were no substantial ATI for the verbal or spatial criteria. Although the pictorial treatment was best for everyone, an ordinal interaction indicated that this treatment was least advantageous for students high on Gc and low on Gv.

More recent research has not changed the picture appreciably. James and Knief (1978), for example, taught students to determine the number of

On the basis of these and other mixed results, Cronbach and Snow (1977) rejected "the conclusion that spatial treatments demand spatial ability and that differentiated Guilford abilities will interact with treatments of the same name" (p. 293). They did not rule out the possibility of positive findings in the future, however, given more powerful and penetrating analyses.

Gustafsson (1974; 1976) also obtained conflicting results in a series of studies exploring the verbal vs. figural contrast. Two of these studies used a text on polar lights as a verbal treatment; the pictorial treatment was a slightly reduced text supplemented with illustrations. Aptitude measures included a vocabulary test, a reasoning test, and a spatial-visualization test. Learning was measured by a short answer test and an essay test. Results on the essay test were not consistent across the two studies. On the short-answer tests in both studies, the slope of the regression on verbal ability was steeper in the verbal treatment than in the pictorial treatment; students low in Gc did best with pictures, especially if they were also high on Gv. Students in the third study were taught about the heart and the blood circulation system using either illustrated or unillustrated materials. Immediate and delayed outcome measures included items assessing verbal, pictorial, and spatial criteria. Aptitude measures represented Gc and Gv. There were no substantial ATI for the verbal or spatial criteria. Although the pictorial treatment was best for everyone, an ordinal interaction indicated that this treatment was least advantageous for students high on Gc and low on Gv.

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subsets in a set of elements using a treatment designed to capitalize on either Gf or Gc. A sum of Gc and Gf scores represented general ability, and the difference between the two scores represented the differential hypothesis. A pretest and posttest were administered. There were significant main effects and ATI with the sum, but neither the difference score nor any of its interactions were significant. Although high ability students, on average, outperformed low ability students, the treatment designed to capitalize on Gc reduced their advantage.

The consistent results for the general-ability hypothesis, and the inconsistent results for the differential ability hypothesis, are both understandable in hindsight. The wide variety of instructional treatment contrasts that yield ATI with general ability can be summarized in terms of variation in amount of information processing demand, but this is only a crude summary, at best. The demand characteristics of different kinds of instruction are not understood in detail, nor is a process theory of ability for analyzing task demands in relation to individual differences available. Treatments are usually poorly specified, and this hampers our pursuit of both the general and the differential-ability hypothesis. An enormous range of instructional materials have been labeled "spatial" or "verbal" with little thought about their processing demands. The presence of figures or pictures does not indicate that a treatment requires spatial ability. Diagrams can tax ability but they can also compensate for weakness. Similarly, it is insufficient to attach global labels to categories of ability. A "spatial" ability test does not necessarily measure spatial ability (Lohman, 1979a; 1979b). Aptitude measures should be understood in terms of amount and kind of processing demand.

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There is not likely to be a simple match of aptitudes and treatments (Cronbach and Snow, 1977; Salomon, 1972). Some kinds of instruction build upon the learner's capacities or preferences, requiring students to bring possessed abilities to bear in learning. Alternatively, instructional materials may do for learners what they cannot do for themselves, and so may reduce ability-outcome correlations. Less able students might profit from such assistance, whereas able students might be turned away by it. Further, learners may substitute abilities they possess for those they lack. Thus, graphic problems might be solved by either verbal processing strategies or by direct manipulation of lines and curves.

Thus, the inconsistency and complexity of earlier ATI results seem due, in part, to the failure to specify requisite abilities for carefully delineated treatments, or to provide a common process description for aptitude and learning tasks. There has also been inadequate consideration given to the multiple ways in which aptitudes and treatments might be matched. The notion that students of high spatial ability necessarily do better in spatial treatments ignores the complexities of both ability and instructional material.

The Present Study

The primary hypothesis investigated here related general ability to learning. First, students higher in general ability were expected to obtain higher posttest scores on the average than lower ability students. Further, both verbal and figural supplements were expected to reduce the slope of the regression of outcome on general ability. The effect of verbal supplements was expected to be greatest on verbal outcome measures; the effect of figural supplements was expected to be greatest on figural outcome measures.

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The present study also explored the differential impact of Gc and Gfv on learning. It was hypothesized that students high in either Gc or Gfv would learn more than lower ability students. It was further hypothesized that Gc and Gfv would moderate the relations between instruction and outcome differently. Verbal supplements were expected to be particularly useful to students low in Gc; figural supplements were expected to be particularly useful to students low in Gfv.

Finally, the study was planned to examine long-term as well as immediate learning. A reduction in average scores from immediate to delayed posttest was expected. The greatest drop in performance was expected when instructional supplements were used. By reducing processing demands, supplements might enhance short-term learning while reducing long-term learning. This effect would be particularly evident where instructional content and outcome were matched. That is, losses on verbal outcome measures would be greater when verbal supplements were used than when figural supplements were used; losses on figural outcome measures would be greater with figural supplements.

To summarize, this study assessed the relations among aptitudes, instructional supplements, and learning outcomes. Gc and Gfv were the aptitudes of particular interest, although more specific aptitudes were also included. Instructional materials differed in the use of verbal and figural supplements. Outcome measures distinguished verbal from figural responses. In general, this study was intended to illuminate the relations between aptitude and instructional treatment.

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CHAPTER 2

METHOD

A 2-week course in Economics was presented to high school students using one of three sets of instructional materials. Beforehand, participants completed a 3-hour aptitude test battery and were randomly assigned to treatment. One posttest was administered at the end of the course; another was given two weeks later.

Sample

Participants were recruited from three Palo Alto, California, high schools. Tenth- and eleventh-grade students responded to an advertisement in a local newspaper and were paid an hourly fee for their participation. The initial 3-hour aptitude session included a 10-item screening test to eliminate those already familiar with the instructional content. Of the 146 students who initially responded, 132 were retained and completed the experiment. The final sample included 86 females and 46 males; 44 participants were assigned to each of the three conditions.

Treatments

The basic instruction covered the theory of supply and demand, determination of market price, elasticity of supply and demand, and the application of these principles to price floors and ceilings, taxation, and agricultural problems. Materials were adapted from introductory college economics textbooks (Lipsey and Steiner, 1969; Samuelson, 1976; Spencer, 1977; Sutton, 1976), but presented at a level appropriate for high school.

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(MIN), Verbal Elaboration (VE), and Figural Elaboration (FE).

Information in MIN was presented with little redundancy, few examples, and limited explanations. Participants were encouraged to solve problems on their own and to generate their own explanations for facts and principles. Principles were presented with limited verbal explanations and figural displays.

VE covered the same basic information as MIN, but with additional verbal material. Examples were given, verbal explanations were presented, and basic concepts were redefined as learners encountered new material. Figural content was identical to that of MIN.

FE also covered the same basic MIN material, but with additional graphs and diagrams. Examples and exercises using graphs in problem solving were added. Additional verbiage was used only to help students understand and manipulate diagrams. The differences among treatments are summarized in Table 1.

Each treatment consisted of eight 50-minute instructional sessions. Participants were limited to one instructional session per day.

Materials

Aptitude Measures

Four tests were selected to measure G_{fv}: The Advanced Progressive Matrices Test (Raven, 1962), Paper Folding Test (French, Ekstrom, and Price, 1963), Copying Test (French et al., 1963), and Memory for Designs (Graham and Kendall, 1960). Measures of G_c included the Terman Concept Mastery Test (Terman, 1956), Advanced Vocabulary Test V-4 (French et al., 1963), and a fill-in vocabulary test adapted from the Wechsler Adult Intelligence Scale (Wechsler, 1955). The latter consisted of 20 words

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TABLE 1
Summary of Treatment Specifications

Component of Instruction	Treatment		
	MIN	VE	FE
General information	+	+	+
Basic statement of economic principles			
Verbal	+	+	+
Figural	+	+	+
Explanation of principles			
Verbal	-	+	-
Figural	-	-	+
Examples	-	+	+
Practice problems	+	+	+
Solutions to practice problems	+	+	+
Explanations of solutions for practice problems			
Verbal	-	+	-
Figural	-	-	+
Redundancy			
Verbal	-	+	-
Figural	-	-	+
Underlining	-	+	-

Note. "+" indicates a component present in the treatment
 "-" indicates a component not present or used minimally

from the WAIS vocabulary section, representing the full range of item difficulty. Items were scored using the guidelines presented in the test manual.

A test of graph processing (GRAPH) was designed and administered to supplement the broader ability tests. This test measured the ability to

the end of the session to review it, thereby equalizing students' working times.

Outcome Measures

An immediate and a delayed posttest were administered after the completion of each instructional unit. The two posttests were similar in format and content. Each test consisted of 40 items and covered most of the material presented during the instructional period. On each test, 15 items required students to answer verbal questions, 15 required students to deal with figural information, and 10 questions required both verbal and figural explanations. For these 10 items, the student was asked to indicate the explanation given first. Within each of these categories, items required either the application of principles to solve a problem, or simple recall or recognition of information specifically discussed during instruction. Response formats included multiple-choice, fill in, and short problems. Approximately one hour was allotted to complete each posttest. Table 2 lists the parts of each posttest, including item type (figural vs. verbal), response format, and the number of items.

Procedure

Instruction began approximately one week after aptitude testing. Participants attended one 50 minute session for each of four days during the first week of instruction, and for each of five days during the second week of instruction. Students completed one packet of material during each session. Sessions were held hourly between 3 p.m. and 11 p.m. on weekdays, and between 9 a.m. and 5 p.m. during the weekend. Students

Table 2
Summary of Outcome Measures

Outcome Measure	Description	Maximum # of Points
Total Posttest	Total number of correct items	40
Verbal Total	Total number of correct verbal items	15
Part 1	Fill-in verbal items	10
Part 2	Multiple-choice verbal items	5
Figural Total	Total number of correct figural items	15
Part 1	Fill-in figural items; draw figure	5
Part 2	Fill-in figural items; interpret figure	5
Part 3	Multiple-choice figural items	5
Problems	Total number of correct problems	10
Verbal correct	Number of correct verbal explanations on problems	10
Figural correct	Number of correct figural explanations on problems	10
Verbal first ^a	Number of correct verbal explanations given first	10
Figural first ^a	Number of correct figural explanations given first	10

Note. Format of immediate and delayed posttest was identical

^aNumbers of verbal first and figural first apply only to correct explanations on the problems.

were allowed to schedule themselves freely except that no more than 30 students could be accommodated in a single session.

Upon arrival, students would take a folder bearing their name, and remove the appropriate packet. At the end of the session, students returned the packet to the investigator, who checked that the student had worked on the proper materials. It was not necessary to schedule participants in the same treatment for the same hours as all students worked individually.

The immediate posttest was administered to each student after all instructional materials were completed. All participants took the immediate posttest on the Friday of the second week of instruction. Most participants returned for the delayed posttest two weeks later; those who could not were scheduled individually for their delayed posttest. All participants completed the delayed posttest within 11 to 17 days after the immediate posttest.

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CHAPTER 3

RESULTS

Descriptive Statistics

Aptitude Measures

Means, standard deviations, reliabilities, and correlations among aptitude measures for the entire sample are presented in Table 3. Similar tables for the separate samples in MIN, VE, and FE are presented in Appendix A.

Scores from the two vocabulary tests and the Terman Concept Mastery Test were standardized in the total sample and combined to form a composite labeled Gc. The Gfv composite included standardized scores for Copying, Memory for Designs, Paper Folding, and the Advanced Progressive Matrices Test. Although GRAPH showed high correlations with both composites it was left as a separate third aptitude since it was thought to be specifically relevant to this instructional setting. About 42% of its variance was estimated to be specific.

Tests included in the Gc composite showed higher correlations with each other than with measures of Gfv. Copying and Memory for Designs had higher correlations with other measures of Gfv than with indicators of Gc. As expected, however, Paper Folding and the Advanced Progressive Matrices Test, both complex measures of Gfv, showed higher correlations with Gc than did Memory for Designs and Copying.

The Gc and Gfv composites were combined to form two orthogonal indices to investigate their combined and differential importance: SUM, the sum of the Gc and Gfv composites represented general ability, and DIFF, Gc minus Gfv represented the ability profile difference. Positive values on DIFF thus indicate students higher in Gc than Gfv, and negative

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Table 3

Means, Standard Deviations, and Correlations of
Aptitude Measures for Total Sample (N = 146)

Variable	Mean	S.D.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
(1) Vocabulary Multiple Choice	15.11	4.58	80 ^b	68	67	26	11	33	38	36	88	36	71	55
(2) Vocabulary Fill In	26.62	5.76	78 ^a	78 ^a	71	30	27	49	54	53	90	52	81	39
(3) Terman Concept Mastery	30.10	5.10			78 ^a	36	32	49	54	56	89	56	83	34
(4) Copying	32.06	9.41				88 ^b	37	49	53	40	35	79	65	-46
(5) Memory for Designs	17.00	2.09					60 ^a	31	37	38	26	68	53	-43
(6) Paper Folding	13.45	3.50					80 ^b	53	50	49	77	77	71	-29
(7) Advanced Progressive Matrices	23.64	5.47						83 ^a	62	54	80	80	77	-27
(8) GRAPII	22.64	5.50							86 ^a	54	62	62	66	-08
(9) Gc	.00	1.00								91 ^c	54	54	88	48
(10) Gfv	.00	1.00									93 ^c	93 ^c	88	-48
(11) SUM	.00	1.76											95 ^c	00
(12) DIFF	.00	.96												83 ^c

Note. Decimals omitted from correlations.

Reliabilities appear in the main diagonal.

^aReliability estimate coefficient α .^bSplit-half reliability estimate.^cReliability estimated as composite.

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Although students were randomly assigned, the equivalence of groups was checked. There were no significant mean or variance differences among the treatment conditions on any of the aptitude measures and only minor differences in the pattern of correlations in the three treatments. Thus, no systematic aptitude differences among the three groups could be identified.

Outcome Measures

Reliabilities of the immediate and delayed posttest were estimated at .82 and .84, respectively, using coefficient alpha. Correlations between total scores and major part scores on the immediate and delayed posttests are presented in Appendix B.

Means and standard deviations for all parts of both posttests are reported in Table 4. While treatment differences on the immediate posttest were not always large, group averages in VE and FE were consistently higher on items corresponding to the type of assistance the group had received. On the average, students in VE and FE also obtained higher scores on the problems than students in MIN. Thus, the mean total posttest score was higher for VE and FE than for MIN.

This pattern was not found in the delayed posttest means, also reported in Table 4. Here, MIN showed a slight overall advantage over

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Table 4

Means and Standard Deviations on Posttest

Treatment	Immediate Posttest						Delayed Posttest					
	MIN		VE		FE		MIN		VE		FE	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Total Posttest	26.27	7.20	29.52	5.25	28.34	4.66	28.89	6.80	27.98	6.18	26.39	6.39
Verbal Total	10.11	2.94	11.89	1.82	10.23	2.11	10.91	2.30	10.09	1.96	10.11	2.22
Part 1	7.43	1.68	8.48	1.30	7.41	1.57	7.57	1.93	6.95	1.61	7.16	1.79
Part 2	2.68	1.58	3.41	1.00	2.82	1.11	3.34	.96	3.14	.85	2.95	1.03
Figural Total	9.57	2.71	10.50	2.62	11.20	1.71	11.11	3.08	10.82	2.74	9.48	2.81
Part 1	3.52	1.27	4.09	1.01	4.27	.85	3.93	1.28	3.84	1.01	3.57	1.15
Part 2	3.95	1.06	4.05	.91	4.09	.80	3.98	1.15	3.57	1.00	3.05	.99
Part 3	2.09	1.14	2.36	1.12	2.84	1.03	3.20	1.27	3.41	1.26	2.86	1.29
Problems	6.59	2.67	7.14	2.11	6.91	2.17	6.86	2.46	7.07	2.29	6.80	2.54
Verbal Correct	4.02	3.24	5.52	2.83	4.09	3.23	4.61	3.24	5.34	3.28	5.14	3.32
Figural Correct	3.55	2.97	3.43	2.67	3.64	2.74	4.25	3.37	4.91	3.45	4.95	3.54
Verbal First	2.14	2.46	4.20	2.83	2.52	2.52	2.25	2.66	2.70	2.75	2.59	2.74
Figural First	1.80	2.48	.98	1.68	1.95	2.06	2.50	3.02	2.48	2.54	2.98	3.14

VE and FE on total posttest score. Thus, although elaborating and simplifying instruction (as in VE and FE) apparently produced immediate gains, information acquired through such instruction was not retained as well as it was in MIN. MIN actually showed a small average gain from immediate to delayed tests, while VE and FE showed losses. The greatest losses occurred when treatment and posttest item type were alike. That is, the greatest losses on verbal items appeared in VE; the greatest losses on figural items appeared in FE.

On the immediate posttest, there were small differences among groups in the type of explanation given on the problems. On average, students in VE gave correct verbal explanations more frequently than did students in either MIN or FE. Verbal explanations were also more likely to be given before figural explanations by students in VE. Similarly, in FE, correct figural explanations to the problems were, on average, given before verbal explanations. Similar trends were found on the delayed posttest.

Correlations Between Aptitude and Outcome

Table 5 gives selected correlations between outcome and aptitude measures. (See Appendix C for complete correlation matrices.)

Significant correlations between SUM and all outcome measures appeared in all treatments, while correlations for DIFF never differed from zero. The correlations between total posttests and SUM were similar in the three treatments, but part scores on the immediate posttest showed some variation across treatments, particularly when item type and treatment matched. So, for example, SUM and the immediate verbal total correlated .50 in VE, but .74 and .72 in MIN and FE, respectively. Similarly, SUM and the immediate figural total correlated .50 in FE, but

Table 5
Correlations Between Selected Aptitude and Posttest Variables

Treatment	Outcome Measure	MIN			VE			FE		
		SUM	DIFF	GRAPH	SUM	DIFF	GRAPH	SUM	DIFF	GRAPH
Immediate Posttest	Total Score	83*	04	69*	75*	02	64*	79*	12	65*
	Verbal Total	74*	-05	63*	50*	00	38*	72*	05	65*
	Figural Total	68*	04	65*	69*	-02	64*	50*	22	39*
	Problems	73*	13	57*	59*	06	47*	60*	03	46*
Delayed Posttest	Total Score	78*	03	71*	83*	00	62*	76*	03	70*
	Verbal Total	54*	05	38*	72*	01	42*	52*	04	58*
	Figural Total	70*	-04	76*	78*	-07	61*	69*	08	54*
	Problems	77*	09	65*	69*	07	58*	70*	-06	66*

Note. Decimals omitted from correlations

*p less than .05

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Correlations Between Selected Aptitude and Posttest Variables

Treatment	Outcome Measure	MIN			VE			FE		
		SUM	DIFF	GRAPH	SUM	DIFF	GRAPH	SUM	DIFF	GRAPH
Immediate Posttest	Total Score	83*	04	69*	75*	02	64*	79*	12	65*
	Verbal Total	74*	-05	63*	50*	00	38*	72*	05	65*
	Figural Total	68*	04	65*	69*	-02	64*	50*	22	39*
	Problems	73*	13	57*	59*	06	47*	60*	03	46*
Delayed Posttest	Total Score	78*	03	71*	83*	00	62*	76*	03	70*
	Verbal Total	54*	05	38*	72*	01	42*	52*	04	58*
	Figural Total	70*	-04	76*	78*	-07	61*	69*	08	54*
	Problems	77*	09	65*	69*	07	58*	70*	-06	66*

Note. Decimals omitted from correlations

*p less than .05

.68 and .69 in MIN and VE. On the problems on the immediate posttest, correlations with SUM were virtually identical in VE and FE, somewhat smaller than in MIN. On the delayed posttest, the correlation between SUM and the verbal total was largest in VE.

Correlations between GRAPH and the immediate outcome were generally lower than those between SUM and outcome. There were, however, also lower correlations between GRAPH and immediate outcome when item type and treatment were matched. On the delayed posttest, there were only small differences among the treatments in the correlations of GRAPH with total posttest score and the problems. The correlation between the verbal total and GRAPH was greatest in FE. The figural total and GRAPH had the largest correlation in MIN.

Regression Analyses on Outcome

Cronbach and Snow (1977) recommended generalized regression analysis for investigating ATI. The model for the present study took the form:

$$Y = \beta_0 + \beta_S S + \beta_D D + \beta_G G + \beta_T T + \beta_{ST} ST + \beta_{DT} DT + \beta_{GT} GT$$

where:

Y = dependent variable

β_0 = constant term

$\beta_S, \beta_D, \beta_G$ = regression coefficients for SUM, DIFF, GRAPH

S, D, G = score on SUM, DIFF, GRAPH

β_T = regression coefficient for treatment

T = orthogonal treatment contrast

$\beta_{ST}, \beta_{DT}, \beta_{GT}$ = regression coefficients for first-order ATI

Two orthogonal contrasts represented the three treatments. The first contrast (T_1) compared MIN with VE and FE (coded 2, -1, -1,

respectively). The second contrast (T2) compared VE with FE (coded 1, -1, respectively, with MIN coded 0). ATI terms were computed by multiplying treatment contrasts with aptitude.

Separate analyses were conducted for total and part scores on immediate and delayed posttest. A step-up procedure was used, with

respectively). The second contrast (T2) compared VE with FE (coded 1, -1, respectively, with MIN coded 0). ATI terms were computed by multiplying treatment contrasts with aptitude.

Separate analyses were conducted for total and part scores on immediate and delayed posttest. A step-up procedure was used, with variables forced into the equation in a specified order. Aptitude main effects were entered before treatment effects, with SUM entered first to test the general-ability hypothesis. DIFF was entered next to test the differential-ability hypothesis. GRAPH was then entered to assess its specific contribution, independent of the proportion of its effects that were associated with general and differential ability. Treatment main effects were then entered using the two orthogonal contrasts. Following all main effects, first-order ATI were entered. This order was used for all dependent variables.

Total Score Analyses

The results of the regression analyses for the immediate and delayed total posttests are presented in Table 6. The percentage of variance accounted for reflects the change in the squared multiple correlation coefficient as each predictor entered the equation. The F-ratio tested whether this change in R^2 was significant using the formula:

$$F = \frac{\Delta R^2 / K_i}{1 - R_t^2 / N - K_t - 1}$$

where:

ΔR^2 = increment in R^2

K_i = number of predictors in change

R_t^2 = R^2 for full model

N = total sample size

K_t = number of predictors in total R^2

Table 6

Summary of Stepwise Regression of Total Posttest

Variable	d.f.	Immediate Posttest		Delayed Posttest	
		% Variance Accounted For	F - ratio	% Variance Accounted For	F - ratio
Full Model	11	70.5	26.03*	68.6	23.83*
Aptitude Main Effects	3	62.7	84.93*	65.2	83.06*
SUM	1	56.3	228.76*	61.2	233.89*
DIFF	1	.4	1.63	.1	<1
GRAPH	1	6.0	24.38*	3.9	14.90*
Treatment Main Effects	2	4.6	9.35*	2.7	5.16*
T1	1	4.0	16.25*	1.8	6.88*
T2	1	.6	2.44	.9	3.44
First-Order ATI	6	3.3	2.24*	.7	<1
SUM X T1	1	2.9	11.78*	.0	<1
SUM X T2	1	.0	<1	.0	<1
DIFF X T1	1	.3	1.22	.2	<1
DIFF X T2	1	.0	<1	.1	<1
GRAPH X T1	1	.0	<1	.0	<1
GRAPH X T2	1	.1	<1	.4	1.53
Residual	120	29.5	--	31.4	--

*p < .05

Table 6

Summary of Stepwise Regression of Total Posttest

Variable	d.f.	Immediate Posttest		Delayed Posttest	
		% Variance Accounted For	F - ratio	% Variance Accounted For	F - ratio
Full Model	11	70.5	26.03*	68.6	23.83*
Aptitude Main Effects	3	62.7	84.93*	65.2	83.06*
SUM	1	56.3	228.76*	61.2	233.89*
DIFF	1	.4	1.63	.1	<1
GRAPH	1	6.0	24.38*	3.9	14.90*
Treatment Main Effects	2	4.6	9.35*	2.7	5.16*
T1	1	4.0	16.25*	1.8	6.88*
T2	1	.6	2.44	.9	3.44
First-Order ATI	6	3.3	2.24*	.7	<1
SUM X T1	1	2.9	11.78*	.0	<1
SUM X T2	1	.0	<1	.0	<1
DIFF X T1	1	.3	1.22	.2	<1
DIFF X T2	1	.0	<1	.1	<1
GRAPH X T1	1	.0	<1	.0	<1
GRAPH X T2	1	.1	<1	.4	1.53
Residual	120	29.5	--	31.4	--

*p < .05

Aptitude main effects, specifically SUM and GRAPH, accounted for the largest proportion of explained variance in both immediate and delayed posttests. High ability students thus routinely achieved higher outcome scores than did low ability students. DIFF accounted for only .4% of the variance in the immediate posttest and only .1% of the variance in the delayed posttest.

Treatment main effects accounted for 4.6% of the variance in the immediate posttest and 2.7% of the variance in the delayed posttest. These effects correspond to the mean differences identified in Table 4. VE and FE showed higher immediate outcomes than did MIN; differences between VE and FE were not significant. In contrast, on the delayed posttest, MIN showed a higher average than did VE and FE.

Interactions were tested in the generalized model. Then, unstandardized regression coefficients within each treatment were plotted graphically for interpretation. The SUM X treatment interaction was statistically significant on the immediate posttest, but not on the delayed posttest. This interaction accounted for 2.9% of the immediate posttest variance; it is shown graphically in Figure 1. The relative advantage of high ability students was most pronounced in MIN. In other words, VE and FE appeared particularly helpful for low ability students, reducing the difference between them and high ability students. There were smaller treatment differences at the mean and reduced ATIs on the delayed posttest.

Part Score Analyses

Verbal items. The results of the generalized regression analyses of verbal outcome measures appear in Table 7. Again, SUM accounted for

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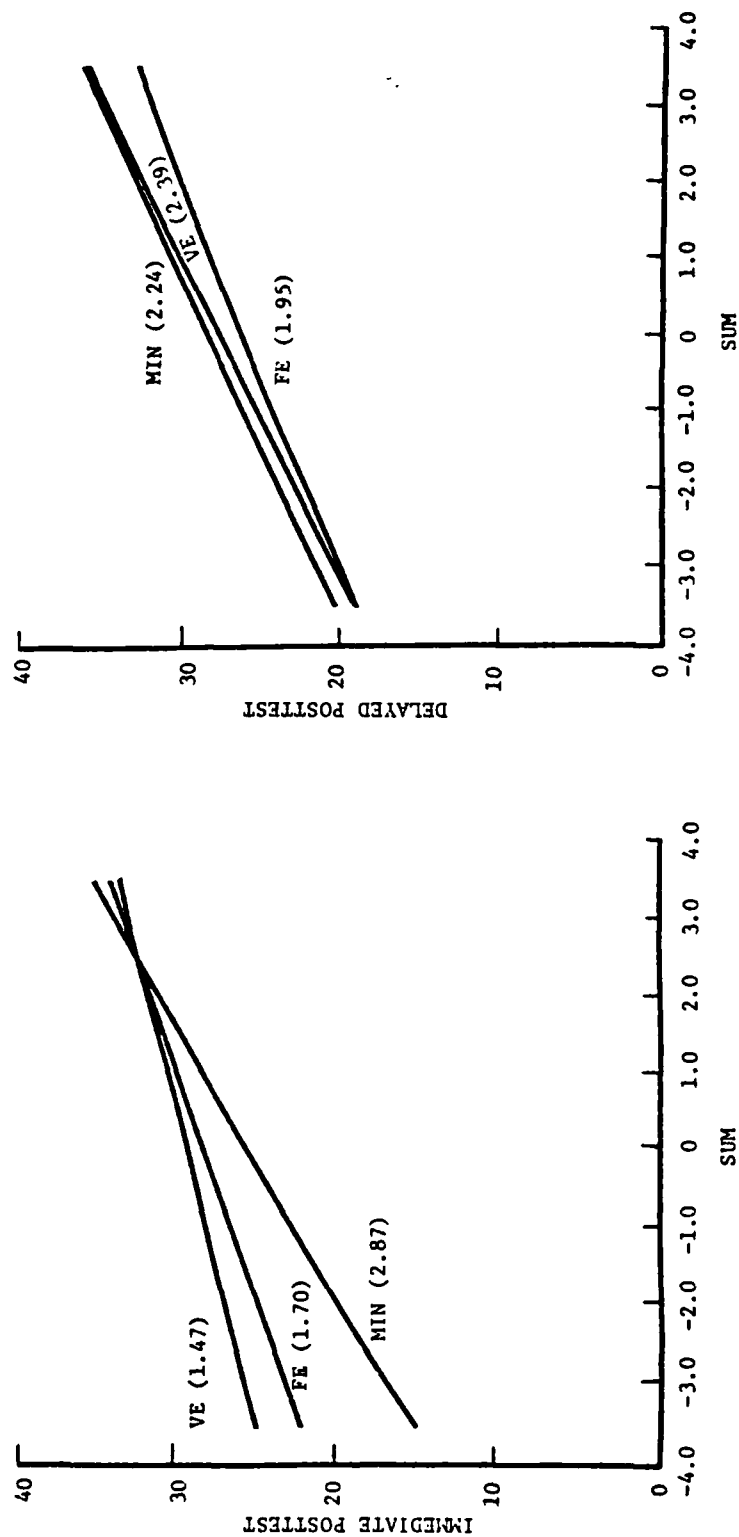


Figure 1. Relation of Total Posttest Scores to SUM, with Unstandardized Regression Coefficients Shown in Parentheses.

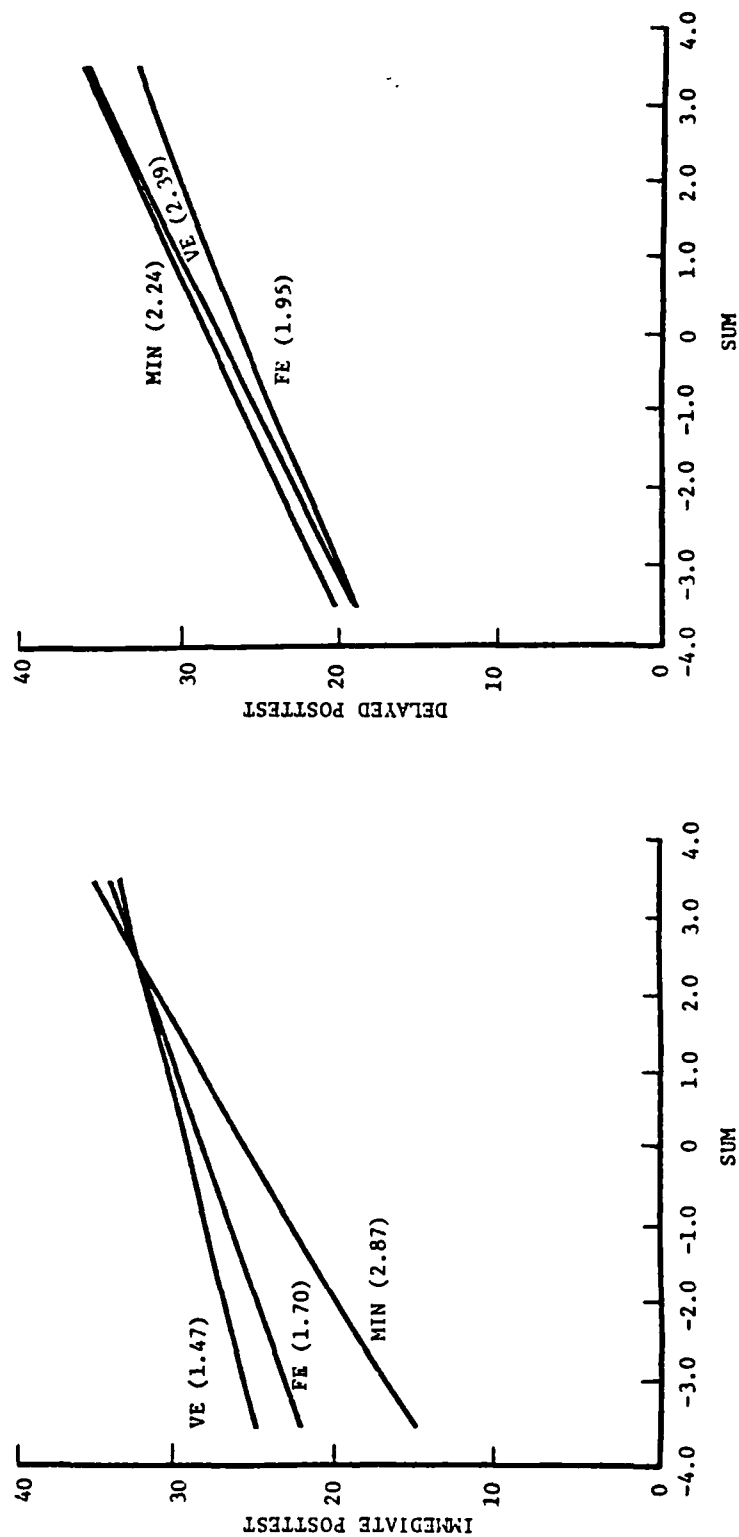


Figure 1. Relation of Total Posttest Scores to SUM, with Unstandardized Regression Coefficients Shown in Parentheses.

Table 7

Summary of Stepwise Regression of Verbal Items

Variable	d.f.	Immediate Posttest		Delayed Posttest	
		% Variance Accounted For	F - ratio	% Variance Accounted For	F - ratio
Full Model	11	57.5	14.74*	40.4	7.40*
Aptitude Main Effects	3	41.7	39.22*	34.6	23.23*
SUM	1	37.1	104.68*	34.0	68.48*
DIFF	1	.0	<1	.2	<1
GRAPH	1	4.6	12.98*	.4	<1
Treatment Main Effects	2	10.0	14.11*	2.9	2.92
T1	1	2.8	7.90*	2.9	5.84*
T2	1	7.2	20.31*	.0	<1
First-Order ATI	6	5.8	2.73*	2.8	<1
SUM X T1	1	3.4	9.60*	.0	<1
SUM X T2	1	1.3	3.67	.1	<1
DIFF X T1	1	.7	1.98	.0	<1
DIFF X T2	1	.0	<1	.0	<1
GRAPH X T1	1	.1	<1	.4	<1
GRAPH X T2	1	.3	<1	2.3	4.63*
Residual	120	42.5	--	59.6	--

*p < .05

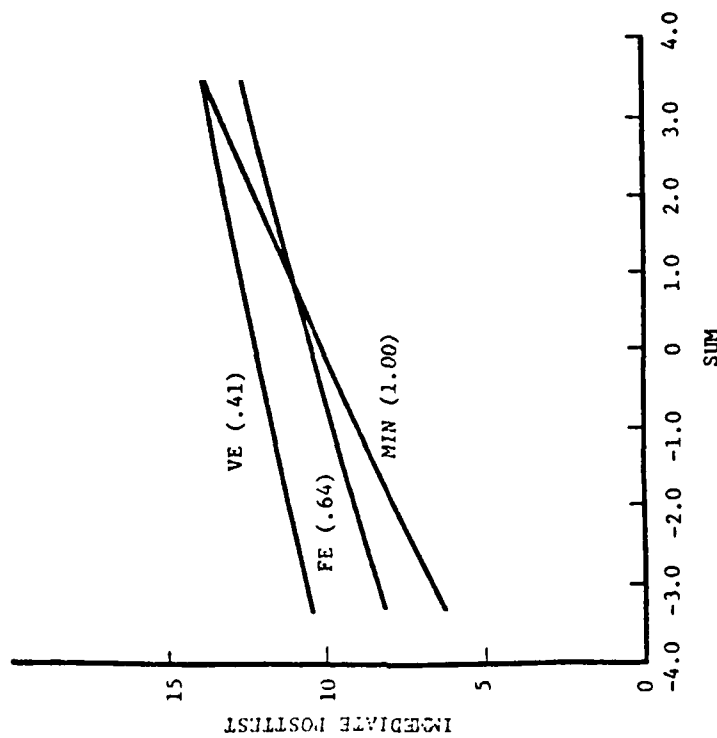
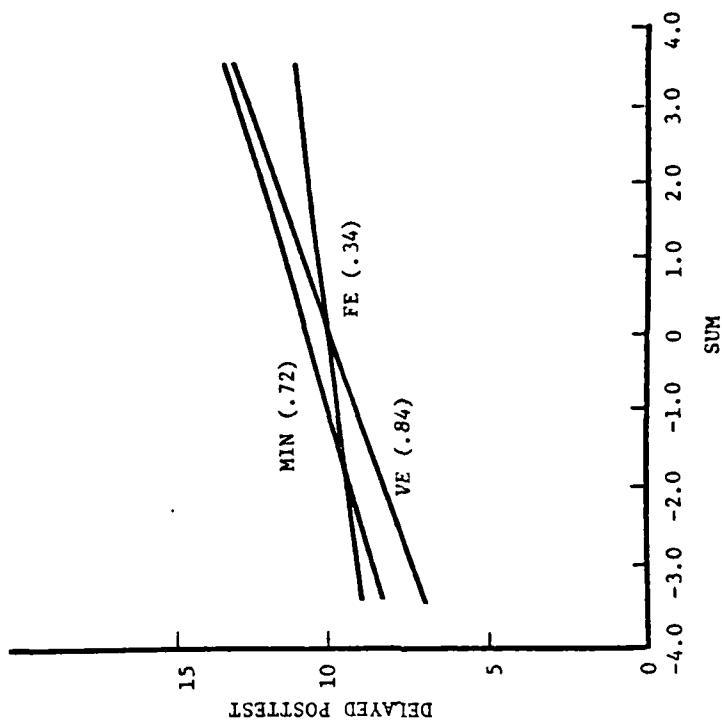


Figure 2. Relation of Verbal Items to SUM, with Unstandardized Regression Coefficients Shown in Parentheses.

the largest proportion of explained variance in each posttest. GRAPH accounted for a significant proportion of variance in the immediate posttest, accounting for 4.6% of the variance in it. Students with higher aptitude scores had higher outcome scores. DIFF was never significant.

Treatment main effects correspond to the mean differences shown previously. On the immediate posttest, treatment main effects accounted for 10.0% of the variance; VE was superior to MIN and FE. Treatment main effects accounted for 2.9% of the variance in the delayed posttest, with MIN superior to VE and FE.

First-order ATI accounted for 5.8% of the variance in the immediate posttest; ATI with SUM accounted for most of this variance. Figure 2 shows that VE was particularly helpful for low ability students.

The only significant ATI on the delayed posttest was between GRAPH and treatment. As shown in Figure 3, only in FE did students with high GRAPH scores outperform students with low GRAPH scores.

Figural Items. Table 8 presents the results of the generalized regression analyses for figural items. As before, SUM and GRAPH accounted for a significant proportion of the variance on both the immediate and delayed posttests. DIFF was not significant, accounting for only .5% of the immediate posttest variance and .0% of the delayed posttest variance.

Treatment main effects accounted for 6.6% of the variance on the immediate posttest and 6.0% of the variance on the delayed posttest. Thus, on the immediate posttest, VE and FE were superior to MIN, on average. FE had a slight advantage over VE. In contrast, on the delayed posttest, both MIN and VE were superior to FE.

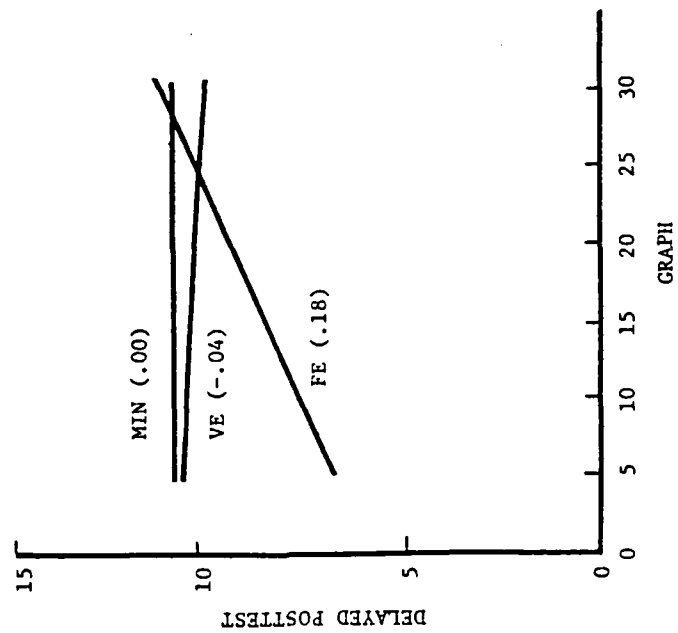
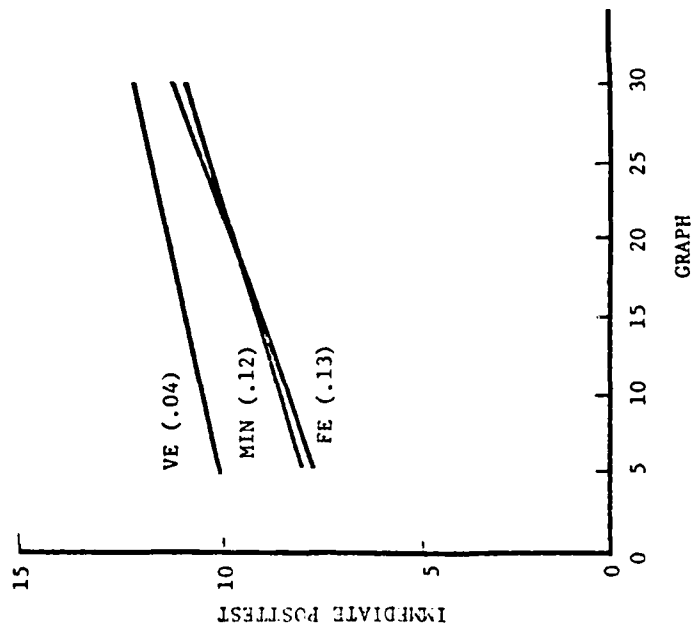


Figure 3. Relation of Verbal Items to GRAPH with Unstandardized Regression Coefficients Shown in Parentheses.

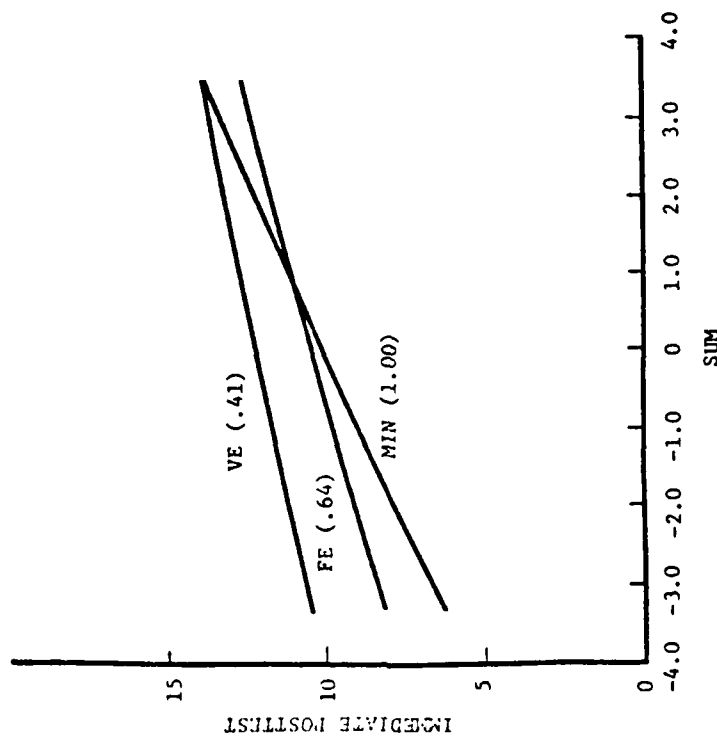
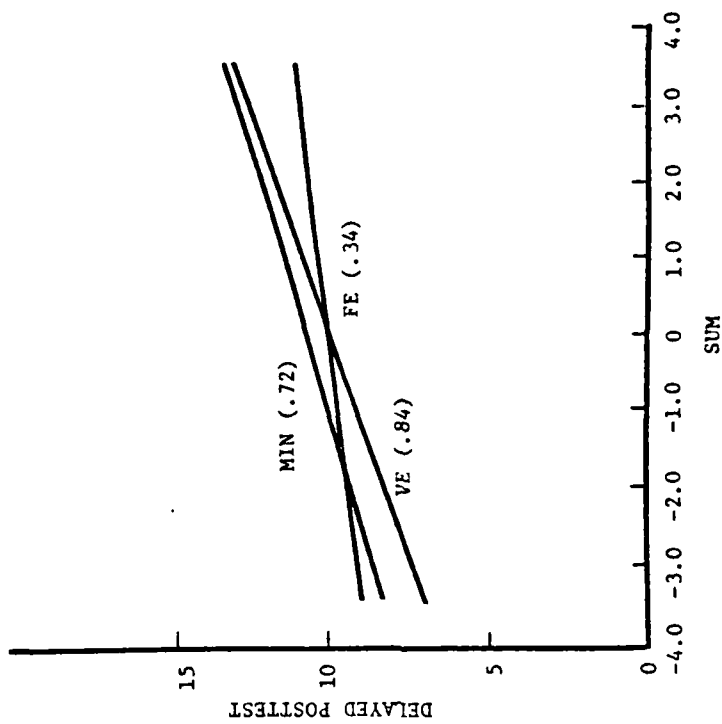


Figure 2. Relation of Verbal Items to SUM, with Unstandardized Regression Coefficients Shown in Parentheses.

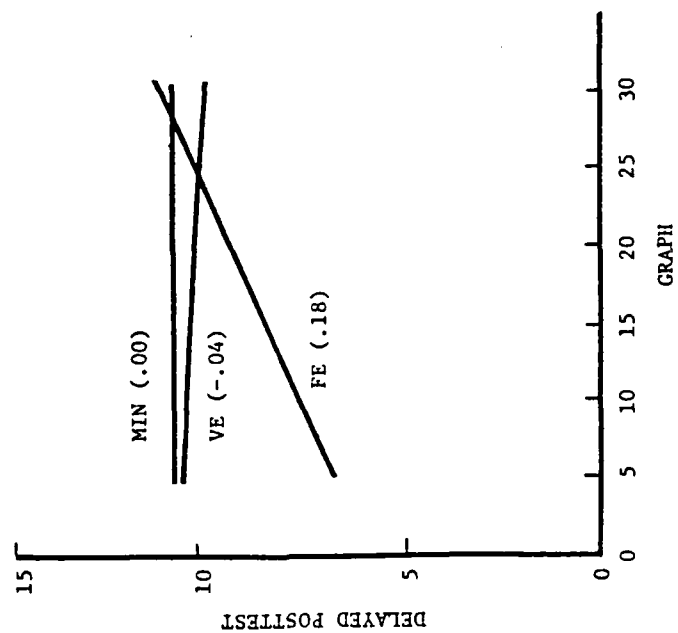
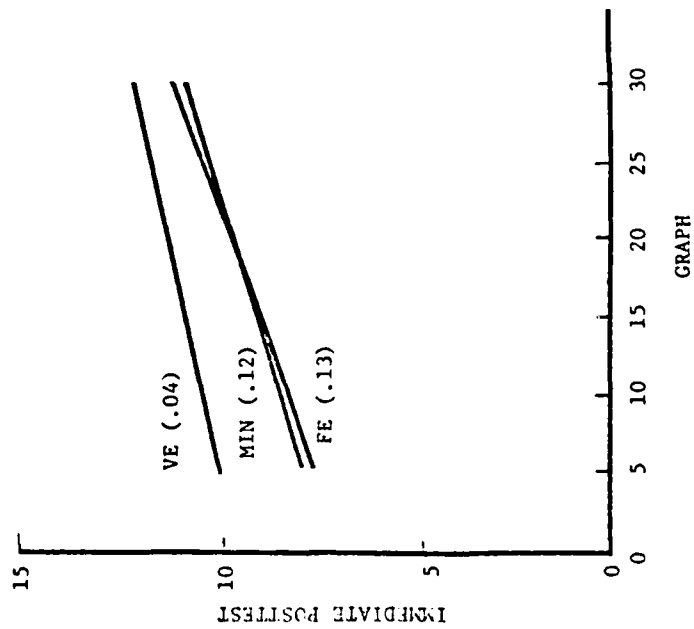


Figure 3. Relation of Verbal Items to GRAPH with Unstandardized Regression Coefficients Shown in Parentheses.

The SUM X treatment interaction was, again, significant on the immediate and not on the delayed posttest. In Figure 4, the immediate regression slope on SUM was shallower in FE than in MIN and VE. FE was particularly helpful to low ability students in reducing differences between them and high ability students. The mean disadvantage on the delayed posttest for students in FE can also be seen.

Interactions with GRAPH accounted for 1.2% of the variance in the immediate posttest, and 1.4% of the variance in the delayed posttest. While not significant in the immediate posttest, the interaction suggested that FE reduced the advantage of students with high GRAPH scores. On the delayed posttest, both VE and FE reduced the advantage of students with high GRAPH scores. These relations are shown in Figure 5.

Problems. As with all other dependent variables, SUM accounted for the largest proportion of explained variance in the problems on both the immediate and delayed posttests (see Table 9). Although GRAPH was not a statistically significant predictor of the immediate posttest, it accounted for 1.3% of its variance, and did account for a significant proportion of variance (4.9%) on the delayed posttest. Again, the effects of DIFF were small. No treatment main effects were significant, and the only significant ATI was, again, with SUM on the immediate posttest. As shown in Figure 6, differences between high and low ability students were greatest in MIN.

Summary of Regression Analyses

SUM accounted for the vast majority of variance in all dependent measures, and GRAPH accounted for significant proportions of variance in most. Again, because GRAPH and SUM were correlated, and because SUM was entered into the regression analyses before GRAPH, effects associated

Table 8

Summary of Stepwise Regression of Figural Items

Variable	d.f.	Immediate Posttest		Delayed Posttest	
		% Variance Accounted For	F - ratio	% Variance Accounted For	F - ratio
Full Model	11	54.3	12.94*	62.2	17.96*
Aptitude Main Effects	3	43.3	37.86*	54.2	57.45*
SUM	1	35.7	93.65*	49.9	158.66*
DIFF	1	.5	1.31	.0	<1
GRAPH	1	7.1	18.62*	4.3	13.67*
Treatment Main Effects	2	6.6	8.66*	6.0	9.54*
T1	1	5.1	13.38*	2.9	9.22*
T2	1	1.5	3.93*	3.1	9.86*
First-Order AT1	6	4.3	1.88	2.0	1.06
SUM X T1	1	.8	2.10	.0	<1
SUM X T2	1	1.9	4.98*	.0	<1
DIFF X T1	1	.4	1.05	.6	1.91
DIFF X T2	1	.0	<1	.0	<1
GRAPH X T1	1	.1	<1	1.4	4.45*
GRAPH X T2	1	1.1	2.89	.0	<1
Residual	120	45.7	--	37.8	--

*p < .05

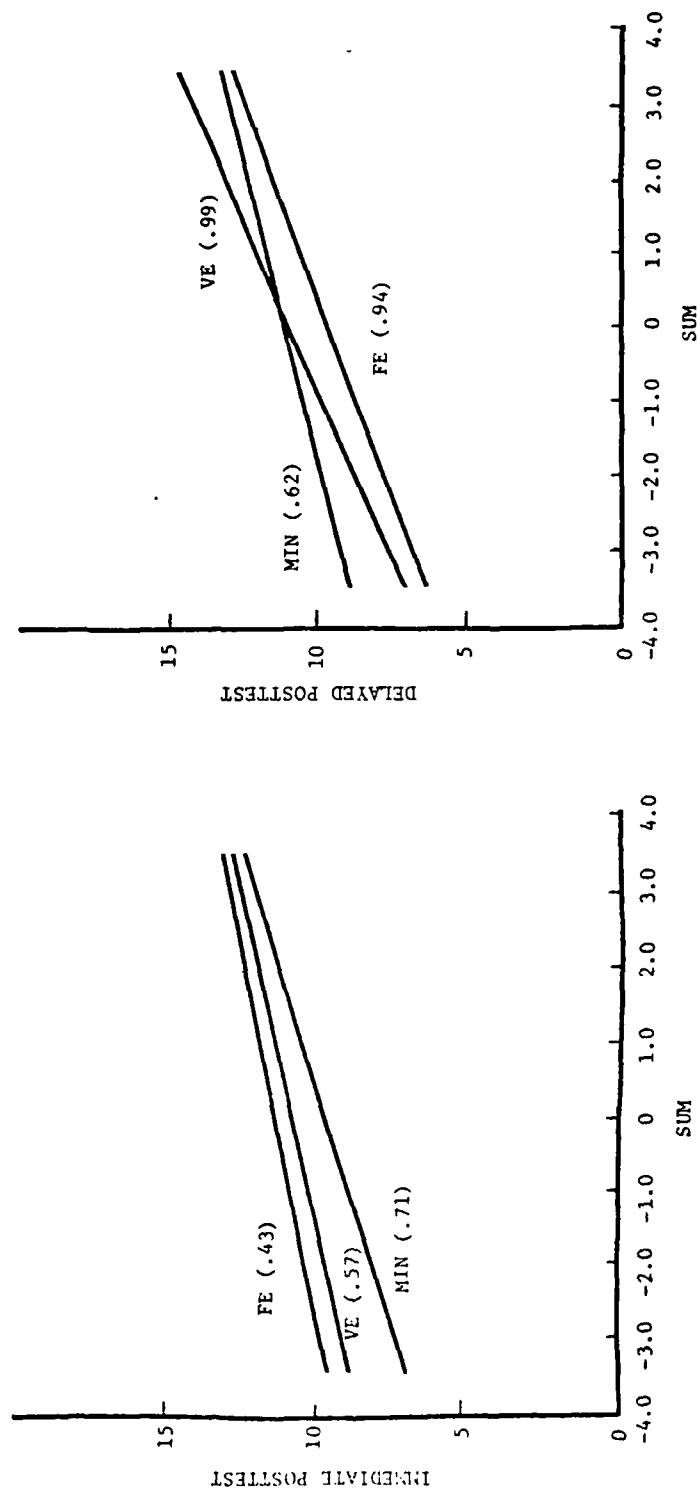


Figure 4. Relation of Figural Items to SUM, with Unstandardized Regression Coefficients Shown in Parentheses.

The SUM X treatment interaction was, again, significant on the immediate and not on the delayed posttest. In Figure 4, the immediate regression slope on SUM was shallower in FE than in MIN and VE. FE was particularly helpful to low ability students in reducing differences between them and high ability students. The mean disadvantage on the delayed posttest for students in FE can also be seen.

Interactions with GRAPH accounted for 1.2% of the variance in the immediate posttest, and 1.4% of the variance in the delayed posttest. While not significant in the immediate posttest, the interaction suggested that FE reduced the advantage of students with high GRAPH scores. On the delayed posttest, both VE and FE reduced the advantage of students with high GRAPH scores. These relations are shown in Figure 5.

Problems. As with all other dependent variables, SUM accounted for the largest proportion of explained variance in the problems on both the immediate and delayed posttests (see Table 9). Although GRAPH was not a statistically significant predictor of the immediate posttest, it accounted for 1.3% of its variance, and did account for a significant proportion of variance (4.9%) on the delayed posttest. Again, the effects of DIFF were small. No treatment main effects were significant, and the only significant ATI was, again, with SUM on the immediate posttest. As shown in Figure 6, differences between high and low ability students were greatest in MIN.

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SUM accounted for the vast majority of variance in all dependent measures, and GRAPH accounted for significant proportions of variance in most. Again, because GRAPH and SUM were correlated, and because SUM was entered into the regression analyses before GRAPH, effects associated

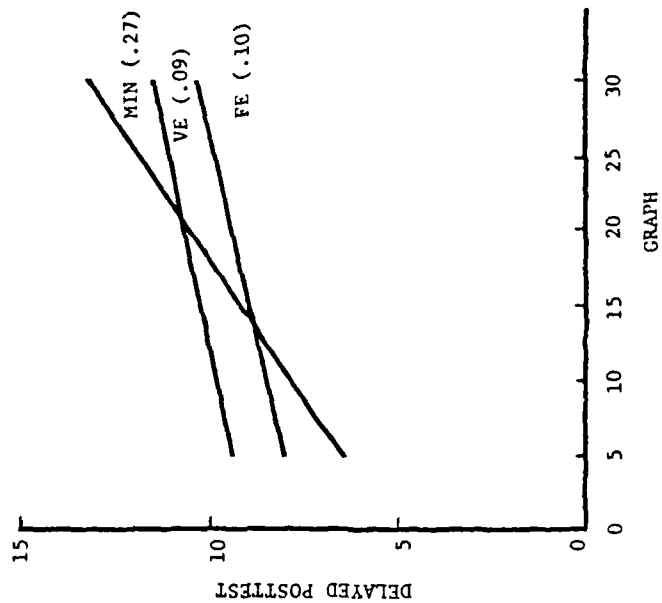
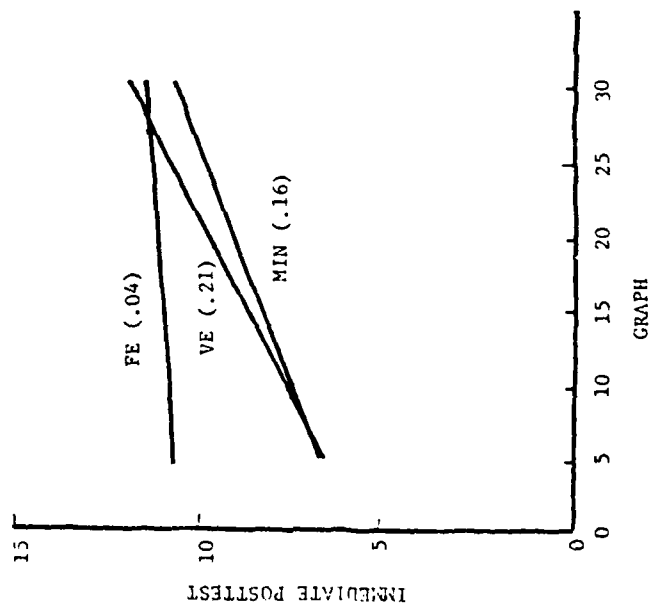


Figure 5. Relation of Figurative Items to GRAPH, with Unstandardized Regression Coefficients Shown in Parentheses.

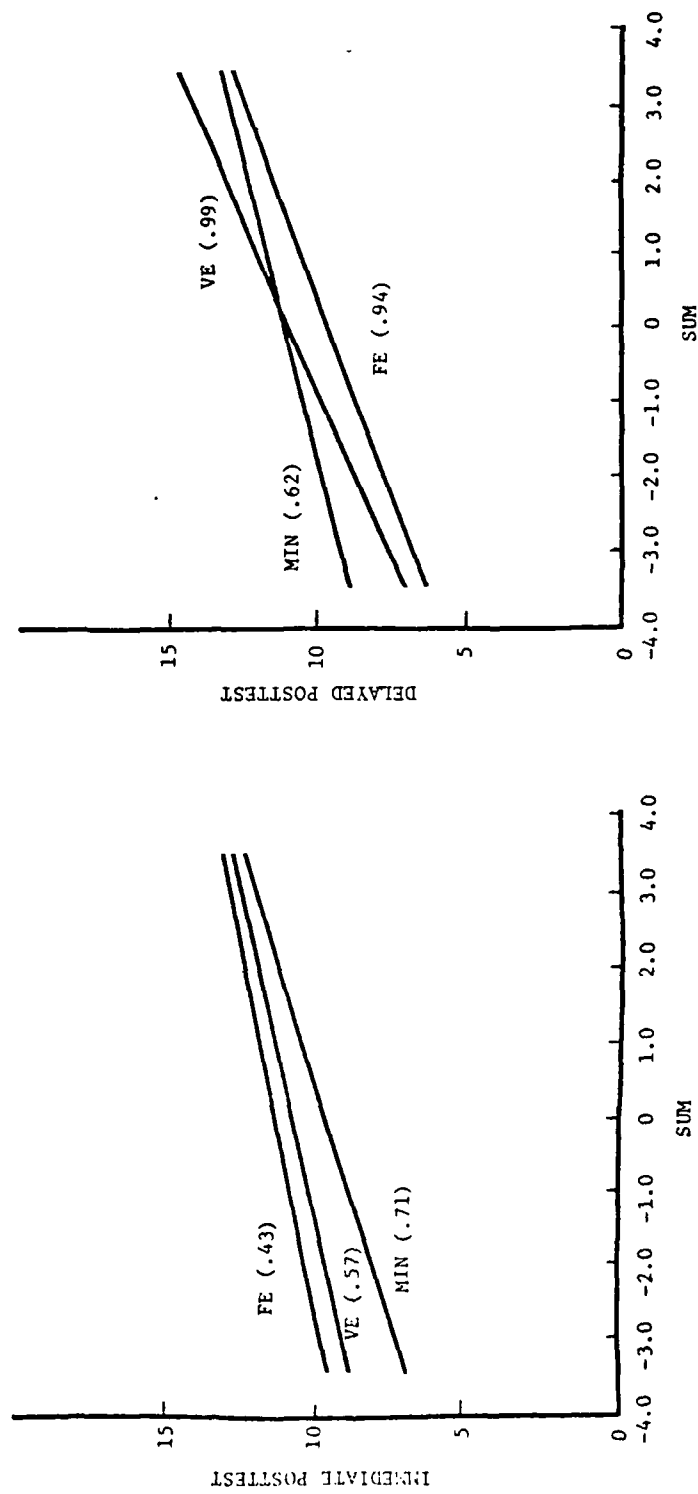


Figure 4. Relation of Figural Items to SUM, with Unstandardized Regression Coefficients Shown in Parentheses.

Table 9

Summary of Stepwise Regression of Problems

Variable	d.f.	Immediate Posttest		Delayed Posttest	
		% Variance Accounted For	F - ratio	% Variance Accounted For	F - ratio
Full Model	11	45.8	9.21*	58.2	15.21*
Aptitude Main Effects	3	42.0	30.98*	56.3	53.64*
SUM	1	39.9	88.28*	51.2	147.12*
DIFF	1	.8	1.77	.2	<1
GRAPH	1	1.3	2.88	4.9	14.08*
Treatment Main Effects	2	1.0	1.11	.2	<1
T1	1	.8	1.77	.0	<1
T2	1	.2	<1	.2	<1
First-Order ATI	6	2.9	1.07	1.9	<1
SUM X T1	1	2.1	4.65*	.2	<1
SUM X T2	1	.1	<1	.3	<1
DIFF X T1	1	.0	<1	.0	<1
DIFF X T2	1	.1	<1	.9	2.59
GRAPH X T1	1	.5	1.11	14	1.15
GRAPH X T2	1	.1	<1	.1	<1
Residual	120	54.2	--	41.8	--

*P < .05

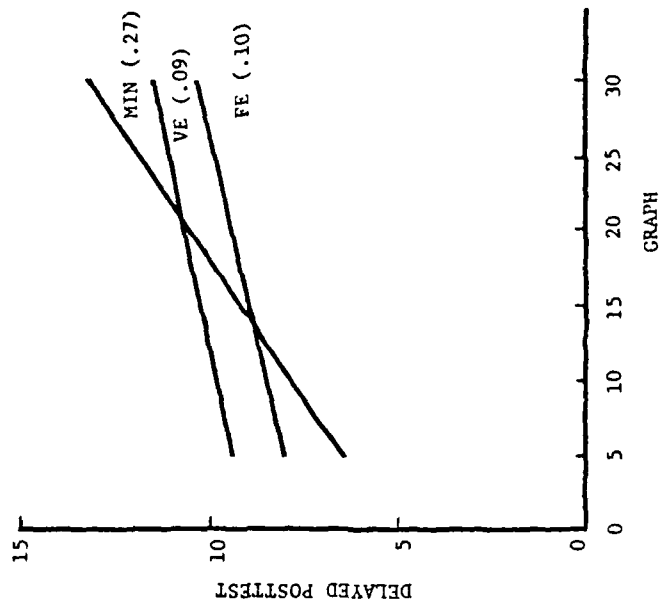
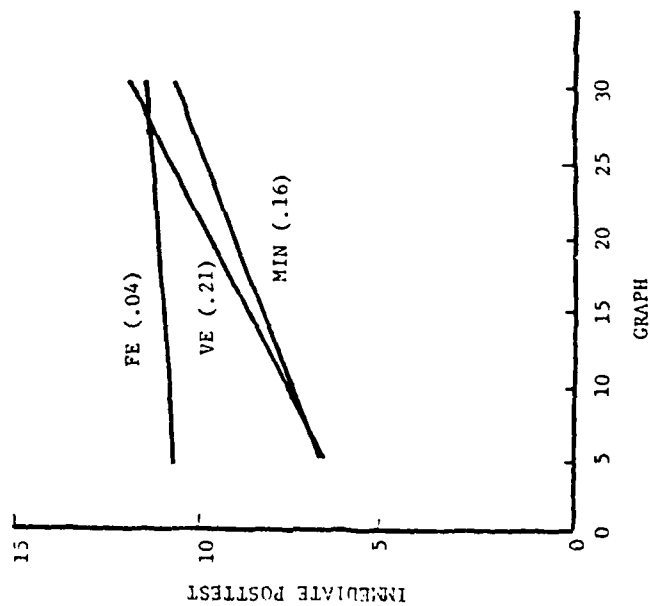


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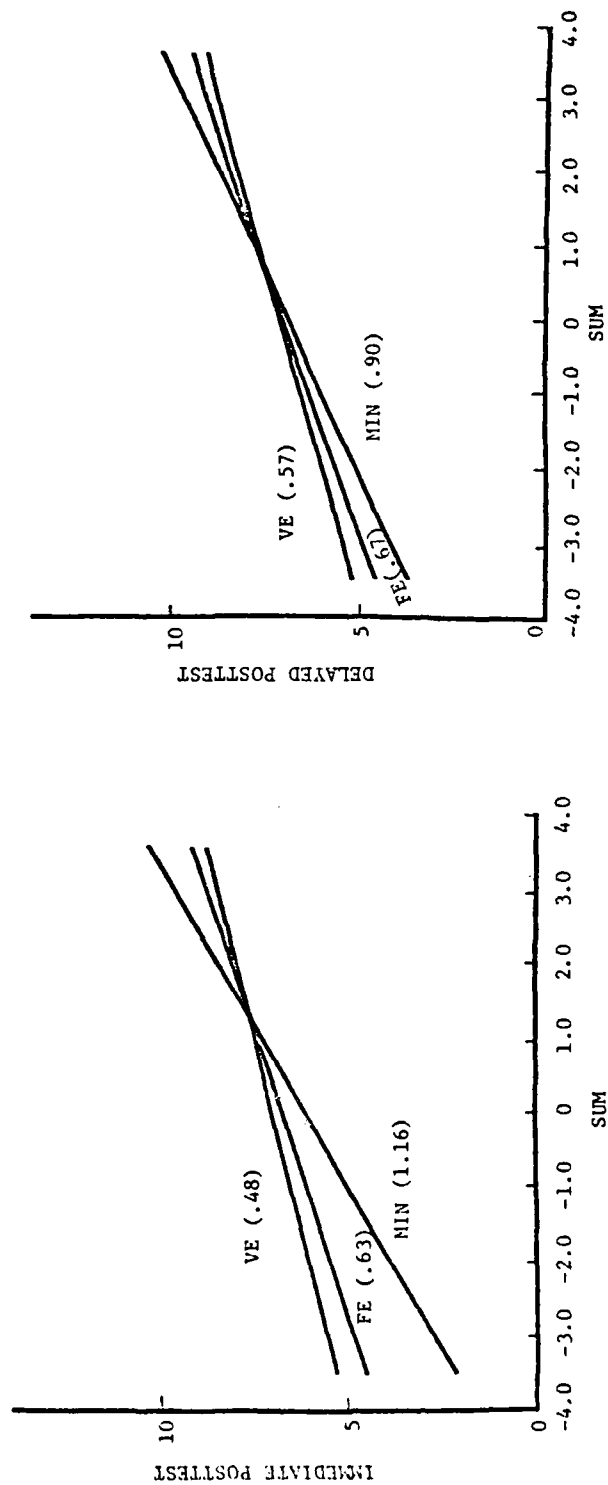


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T1	1	.8	1.77	.0	<1
T2	1	.2	<1	.2	<1
First-Order ATI	6	2.9	1.07	1.9	<1
SUM X T1	1	2.1	4.65*	.2	<1
SUM X T2	1	.1	<1	.3	<1
DIFF X T1	1	.0	<1	.0	<1
DIFF X T2	1	.1	<1	.9	2.59
GRAPH X T1	1	.5	1.11	14	1.15
GRAPH X T2	1	.1	<1	.1	<1
Residual	120	54.2	--	41.8	--

* $P < .05$

with GRAPH reflect its specific variance, not variance shared with SUM. The differential-ability hypothesis, tested by DIFF was never significant.

Treatment main effects were significant for the total, verbal, and figural scores on both posttests. The immediate posttest showed a general advantage for VE and FE over MIN. VE was most advantageous on verbal items, FE on figural items. But this trend was reversed on the delayed posttest where students in MIN outperformed those in VE and FE. In fact, the lowest mean figural part score occurred in FE.

All significant ATI on the immediate posttest involved general ability (SUM); VE and FE reduced the advantage of high ability students. This advantage was reduced most in VE on verbal items and in FE on figural items.

Similar relations were not found on the delayed posttest. High ability students continued to outperform low ability students on the delayed posttest; the relative advantages for students in VE and FE were not retained over time. Significant ATI were obtained only with GRAPH.

Thus, in this study, instruction that was most effective for immediate learning was not most effective in the long run. ATI effects suggested that this shift may have come primarily from low ability students who did not retain the additional information that enhanced immediate learning.

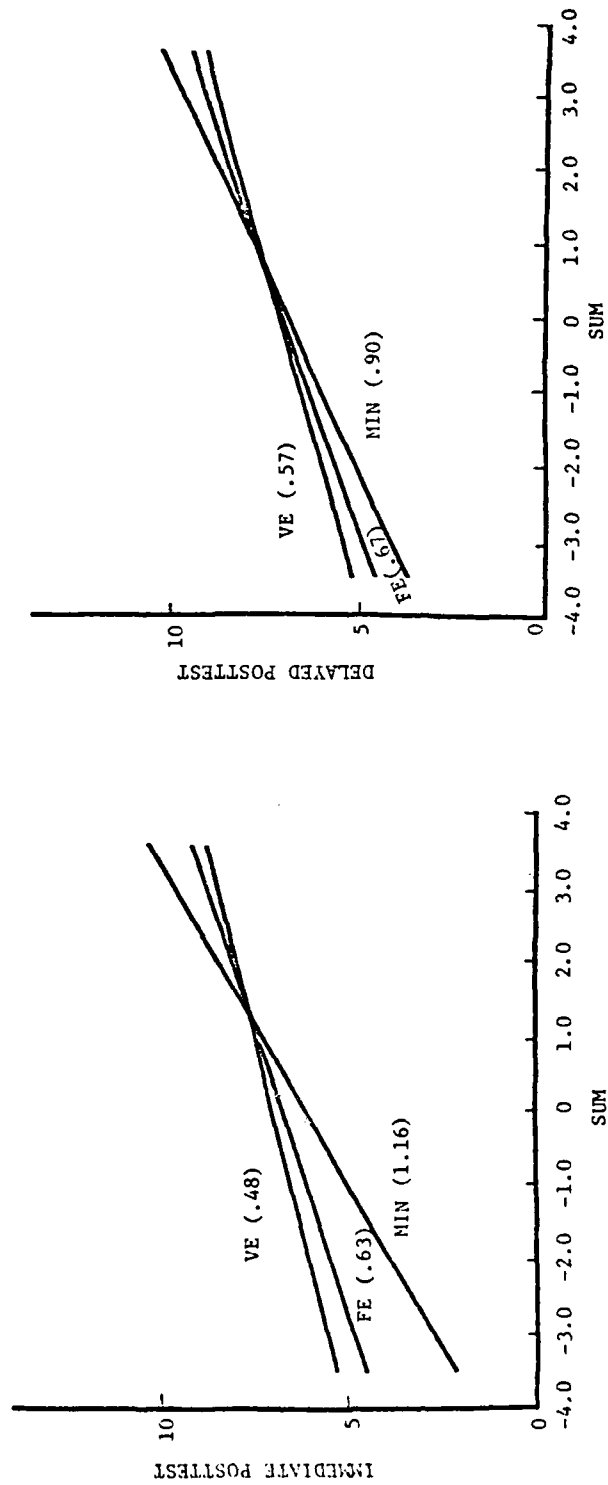


Figure 6. Relation of Problems to SUM, with Unstandardized Regression Coefficients Shown in Parentheses.

CHAPTER 4

SUMMARY AND CONCLUSIONS

The present study examined the effects of verbal and figural supplements on learning, and their relation to general ability, Gc and Gfv, and a specific graph-processing test. This chapter summarizes prior research and the procedures and results of the present study. Implications for future research and educational practice are discussed.

The Research Problem

Although numerous studies have investigated interactions between aptitude and verbal and figural instructional supplements, few consistent relations have been established. In some studies, the regression of outcome on aptitude was steeper when aptitude and instructional condition were matched; in others, the regression was shallower. Some studies obtained similar regression slopes. These relations varied, in part, as a function of the delay between instruction and the posttest. Inconsistencies also resulted from not specifying aptitude and treatment in sufficient detail or considering all the ways they might be matched.

The Present Research

The present study compared the effects of minimal instruction, instruction elaborated with verbal supplements, and instruction elaborated with figural supplements. Aptitude was represented by a Gc composite, a Gfv composite, and a graph-processing test. The Gc and Gfv composites were summed to indicate general ability and their difference was used to investigate their differential impact. Immediate and delayed outcome measures included verbal items, figural items, and problems that could be solved either verbally or figurally. Learning was described as a function of aptitude and instructional material.

with GRAPH reflect its specific variance, not variance shared with SUM. The differential-ability hypothesis, tested by DIFF was never significant.

Treatment main effects were significant for the total, verbal, and figural scores on both posttests. The immediate posttest showed a general advantage for VE and FE over MIN. VE was most advantageous on verbal items, FE on figural items. But this trend was reversed on the delayed posttest where students in MIN outperformed those in VE and FE. In fact, the lowest mean figural part score occurred in FE.

All significant ATI on the immediate posttest involved general ability (SUM); VE and FE reduced the advantage of high ability students. This advantage was reduced most in VE on verbal items and in FE on figural items.

Similar relations were not found on the delayed posttest. High ability students continued to outperform low ability students on the delayed posttest; the relative advantages for students in VE and FE were not retained over time. Significant ATI were obtained only with GRAPH.

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The Effects of General Ability

On the immediate posttest, students in VE and FE did better than students in MIN, suggesting that the elaboration provided in these conditions helped students learn. Significant ATI suggested that the elaboration was particularly useful to low ability students. High ability students did as well or better in MIN. Thus, the regression of a ment on general ability was steepest in MIN and reduced in VE and FE.

Partitioning of the total test score by item type indicated that VE was particularly helpful on verbal items and FE was particularly helpful on figural items. Again, significant ATI indicated that these treatments were particularly helpful to low ability students. Hence, the regression of verbal items on general ability was least steep in VE; the regression of figural items on general ability was least steep in FE.

Examination of learning outcomes on retention, however, led to strikingly different conclusions. While students in MIN were worst on average achievement on the immediate posttest, they performed best on the delayed test.

VE and FE provided more information to learners through additional explanations and examples. MIN required students to provide this information for themselves, thereby demanding more active work from learners. More able students, capable of doing it, did equally well in MIN as in VE and FE. Less able students that could not generate that information for themselves benefitted from the assistance. The gains were short-lived, however. Active mental work, necessary in MIN, appeared to aid retention. Hence, there was a greater decline in performance in VE and FE than in MIN. This contention was further supported by the observation that losses

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were greatest when the assistance was most direct. That is, losses on verbal items were greatest in VE; losses on figural items were greatest in FE.

The Differential Effect of Gc and Gfv

The differential impact of Gc and Gfv as measured in this study, did not enter differently into outcome on aptitude relations. This may be due, in part, to a failure to adequately distinguish Gc from Gfv. That is, measures of Gc and Gfv shared a considerable proportion of variance. Reducing that overlap might increase the chance of detecting differences in their impact. Thus, future research in this area must strive to do this.

The Effect of GRAPH

The instructional materials in this study used many graphic displays. Therefore, GRAPH was included as a specific-ability measure. Significant main effects were associated with GRAPH at both testings, even after accounting for the effects of general ability. As with general ability, students with higher aptitude scores did better. Thus, learning outcomes were not fully described by the effects of general ability.

Conclusions and Implications

This study provided evidence that neither aptitude nor instructional treatment alone can fully describe learning outcomes. Interactions between them exist and can be demonstrated. Further, instructional supplements, whether verbal or figural, can be effective in filling-in for students weaknesses and reducing differences between high and low ability students.

Such supplements, however, must be used with caution. Reducing the difficulty of instructional materials may indeed enhance immediate learning,

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but these advantages may be short-lived. In the present study, increasing the difficulty of the work required for initial learning appeared to increase retention. The benefits in immediate learning must be weighed with the need to ensure that information is retained.

The implications for educational practice are clear. The present study indicated that instruction that enhances immediate learning is not necessarily best for retention. Ultimately, educators must be concerned with how much information is retained and not limit their concerns to immediate outcomes. Thus, not only must achievement be assessed at more than one point in time, curricula must be developed to promote long-term learning. The current emphasis on testing after only short delays should be reconsidered.

Additional research is necessary to confirm the findings of this study and support these contentions. ATI research is one avenue for exploring this area, but it should be supplemented with more basic research in information processing. Improved methods of distinguishing Gc from Gfv are required to explore their differential impact on learning. These methods may emerge as we gain a better process understanding of these abilities through further research.

Finally, researchers should examine both immediate and delayed outcomes, and attempt to identify instructional conditions likely to promote long-term retention. At a minimum, delayed outcome measures may be added to instructional research conducted in different contexts. Additional, more directed research may probe more deeply the relations among instructional materials, immediate learning, and retention. The present study suggests that we cannot limit research to immediate outcomes if we are

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Such supplements, however, must be used with caution. Reducing the difficulty of instructional materials may indeed enhance immediate learning,

truly interested in the long-term impact of instruction.

In conclusion, this study examined the relations among aptitude, instruction, and learning. While it provided data to help answer some questions in this area, it raised many others that only future research may resolve.

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Means, Standard Deviations, and Correlations
of Aptitude Measures in VE (N = 44)

Variable	Mean	S.D.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
(1) Vocabulary Multiple-Choice	15.25	4.23	-	67	66	26	16	36	33	14	85	36	68	52
(2) Vocabulary Fill-in	26.34	5.89		-	76	48	36	57	63	49	91	66	88	25
(3) Terman Concept Mastery	30.36	5.74			-	25	29	50	50	43	91	51	80	43
(4) Copying	31.75	9.03				-	33	62	57	54	37	81	67	-49
(5) Memory for Designs	16.98	2.02					-	34	40	51	30	66	54	-40
(6) Paper Folding	13.43	3.85						-	50	64	54	81	76	-31
(7) Advanced Progressive Matrices	24.43	5.99							-	62	55	81	77	-30
(8) CRAPII	23.48	5.51								-	41	75	65	-39
(9) Gc	.01	1.03									-	58	89	44
(10) Gfv	.03	1.05										-	89	-48
(11) SUM	.04	1.85											-	-02
(12) DIFF	-.02	.96												-

Note. Decimals omitted from correlations

APPENDIX A
MEANS, STANDARD DEVIATIONS, AND CORRELATIONS BETWEEN APTITUDES

Means, Standard Deviations, and Correlations

of Aptitude Measures in FE (N = 44)

Variable	Mean	S.D.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
(1) Vocabulary Multiple-Choice	15.48	4.72	-	70	79	49	15	37	52	46	92	50	80	41
(2) Vocabulary Fill-in	27.16	5.95		-	69	32	18	50	56	53	89	49	78	39
(3) Terman Concept Mastery	29.91	4.14			-	49	23	37	43	54	90	49	79	40
(4) Copying	31.64	10.82				-	44	40	53	33	48	79	73	-36
(5) Memory for Designs	13.14	2.01					-	26	59	38	20	73	54	-58
(6) Paper Folding	13.32	3.15						-	61	44	46	71	67	-29
(7) Advanced Progressive Matrices	25.52	5.25							-	56	56	87	82	-36
(8) GRAPH	23.05	4.99								-	56	54	63	00
(9) Gc	.05	.97									-	55	87	44
(10) Gfv	-.01	1.02										-	88	-51
(11) SUM	.04	1.75											-	-05
(12) DIFF	.07	.95												-

Note. Decimals omitted from correlations

Means, Standard Deviations, and Correlations
of Aptitude Measures in MIN (N = 44)

Variable	Mean	S.D.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
(1) Vocabulary Multiple-Choice	15.20	4.83	-	71	64	12	02	22	31	42	89	22	65	67
(2) Vocabulary Fill-in	27.18	5.15		-	65	23	25	33	39	57	88	39	74	49
(3) Terman Concept Mastery	30.64	5.29			-	49	41	49	69	68	87	68	99	20
(4) Copying	32.36	9.09				-	43	58	60	44	32	85	68	-52
(5) Memory for Designs	17.16	1.90					-	37	15	24	26	63	51	-36
(6) Paper Folding	13.80	3.66						-	53	34	39	82	70	-42
(7) Advanced Progressive Matrices	23.59	5.15							-	66	53	75	74	-21
(8) GRAPH	22.11	5.95								-	63	55	68	09
(9) Gc	.08	.99									-	49	86	51
(10) Giv	.06	.96										-	86	-50
(11) SUM	.14	1.09											-	01
(12) DIFF	.02	.99												-

Note. Decimals omitted from correlations

APPENDIX B
POSTTEST CORRELATIONS

Means, Standard Deviations, and Correlations
of Aptitude Measures in VE (N = 44)

Variable	Mean	S.D.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
(1) Vocabulary Multiple-Choice	15.25	4.23	-	67	66	26	16	36	33	14	85	36	68	52
(2) Vocabulary Fill-in	26.34	5.89		-	76	48	36	57	63	49	91	66	88	25
(3) Terman Concept Mastery	30.36	5.74			-	25	29	50	50	43	91	51	80	43
(4) Copying	31.75	9.03				-	33	62	57	54	37	81	67	-49
(5) Memory for Designs	16.98	2.02					-	34	40	51	30	66	54	-40
(6) Paper Folding	13.43	3.85						-	50	64	54	81	76	-31
(7) Advanced Progressive Matrices	24.43	5.99							-	62	55	81	77	-30
(8) CRAPII	23.48	5.51								-	41	75	65	-39
(9) Gc	.01	1.03									-	58	89	44
(10) Gfv	.03	1.05										-	89	-48
(11) SUM	.04	1.85											-	-02
(12) DIFF	-.02	.96												-

Note. Decimals omitted from correlations

Posttest Correlations in Total Sample (N = 132)

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Immediate Posttest								
(1) Total Score	82	82	83	81	83	64	72	77
(2) Verbal Total		59	50	48	71	61	60	63
(3) Figural Total			62	51	67	48	65	58
(4) Problems				74	65	49	51	69
Delayed Posttest								
(5) Total Score					84	83	90	85
(6) Verbal Total						44	62	57
(7) Figural Total							73	63
(8) Problems								76

Note. Decimals omitted from correlations.

Reliabilities appear in the main diagonal.

Means, Standard Deviations, and Correlations

of Aptitude Measures in FE (N = 44)

Variable	Mean	S.D.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
(1) Vocabulary Multiple-Choice	15.48	4.72	-	70	79	49	15	37	52	46	92	50	80	41
(2) Vocabulary Fill-in	27.16	5.95		-	69	32	18	50	56	53	89	49	78	39
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(6) Paper Folding	13.32	3.15						-	61	44	46	71	67	-29
(7) Advanced Progressive Matrices	25.52	5.25							-	56	56	87	82	-36
(8) GRAPH	23.05	4.99								-	56	54	63	00
(9) Gc	.05	.97									-	55	87	44
(10) Gfv	-.01	1.02										-	88	-51
(11) SUM	.04	1.75											-	-05
(12) DIFF	.07	.95												-

Note. Decimals omitted from correlations

Posttest Correlations in MIN (N = 44)

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Immediate Posttest								
(1) Total Score	-	86	89	84	92	75	81	82
(2) Verbal Total		-	66	50	87	75	73	78
(3) Figural Total			-	64	80	61	81	62
(4) Problems				-	70	57	56	71
Delayed Posttest								
(5) Total Score					-	82	88	89
(6) Verbal Total						-	56	65
(7) Figural Total							-	67
(8) Problems								-

Note. Decimals omitted from correlations.

APPENDIX B
POSTTEST CORRELATIONS

Posttest Correlations in VE (N = 44)

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Immediate Posttest								
(1) Total Score	-	75	86	76	87	69	78	83
(2) Verbal Total		-	48	40	65	65	50	61
(3) Figural Total			-	48	78	59	78	68
(4) Problems				-	63	42	54	71
Delayed Posttest								
(5) Total Score					-	87	93	84
(6) Verbal Total						-	76	58
(7) Figural Total							-	65
(8) Problems								-

Note. Decimals omitted from correlations.

Posttest Correlations in Total Sample (N = 132)

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Immediate Posttest								
(1) Total Score	82	82	83	81	83	64	72	77
(2) Verbal Total		59	50	48	71	61	60	63
(3) Figural Total			62	51	67	48	65	58
(4) Problems				74	65	49	51	69
Delayed Posttest								
(5) Total Score					84	83	90	85
(6) Verbal Total						44	62	57
(7) Figural Total							73	63
(8) Problems								76

Note. Decimals omitted from correlations.

Reliabilities appear in the main diagonal.

Posttest Correlations in FE (N = 44)

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Immediate Posttest								
(1) Total Score	-	81	72	80	88	71	76	75
(2) Verbal Total		-	41	44	71	67	60	54
(3) Figural Total			-	36	67	44	70	54
(4) Problems				-	67	54	50	66
Delayed Posttest								
(1) Total Score					-	80	88	84
(2) Verbal Total						-	57	50
(3) Figural Total							-	62
(4) Problems								-

Note. Decimals omitted from correlations.

Posttest Correlations in MIN (N = 44)

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Immediate Posttest								
(1) Total Score	-	86	89	84	92	75	81	82
(2) Verbal Total		-	66	50	87	75	73	78
(3) Figural Total			-	64	80	61	81	62
(4) Problems				-	70	57	56	71
Delayed Posttest								
(5) Total Score					-	82	88	89
(6) Verbal Total						-	56	65
(7) Figural Total							-	67
(8) Problems								-

Note. Decimals omitted from correlations.

APPENDIX C
CORRELATIONS BETWEEN APTITUDE AND OUTCOME

Correlations Between Aptitude and Outcome

in Total Sample (N = 132)

	Immediate Posttest				Delayed Posttest			
	Total Score	Verbal Total	Figural Total	Prob- lems	Total Score	Verbal Total	Figural Total	Prob- lems
Vocabulary Multiple Choice	52	41	39	48	51	39	44	49
Vocabulary Fill-in	63	49	53	54	66	53	58	59
Terman Concept Mastery	68	52	57	57	69	49	63	65
Copying	41	40	26	35	46	30	44	42
Memory for Designs	40	40	35	21	42	36	35	38
Paper Folding	49	34	36	49	54	36	53	49
Advanced Progressive Matrices	64	51	53	51	65	49	59	58
GRAPH	66	56	58	49	65	42	61	63
Gc	69	53	56	60	70	53	62	65
Gfv	63	54	49	51	68	49	62	61
SUM	75	61	60	63	78	58	71	72
DIFF	05	-02	06	08	01	03	-02	03

Note. Decimals omitted from correlations

Posttest Correlations in FE (N = 44)

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Immediate Posttest								
(1) Total Score	-	81	72	80	88	71	76	75
(2) Verbal Total		-	41	44	71	67	60	54
(3) Figural Total			-	36	67	44	70	54
(4) Problems				-	67	54	50	66
Delayed Posttest								
(1) Total Score					-	80	88	84
(2) Verbal Total						-	57	50
(3) Figural Total							-	62
(4) Problems								-

Note. Decimals omitted from correlations.

Correlations Between Aptitude and Outcome

in MIN (N = 44)

	Immediate Posttest				Delayed Posttest			
	Total Score	Verbal Total	Figural Total	Prob- lems	Total Score	Verbal Total	Figural Total	Prob- lems
Vocabulary Multiple Choice	53	42	40	56	47	34	38	50
Vocabulary Fill-in	62	52	53	57	62	44	53	64
Terman Concept Mastery	79	68	67	70	73	51	64	74
Copying	50	57	32	40	45	24	47	44
Memory for Designs	49	60	41	23	50	50	40	40
Paper Folding	48	39	40	47	48	28	48	48
Advanced Progressive Matrices	68	52	63	62	60	35	59	59
GRAPH	69	63	65	50	71	38	76	65
Gc	73	61	60	69	69	49	58	71
Gfv	70	67	57	57	66	44	63	62
SUM	83	74	68	73	78	54	76	77
DIFF	04	05	04	13	03	05	04	09

Note. Decimals omitted from correlations.

APPENDIX C
CORRELATIONS BETWEEN APTITUDE AND OUTCOME

Correlations Between Aptitude and Outcome

in VE (N = 44)

	Immediate Posttest				Delayed Posttest			
	Total Score	Verbal Total	Figural Total	Problems	Total Score	Verbal Total	Figural Total	Problems
Vocabulary Multiple Choice	45	32	39	35	50	48	43	43
Vocabulary Fill-In	74	50	64	62	76	71	67	65
Terman Concept Mastery	63	38	59	51	71	54	68	65
Copying	44	30	43	31	53	52	50	39
Memory for Designs	38	21	46	19	38	28	41	29
Paper Folding	54	33	39	58	62	47	63	52
Advanced Progressive Matrices	64	51	61	40	71	67	67	55
GRAPH	64	33	64	47	62	42	61	58
Gc	68	45	61	56	75	65	67	65
Gfv	66	44	61	49	73	63	72	57
SUM	75	50	69	59	83	72	78	69
DIFF	02	00	-02	06	00	01	-07	07

Note. Decimals omitted from correlations.

Correlations Between Aptitude and Outcome

in Total Sample (N = 132)

	Immediate Posttest				Delayed Posttest			
	Total Score	Verbal Total	Figural Total	Prob-Iems	Total Score	Verbal Total	Figural Total	Prob-Iems
Vocabulary Multiple Choice	52	41	39	48	51	39	44	49
Vocabulary Fill-in	63	49	53	54	66	53	58	59
Terman Concept Mastery	68	52	57	57	69	49	63	65
Copying	41	40	26	35	46	30	44	42
Memory for Designs	40	40	35	21	42	36	35	38
Paper Folding	49	34	36	49	54	36	53	49
Advanced Progressive Matrices	64	51	53	51	65	49	59	58
GRAPH	66	56	58	49	65	42	61	63
Gc	69	53	56	60	70	53	62	65
Gfv	63	54	49	51	68	49	62	61
SUM	75	61	60	63	78	58	71	72
DIFF	05	-02	06	08	01	03	-02	03

Note. Decimals omitted from correlations

Correlations Between Aptitude and Outcome
in FE (N = 44)

	Immediate Posttest				Delayed Posttest			
	Total Score	Verbal Total	Figural Total	Prob- lems	Total Score	Verbal Total	Figural Total	Prob- lems
Vocabulary Multiple Choice	66	57	46	50	60	40	50	54
Vocabulary Fill-in	71	66	51	48	65	48	67	51
Terman Concept Mastery	71	59	55	51	63	44	58	57
Copying	38	39	08	37	41	20	40	42
Memory for Designs	40	47	20	23	41	30	29	44
Paper Folding	55	43	40	45	54	35	49	50
Advanced Progressive Matrices	64	58	38	52	67	51	56	61
GRAPH	65	65	39	46	70	58	54	66
GC	76	68	55	55	70	49	66	59
GTV	62	60	33	50	64	43	56	63
SUM	79	72	50	60	76	52	69	70
DIFF	12	05	22	03	03	04	08	-07

Note. Decimals omitted from correlations.

Correlations Between Aptitude and Outcome

in MIN (N = 44)

	Immediate Posttest				Delayed Posttest			
	Total Score	Verbal Total	Figural Total	Prob- lems	Total Score	Verbal Total	Figural Total	Prob- lems
Vocabulary Multiple Choice	53	42	40	56	47	34	38	50
Vocabulary Fill-in	62	52	53	57	62	44	53	64
Terman Concept Mastery	79	68	67	70	73	51	64	74
Copying	50	57	32	40	45	24	47	44
Memory for Designs	49	60	41	23	50	50	40	40
Paper Folding	48	39	40	47	48	28	48	48
Advanced Progressive Matrices	68	52	63	62	60	35	59	59
GRAPH	69	63	65	50	71	38	76	65
Gc	73	61	60	69	69	49	58	71
Gfv	70	67	57	57	66	44	63	62
SUM	83	74	68	73	78	54	76	77
DIFF	04	05	04	13	03	05	04	09

Note. Decimals omitted from correlations.

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Correlations Between Aptitude and Outcome

in VE (N = 44)

	Immediate Posttest				Delayed Posttest			
	Total Score	Verbal Total	Figural Total	Problems	Total Score	Verbal Total	Figural Total	Problems
Vocabulary Multiple Choice	45	32	39	35	50	48	43	43
Vocabulary Fill-In	74	50	64	62	76	71	67	65
Terman Concept Mastery	63	38	59	51	71	54	68	65
Copying	44	30	43	31	53	52	50	39
Memory for Designs	38	21	46	19	38	28	41	29
Paper Folding	54	33	39	58	62	47	63	52
Advanced Progressive Matrices	64	51	61	40	71	67	67	55
GRAPH	64	33	64	47	62	42	61	58
Gc	68	45	61	56	75	65	67	65
Gfv	66	44	61	49	73	63	72	57
SUM	75	50	69	59	83	72	78	69
DIFF	02	00	-02	06	00	01	-07	07

Note. Decimals omitted from correlations.

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Correlations Between Aptitude and Outcome
in FE (N = 44)

	Immediate Posttest				Delayed Posttest			
	Total Score	Verbal Total	Figural Total	Prob- lems	Total Score	Verbal Total	Figural Total	Prob- lems
Vocabulary Multiple Choice	66	57	46	50	60	40	50	54
Vocabulary Fill-in	71	66	51	48	65	48	67	51
Terman Concept Mastery	71	59	55	51	63	44	58	57
Copying	38	39	08	37	41	20	40	42
Memory for Designs	40	47	20	23	41	30	29	44
Paper Folding	55	43	40	45	54	35	49	50
Advanced Progressive Matrices	64	58	38	52	67	51	56	61
GRAPH	65	65	39	46	70	58	54	66
GC	76	68	55	55	70	49	66	59
GTV	62	60	33	50	64	43	56	63
SUM	79	72	50	60	76	52	69	70
DIFF	12	05	22	03	03	04	08	-07

Note. Decimals omitted from correlations.

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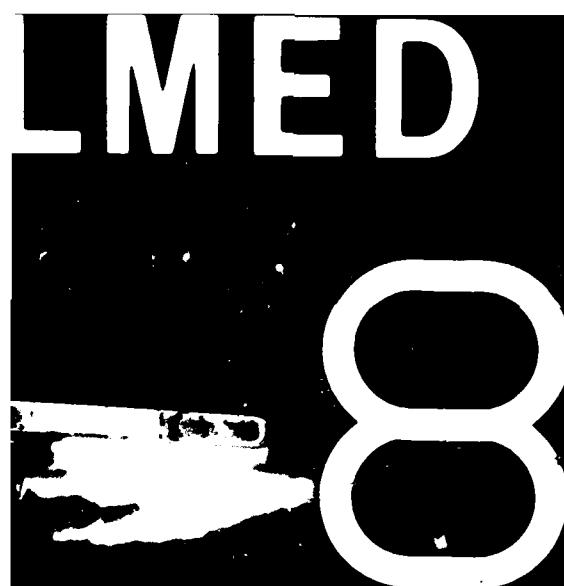
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