DOCUMENT RESUME

ED 205 571 TM 810 456

AUTHOR Yalow, Elanna
TITLE Individual Differences in Learning from Verbal and Figural Materials. Technical Report No. 12: Aptitude Research Project.
INSTITUTION Stanford Univ., Calif. School of Education.
SPONS AGENCY Advanced Research Projects Agency (DOD), Washington, D.C.: Office of Naval Research, Arlington, Va. Personnel and Training Research Programs Office.
PUB DATE Sep 80
CONTRACT N00014-75-C-0882
NOTE 90p.

EDRS PRICE MF01/PC04 Plus Postage.
DESCRIPTORS *Academic Ability: Aptitude Tests: *Aptitude Treatment Interaction: *Educational Strategies: High Schools: Individual Differences: *Instructional Materials: Pretests Posttests: *Remedial Instruction: Social Studies: *Time Factors (Learning)

ABSTRACT

Of primary interest in this study was the effect of general ability on learning. It was hypothesized that students higher in general ability would obtain higher posttest scores on the average than lower ability students, and that verbal and figural explanatory supplements to minimal instructional materials would reduce the regression of general ability on outcome. It was expected that students with higher aptitude scores would obtain higher posttest scores. The effects of a more task-specific aptitude, graph processing, were explored, and involved both immediate and delayed learning outcome measures. A course in Economics was presented to high-school students using one of three sets of instructional materials. Before the course, participants took a three-hour aptitude battery and were randomly assigned to treatment. Posttests were administered at the end of the course and two weeks later. Generalized regression analysis was used to assess the effects of aptitudes, treatments, and interactions. This study provided evidence that neither aptitude nor instructional treatment alone can fully describe learning outcomes. Further, instructional supplements, can be effective in filling in for student weaknesses and reducing differences between high and low ability students. (Author/GK)

# 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
Personnel and Training Research Programs
Psychological Sciences Division
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SEPTEMBER 1980

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UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

# REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

| | |
|---|---|
| 1. REPORT NUMBER: 12 | 2. GOVT ACCESSION NO. |
| | 3. RECIPIENT'S CATALOG NUMBER |
| 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

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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S/N 0102-LF-014-6601

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) 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 expects 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 particulary 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 retnetion. 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.

## 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 addressed to:

Professor Richard E. Snow, Principal Investigator
Aptitude Research Project
School of Education
Stanford University
Stanford, California 94305



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# CHAPTER I

## 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

[illegible]

[illegible]

A second ... hypothesis [illegible] verbal and nonverbal abilities. This is the major distinction below general ability in a hierarchical [illegible] of ability organization. The nonverbal side has usually been thought of as spatial (Smith, 1964; 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 after one and five weeks. The regression on verbal ability was shallower in the verbal treatment than in the figural or symbolic treatments at all three testings, suggesting that low verbal students were compensated by a verbal treatment. The regressions of outcome on figural and symbolic ability were shallower when aptitude matched the instructional condition only on the immediate posttest. On both retention measures, regressions were steepest for figural and symbolic ability in the figural and symbolic treatments, suggesting that one should match to strengths.

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 vusualization to a presentation that uses graphs" (p.285).

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 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.

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 ription 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.

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.

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.

The same material was covered in each treatment condition. Treatments varied, however, in the explanatory displays and the difficulty of the processing demands. The three instructional conditions were Minimal

(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 Gfv: 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 Gc 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

TABLE 1

Summary of Treatment Specifications

| | Treatment | | |
|---|---|---|---|
| Component of Instruction | 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 read graphs and to interpret data presented figurally. Items required either translating verbal information to graphs or giving verbal descriptions to interpret graphs.

Another instrument designed specifically for this study was the Cognitive Preference Questionnaire. This questionnaire asked students if they preferred learning from verbal material or by reasoning about diagrams and figures. Attitudes toward selected instructional features and learning strategies were also solicited.

Instructional Materials

Three workbooks, corresponding to MIN, VE, and FE, were developed. Each workbook was composed of eight 10-20 page packets and introduced approximately three new topics. Students worked through the workbook in a prescribed manner, answering questions and solving problems in the packet.

Each packet began with a Summary Sheet listing the major topics covered in previous sections. In VE and FE, major points were summarized in the appropriate mode. Participants in MIN were cued to generate the summary for themselves.

The last pages in each packet contained problems relevant to the material covered during the instructional session. These Problem Sets were included to encourage students who completed the material before 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 alloted 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

[a]Numbers 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 accomodated 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.

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

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] | 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 | 71 | -29 |
| (7) Advanced Progressive Matrices | 23.64 | 5.47 | | | | | | | 83[a] | 62 | 54 | 80 | 77 | -27 |
| (8) GRAPH | 22.64 | 5.50 | | | | | | | | 86[a] | 54 | 62 | 66 | -08 |
| (9) Gc | .00 | 1.00 | | | | | | | | | 91[c] | 54 | 88 | 48 |
| (10) Gfv | .00 | 1.00 | | | | | | | | | | 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.

[a]Reliability estimate coefficient $\alpha$.

[b]Split-half reliability estimate.

liability estimated as composite.

values indicate an advantage in Gfv. This procedure has advantages over using Gc and Gfv directly in the analysis (Cronbach and Snow, 1977). First, hypotheses can be ordered so that the general-ability hypothesis can be tested independently from the more exploratory differential-ability hypothesis. Second, SUM and DIFF are uncorrelated, whereas, Gc and Gfv usually correlate (r = .54 in this study). Thus, using SUM and DIFF provides less ambiguous interpretations than using Gc and Gfv directly.

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

Table 4

Means and Standard Deviations on Posttest

| | Immediate Posttest | | | | | | Delayed Posttest | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Treatment | MIN | | VE | | FE | | MIN | | VE | | FE | |
| Outcome | 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 | [illegible].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 | MIN | | | VE | | | FE | | |
|---|---|---|---|---|---|---|---|---|---|
| Outcome Measure \ Aptitude | 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:

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

where:

$Y$ = dependent variable

$\beta_O$ = constant term

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

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

$\beta_T$ = 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 (T1) compared MIN with VE and FE (coded 2, -1, -1, respectively). The second contrast (T2) compared VL with FT (coded 1, 1, respectively, with MIH coded 0). All 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:

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

where:

$\Delta R^2$ = increment in R2

$K_i$ = number of predictors in change

$R^2_t$ = $R^2$ 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: % Variance Accounted For | Immediate Posttest: F ratio | Delayed Posttest: % Variance Accounted For | Delayed Posttest: 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 SMATH, 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. SUM accounted for [illegible]% of the variance in the immediate posttest and only [illegible]% of the variance in the delayed posttest.

Treatment main effects accounted for 5.6% 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 5. 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

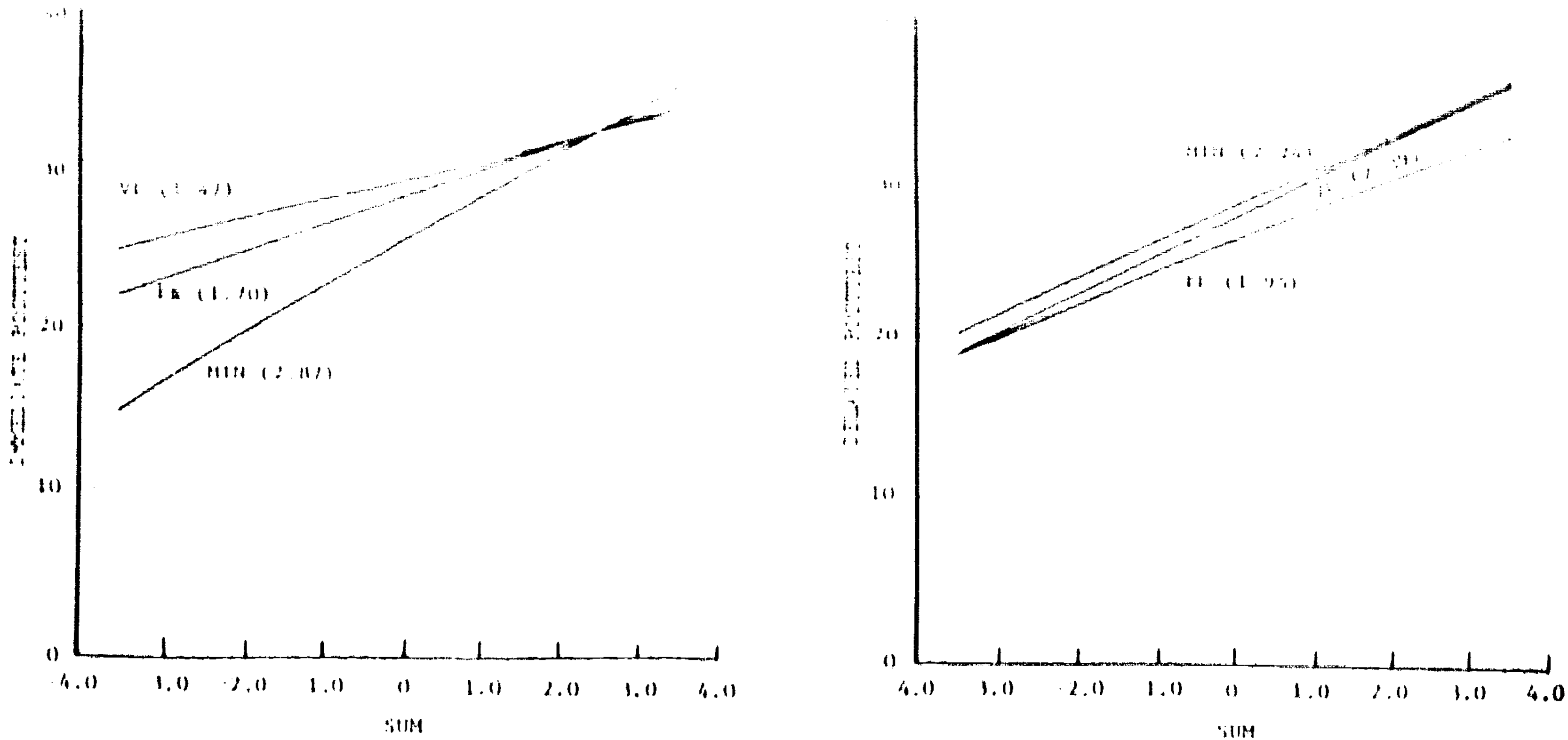



Figure 1. Relation of Total Posttest Scores to SUM, with Unstandardized Regression Coefficients Shown in Parentheses.

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

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.

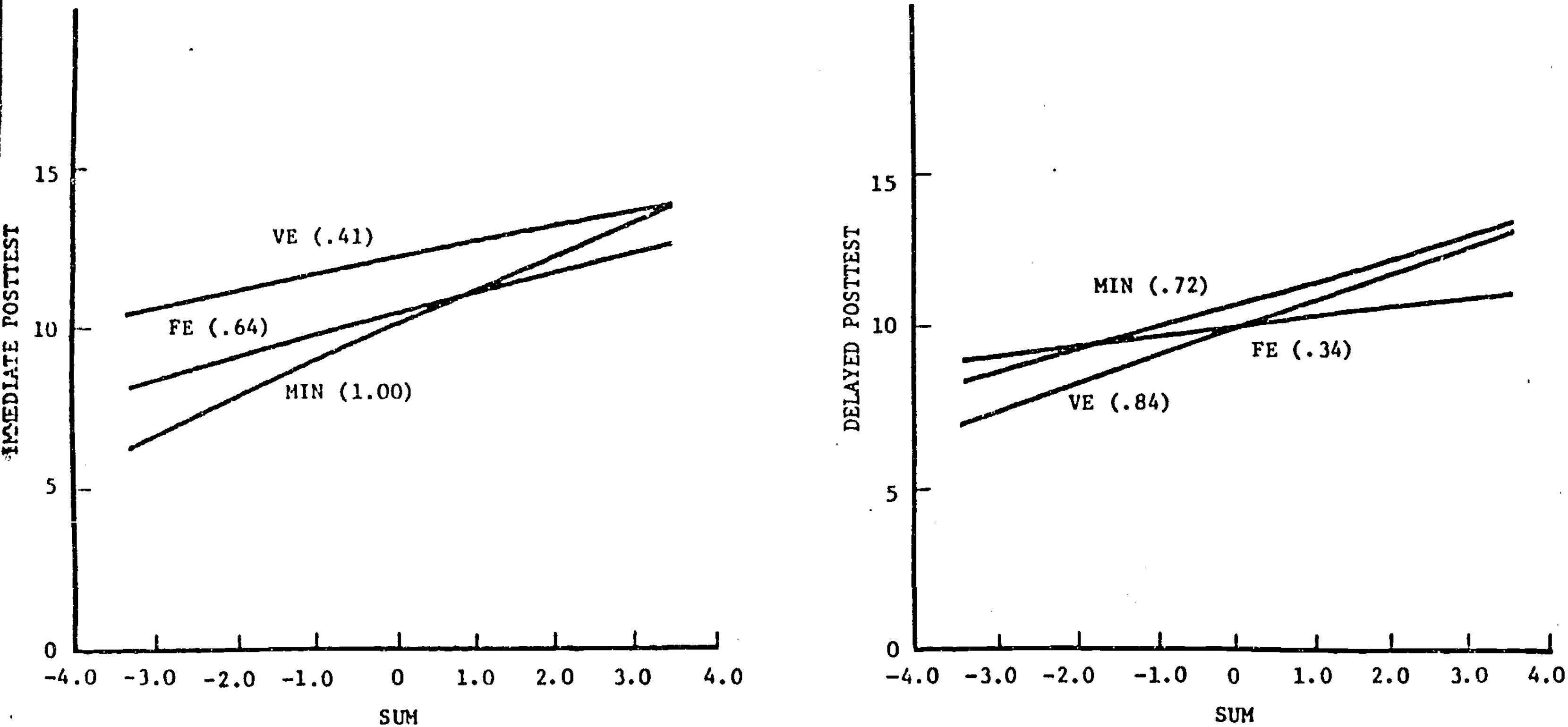
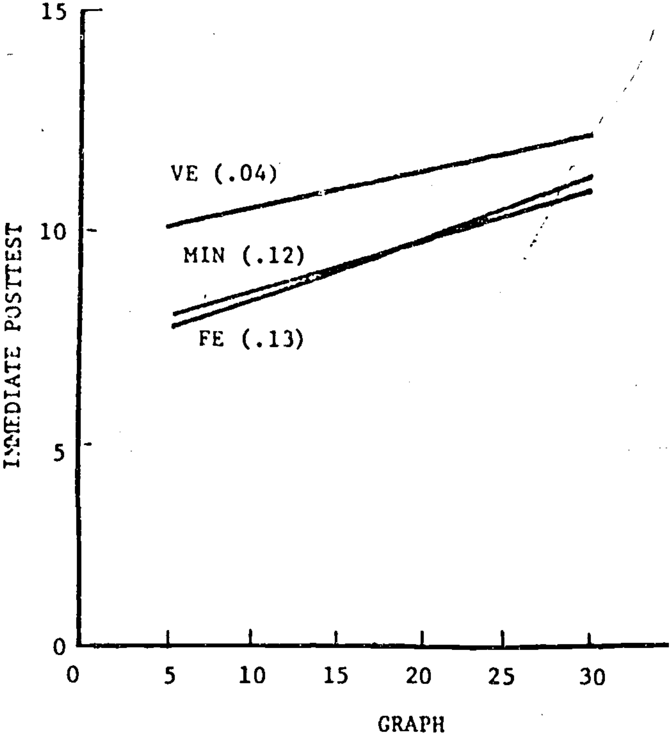



Figure 2. Relation of Verbal Items to SUM, with Unstandardized Regression Coefficients Shown in Parentheses.



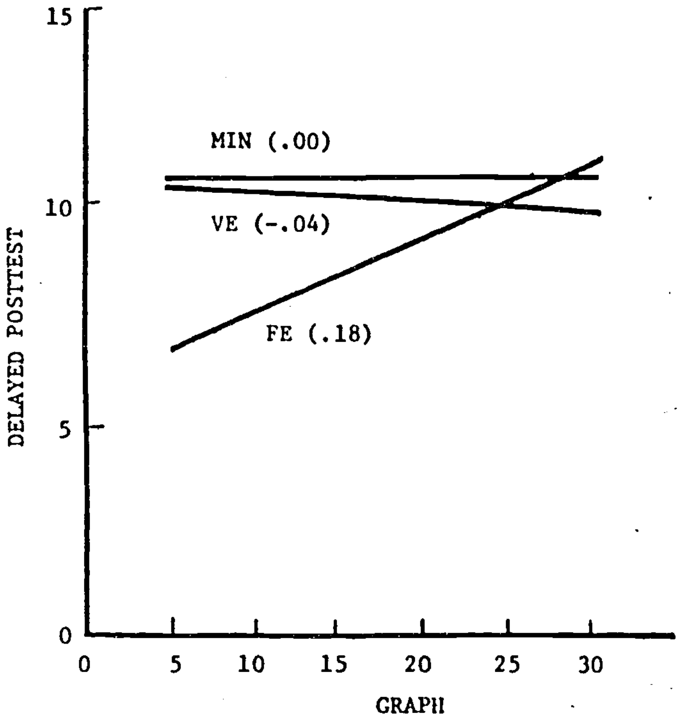




Figure 3. Relation of Verbal Items to GRAPH with Unstandardized Regression Coefficients Shown in Parentheses.

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 ATI | 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 | -- |

*$p < .05$

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

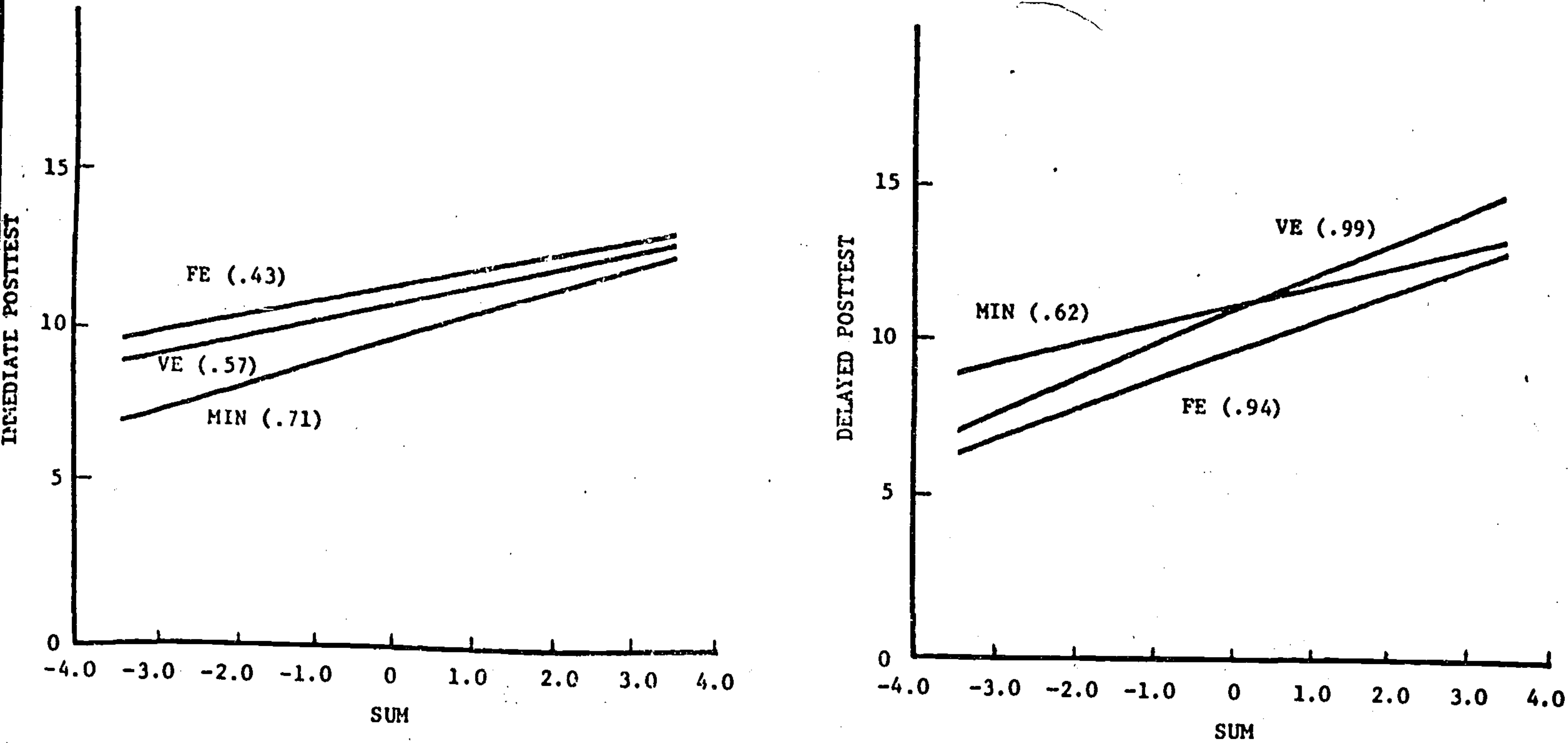



Figure 4. Relation of Figural Items to SUM, with Unstandardized Regression Coefficients Shown in Parentheses.

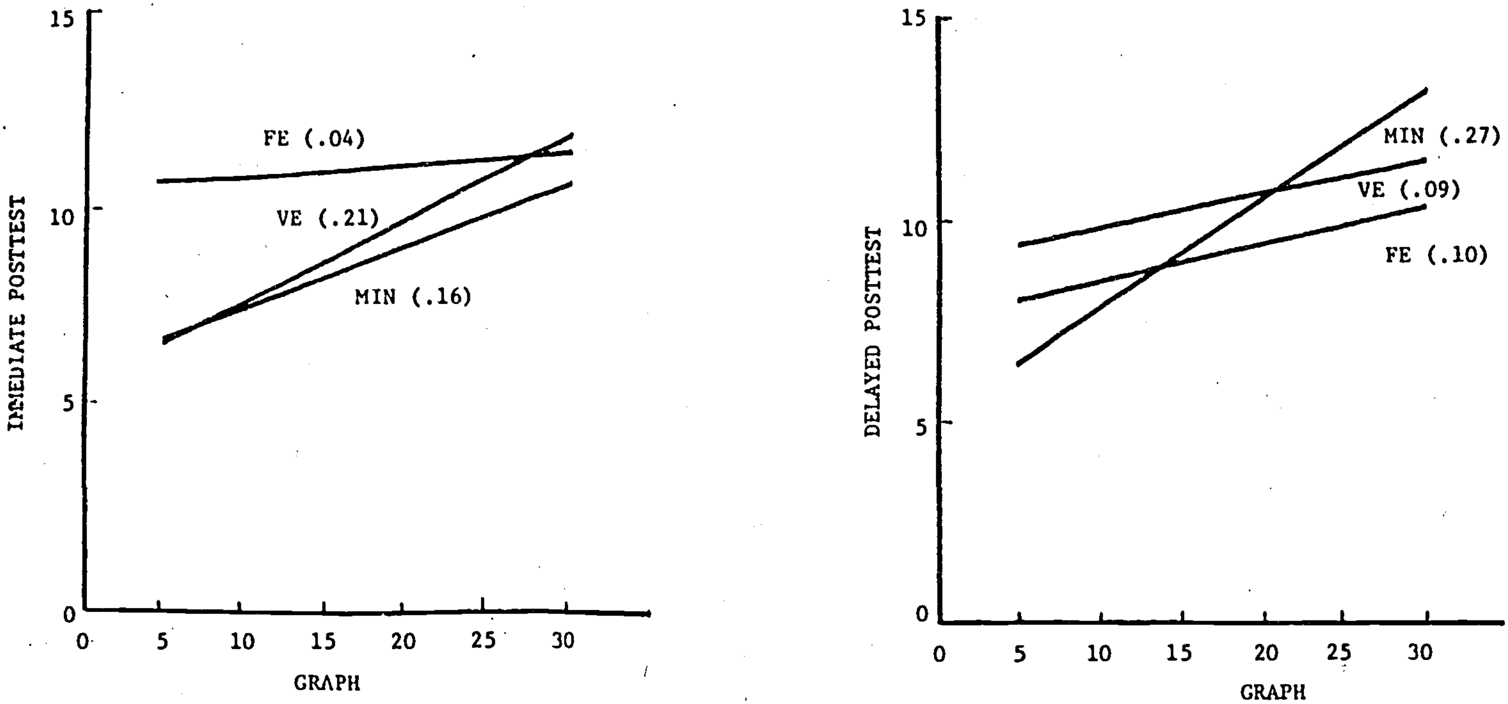



Figure 5. Relation of Figural Items to GRAPH, with Unstandardized Regression Coefficients Shown in Parentheses.

Table 9

Summary of Stepwise Regression of Problems

| Variable | d.f. | Immediate Posttest % Variance Accounted For | Immediate Posttest F - ratio | Delayed Posttest % Variance Accounted For | Delayed Posttest 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 | -- |

*$p < .05$

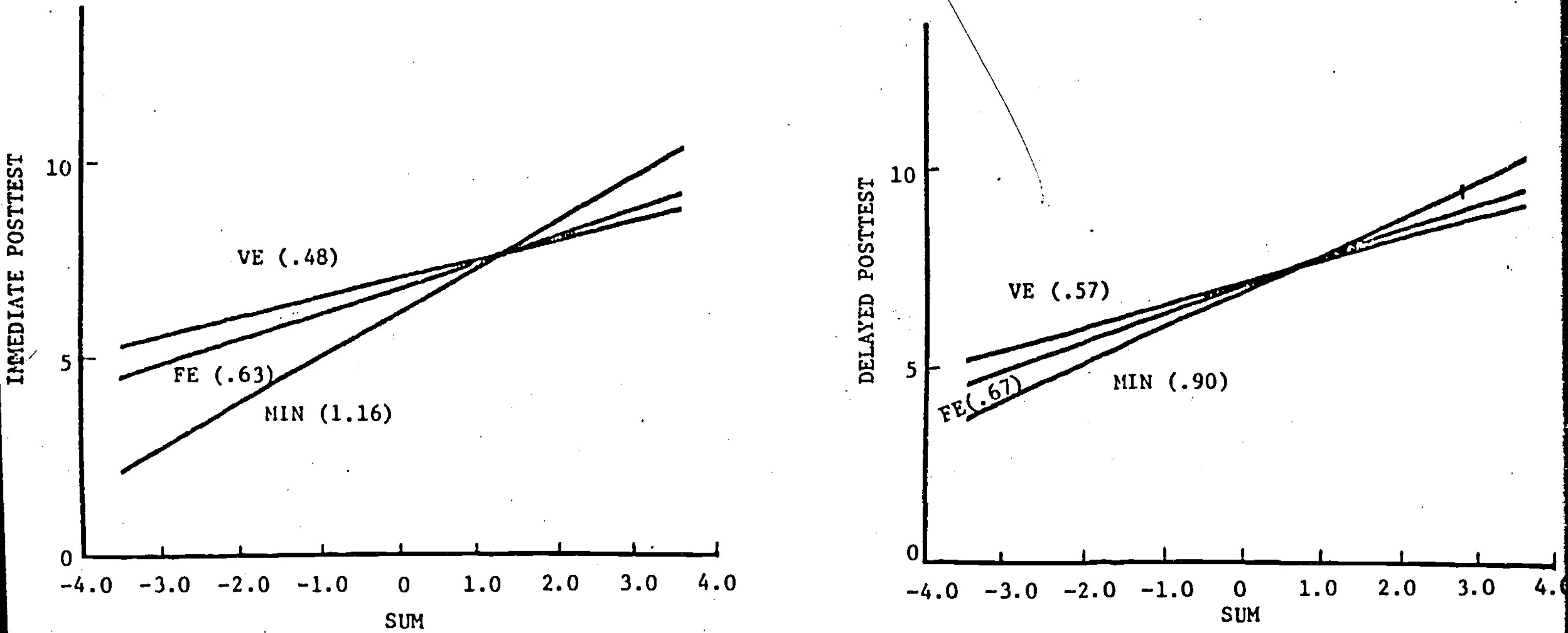



Figure 6. Relation of Problems to SUM, with Unstandardized Regression Coefficients Shown in Parentheses.

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.

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.

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 achievement 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 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, 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 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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APPENDIX A

MEANS, STANDARD DEVIATIONS, AND CORRELATIONS BETWEEN APTITUDES

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 | 90 | 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) | Gfv | .06 | .96 | | | | | | | | | | – | 86 | -50 |
| (11) | SUM | .14 | 1.69 | | | | | | | | | | | – | 01 |
| (12) | DIFF | .02 | .99 | | | | | | | | | | | | – |

*Note.* Decimals omitted from 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) | GRAPH | 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

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

APPENDIX B

POSTTEST CORRELATIONS

[illegible]

| Variables | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| Immediate Posttest | | | | | | | | |
| (1) Total Score | [illegible] | [illegible] | [illegible] | 31 | [illegible] | [illegible] | [illegible] | [illegible] |
| (2) Verbal Total | | [illegible] | 40 | [illegible] | 71 | 61 | 60 | [illegible] |
| (3) Figural Total | | | [illegible] | 51 | [illegible] | 48 | 65 | [illegible] |
| (4) Problems | | | | [illegible] | [illegible] | 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 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 | 56 | 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.

Posttest Correlations in VE (N = 44)

| Variable | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| Immediate Posttest | | | | | | | | |
| (1) Total Score | – | 75 | 86 | 78 | 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 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.

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

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 Choce | 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 | 70 | 77 |
| DIFF | 04 | 05 | 04 | 13 | 03 | 05 | 04 | 09 |

Note. Decimals omitted from correlations.

Correlations Between Aptitude and Outcome

in VE (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 | 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 | 38 | 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 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 | 56 | 54 |
| Vocabulary Fill-in | 71 | 66 | 51 | 48 | 65 | 48 | 64 | 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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