1980

Interaction of field dependence-independence with type of feedback used in computer-assisted equation solving

Vicki Allen Boysen
Iowa State University

8019624

BOYSEN, VICKI ALLEN

INTERACTION OF FIELD DEPENDENCE-INDEPENDENCE WITH TYPE OF FEEDBACK USED IN COMPUTER-ASSISTED EQUATION SOLVING

Iowa State University PH.D. 1980

University
Microfilms
International 300 N. Zeeb Road, Ann Arbor, MI 48106 18 Bedford Row, London WC1R 4EJ, England

Interaction of field dependence-independence with type of feedback used in computer-assisted equation solving

by

Vicki Allen Boysen

A Dissertation Submitted to the
Graduate Faculty in Partial Fulfillment of the
Requirements for the Degree of
DOCTOR OF PHILOSOPHY

Major: Education (Adult and Extension)

Approved:

Signature was redacted for privacy.

Signature was redacted for privacy.

In Charge of Major Work

Signature was redacted for privacy.

For the Major Department

Signature was redacted for privacy.

For the Graduate College

Iowa State University
Ames, Iowa

1980

CONTENTS

page

INTRODUCTION 1

Statement of the Problem 1
The Present Study 6
Hypotheses 7
Limitations of the Study 9

REVIEW OF THE LITERATURE 10

Introduction 10
Feedback and Computer-Assisted Instruction 10
Aptitude-Treatment Interaction in CAI 12
Field Dependence-Independence and Level of Instructional Guidance 15
Summary 20

METHOD 22

Description of Subjects 22
Description of Measuring Instruments 23
Research Design 29
Implicit Feedback Treatment 31
Explicit Feedback Treatment 34
Types of Equations 38
Research Procedure 40

RESULTS AND DISCUSSION 43

Descriptive Data 43
Interaction Data 50
Discussion 65

SUMMARY AND CONCLUSIONS 69

Summary 69
Implications for Future Research 73
Conclusions 74

BIBLIOGRAPHY 76

ACKNOWLEDGMENTS 80

APPENDIX A. POSTTEST 81

APPENDIX B. EVALUATION PROCEDURE FOR THE POSTTEST . . . 84

APPENDIX C. EVALUATION PROCEDURE FOR THE
SIMULTANEOUS EQUATIONS TRANSFER TEST 87

APPENDIX D. ATTITUDE SURVEY 89

APPENDIX E. HUMAN SUBJECTS FORM 92

LIST OF TABLES

Table page

1. Symbols used to request equation operations 34
2. Restrictions imposed by the explicit feedback treatment 37
3. Levels of equations 39
4. Means and standard deviations of all cognitive tests (adolescent sample) 44
5. Means and standard deviations of all cognitive tests (adult sample) 45
6. Means and standard deviations of the attitude survey (adolescent sample) 47
7. Means and standard deviations of the attitude survey (adult sample) 48
8. Correlation matrix for cognitive tests (adolescent sample) 49
9. Correlation matrix for cognitive tests (adult sample) 50
10. Significance tests for all cognitive measures (adolescent sample) 52
11. Significance tests for all cognitive measures (adult sample) 53
12. Regression of cognitive dependent measures on aptitude tests (adolescent sample) 54
13. Regression of cognitive dependent measures on aptitude tests (adult sample) 55

14. Significance tests for attitude survey (adolescent sample) 61

15. Significance tests for attitude survey (adult sample) 62

16. Regression of attitude survey on math achievement (adult sample) 64

LIST OF FIGURES

Figure page

1. Example of implicit feedback treatment 33

2. Example of explicit feedback treatment 36

3. Regression of Equation Solving Transfer score, Operations portion, on GEFT (adolescent sample) . 56

4. Regression of statistics transfer test on GEFT (adult sample) 57

5. Regression of Posttest Computations score on math achievement (adult sample) 59

INTRODUCTION

Statement of the Problem

The instructional usage of computers has undergone many and varied improvements since the concept was first introduced in the 1950s. Computers are now programmed to tutor, provide drill and practice, and simulate the real world. Computers also provide corrective feedback as they teach, usually by showing the correct answer when a question has been answered incorrectly. However, the benefit of feedback in computer-assisted instruction is still unproven despite its popular use and appeal.

> A computer-assisted instruction (CAI) system can provide detailed, immediate feedback following every student response. This is a theoretical advantage, but whether it is a real one remains to be seen. To be sure, one of the best documented propositions in psychology is that feedback facilitates learning.... But experimental demonstrations of the value of immediate feedback using actual lessons have been rare (Tait, Hartley, and Anderson, 1973, p. 161).

Renzi (1974) reviewed the literature on the effects of feedback on achievement and found that results were mixed. In some instances feedback was helpful or had no effect, while in others feedback even seemed to hinder achievement. Similar reviews by Ausubel and Robinson (1969) and Anderson, Kulhavy, and Andre (1971) reached the same conclusion. It appeared to researchers that these conflicting results might be accounted for by the presence of another variable interacting with feedback.

One variable which might account for this interaction is cognitive style. Kogan (1971) defines cognitive style as "individual variations in modes of perceiving, remembering, and thinking, or as distinctive ways of apprehending, storing, transforming, and utilizing information" (p. 244). Kogan emphasizes the word "modes" because cognitive style is concerned with the form rather than the content of cognitive activity. The definition thus describes a process rather than a product.

There are many different types of cognitive styles; Kogan (1971) defines nine. However, one of the best known and best researched is field dependence-independence, first described by Witkin and his associates (Witkin et al., 1954; Witkin et al., 1962; Witkin et al., 1977). Degree of field dependence-independence is usually assessed in one of three ways: the Body Adjustment Test (BAT), the Rod and Frame Test (RFT), and the Embedded Figures Test (EFT).

> The BAT consists of a tilting chair within a tilting room, the seated subject being required to adjust the chair to the true vertical. The subject's score represents the deviation of the chair's adjusted position from the true upright.

> The RFT offers a luminous rod within a luminous frame in a completely dark room. The subject's task is to adjust the rod to the true vertical when rod and frame are tilted in the same or opposite directions. Degree of absolute deviation of the rod setting from the true upright constitutes the subject's score. Finally, the EFT is comprised of a set of complex geometric patterns in which simple figures are embedded. Amount of time required to locate these simple figures is the subject's score (Kogan, 1971, pp. 247-248).

All three tests measure an individual's ability to overcome an embedding context, or the extent to which he or she perceives part of a visual field as discrete from the surrounding field. People whose perception is strongly dominated by the surrounding field are designated "field dependent," while those who experience items as more or less separate from the surrounding field are labeled "field independent." These designations are not absolute. Rather, they represent extremes of a continuum along which lie scores representing tendencies, in varying degrees of strength, toward one mode of perception or the other.

During adulthood, people remain fairly stable in their tendency toward either field dependence or independence. In adolescence, however, this stability is only relative. An individual child high in field independence relative to his or her peers at one age is likely to remain high relative to those peers at a later age, but all children become increasingly field independent as a group (Witkin, Goodenough, and

Karp, 1967). This movement toward field independence appears to stop somewhere before middle age, after which people tend to become increasingly field dependent as they grow older (Schwartz and Karp, 1967). However, Goldstein and Blackman (1978) warn that most studies linking advanced age with increasing field dependence have confounded age with infirmity. They conclude that field dependence is associated with infirmity as well as with age.

Goldstein and Blackman (1978) have also examined studies investigating the relationship between sex and field dependence-independence and found evidence contradicting the generally-held belief that males are more field independent than females. They located several studies which found no statistically significant difference in field dependence between males and females. These studies examined both children and undergraduates. In two studies, females were even found to be significantly more field independent than males.

Although the concept of field dependence-independence was originally only associated with a person's visual perception, it soon became apparent that human faculties other than perception were also involved. Witkin et al. (1977) state:

> Extensive evidence, accumulated over the years, shows that the styles we first identified in perception manifest themselves as well when the person is dealing with symbolic representations, as in thinking and problem solving. The individual, who, in perception, cannot keep an item separate from the surrounding field--in other words, who is relatively field dependent--is likely to have difficulty with that class of problems, and, we must emphasize, only with that class of problems, where the solution depends on taking some critical element out of the context in which it is presented and restructuring the problem material so that the item is now used in a different context (p. 8).

Thus, Witkin theorized that the ability of field independent individuals to analyze and impose structure on an unorganized perceptual field helps them to impose structure on unorganized learning material as well. Field dependent individuals, on the other hand, are more likely to accept a perceptual field "as is," without using the mediational processes of analysis and structuring. This lesser use of structuring may therefore handicap field dependent students when they are confronted with unstructured learning situations.

> Field dependent students may need more explicit instruction in problem solving strategies or more exact definition of performance outcomes than field independent students, who may even perform better when allowed to develop their own strategies. Attention to cognitive style differences in learning under more structured and less structured conditions, and detailed analysis of the problem solving skills and strategies assumed for different learning tasks, are necessary (Witkin et al., 1977, p. 25).

The Present Study

After reviewing the above findings, it was clear that feedback might interact with field dependence-independence in unstructured learning situations, and especially in problem solving tasks. Witkin et al. (1977) have suggested that field dependent students may need "more exact definition of performance outcomes," and one way of meeting this need is with feedback. Thus, the present study investigated the interaction between field dependence-independence and type of feedback in a problem solving situation.

The specific problem solving situation chosen for this study was algebraic equation solving presented through the medium of a computer. The author developed two computer programs which presented simple linear equations to the learner and required him or her to solve these equations by specifying which operations the computer should perform on them. The two programs differed only in the form of feedback provided. In the "explicit" feedback program, students were corrected if the operation they requested did not simplify the equation. The "implicit" program, on the other hand, performed any legal operation requested by the learner regardless of whether the operation simplified the equation or not.

The interaction of most interest in this study was that between feedback and field dependence-independence. However, following the recommendations of Cronbach and Snow (1977) and Berliner and Cahen (1973), the interaction between feedback and a second aptitude variable--mathematics achievement--was also examined. Because of the possible effect of age on cognitive style, the study investigated interactions between feedback and both aptitudes for two separate age groups: eighth grade junior high students and adult university graduate students. The inclusion of two age groups in the study made it possible to examine the interaction of feedback with field dependence-independence and with mathematics achievement at different developmental levels.

Hypotheses

The hypotheses examined in this study were as follows:

1. There is no significant interaction between type of feedback and degree of field dependence-independence in relation to an individual's ability to solve simple linear equations.

2. There is no significant interaction between type of feedback and degree of field dependence-independence

in relation to an individual's ability to utilize their equation-solving skills in a transfer task.

3. There is no significant interaction between type of feedback and mathematics achievement in relation to an individual's ability to solve simple linear equations.

4. There is no significant interaction between type of feedback and mathematics achievement in relation to an individual's ability to utilize their equation-solving skills in a transfer task.

5. There is no significant interaction between type of feedback and degree of field dependence-independence in relation to an individual's attitude toward computer-assisted instruction.

6. There is no significant interaction between type of feedback and mathematics achievement in relation to an individual's attitude toward computer-assisted instruction.

Limitations of the Study

Of the many problem solving skills that are important in educational development, the present study investigated only algebraic equation solving. In addition, the treatments involving practice in equation solving were carried out exclusively by computer. The decision to perform the study in this manner was due to the importance of equation solving in mathematics education and the suitability of a computer for the task of individualizing instruction. Salomon (1972) has pointed out that

> any given group of learners can be divided along numerous, uncorrelated lines. Consequently, numerous types of alternative instructional procedures may be developed. Moreover, learners can be subdivided to receive different curricula, to receive the same curriculum along different structural lines, to be given material along the same structural lines but through different modalities, and so on. Quite possibly, the only practical way to assign students to different curricula, contents, modalities, rates of presentation, and the like, is to use computer-based instruction... (pp. 327-328).

Two other limitations of the study involved the populations studied and the choice of field dependence-independence as the cognitive style of interest. The two age populations included in the study do not allow inference to the full range of intellectual development, but they do allow an age comparison which is not prevalent in the research literature. Similarly, field dependence-independence was selected because of its importance in the literature.

REVIEW OF THE LITERATURE

Introduction

The organization of this chapter is as follows: First, the role of feedback in instruction is discussed. Studies are reviewed which illustrate the inconsistent effect of computer-assisted instruction (CAI) feedback on mathematics achievement. Next, attempts to find interactions between various methods of mathematics instruction and aptitudes other than field dependence-independence are noted. Finally, research similar to the present study is examined. Studies are presented which illustrate the presence of interaction between field dependence-independence and feedback in mathematics instruction.

Feedback and Computer-Assisted Instruction

As was stated earlier, several investigators have made conflicting reports about the effect of feedback on instruction. This section will discuss some of these reports, specifically the ones which are directly related to mathematics instruction. Although the use of feedback in CAI is widespread, only four studies which examined the effect of feedback on mathematics achievement could be located.

In two of these studies, students receiving feedback had significantly higher math achievement than those not receiving feedback. Tait, Hartley, and Anderson (1973) examined the effect of two CAI feedback conditions ("active" and "passive") and one non-feedback condition on the abiity of children to multiply whole numbers. They found that feedback was significantly better than non-feedback, but that active feedback was not significantly better than passive. Another study which found feedback to be beneficial was carried out by Roper (1977). Students who were given the correct answer when they made a mistake in a CAI unit on statistics scored significantly higher on a posttest than students who received either no feedback or only notification that their answer was wrong.

Looking at just the above two studies, it would appear that feedback is an essential part of effective instruction. Such is not always the case, however. In a study which utilized programmed instruction to teach algebraic equation solving, Jacobs and Kulkarni (1966) found no significant difference in achievement between subjects who received feedback and those who did not. Moreover, in a companion study involving instruction on chemical gas laws, the non-feedback group (Group "O") had significantly higher posttest scores than the feedback group. Jacobs and Kulkarni explained their findings in this way:

> The customary procedure, under the assumption that S needs to know after each response whether he is right or wrong, is to supply explicitly the correct answer to him. For Group "O" in the present study this was not done, although S might discover the answer from the material in the succeeding frames of the program. Having the knowledge of results implicit may require S to adopt a more active, searching role in the learning process, which will facilitate learning (p. 109).

One final study which compared various types of feedback was carried out by Schoen (1973). This study was different from the preceding ones in that it did not include a non-feedback condition. Instead, two levels of individualized CAI feedback were examined. One was individualized by both the question asked and the answer choice selected, while the other was individualized by the question alone. The results showed that math students who received the corrective feedback individualized by question alone achieved significantly better than those whose corrective feedback was individualized by both the question asked and the answer chosen. This result was for a posttest; on a mid-unit test, there was no significant difference between the groups.

Aptitude-Treatment Interaction in CAI

It soon became apparent to researchers that no single method of feedback was best for every student. Consequently, they began to search for learner aptitudes that would interact with different forms of feedback, allowing educators to assign students to instructional methods tailored to individual needs. This type of approach, known as aptitude-treatment interaction (ATI) research, has been described in detail by Cronbach and Snow (1977).

In this section, studies which investigated interactions between mathematics CAI and aptitudes other than field dependence-independence are reviewed. The results were largely disappointing and the number of studies small. This lack of studies was noted by Becker (1970), who could locate only a small number of interaction studies which dealt directly with mathematics instruction.

A few studies have been conducted since Becker's review. One was the previously cited experiment conducted by Tait, Hartley, and Anderson (1973). In addition to finding that feedback was significantly better than no feedback, Tait, Hartley, and Anderson also found a significant interaction between feedback and mathematics achievement (as measured by a pretest). Feedback was found to have its greatest effect on subjects whose initial level of achievement was low. Similar results were reported in a review by Cronbach and Snow (1977), who concluded that methods of instruction which provide a high degree of support and guidance are generally the most beneficial for students of low general ability.

The other studies which have investigated ATI in mathematics did not find significant interactions. Lang (1976) compared "computer extended instruction" with conventional instruction in an introductory calculus class. The computer extended instruction allowed students to use the computer as a tool to investigate properties, relations, and concepts underlying mathematical functions in calculus. Although no significant interaction was found between treatment and prior achievement in mathematics, some interesting results were uncovered when the aptitude measure was split into subtests. Specifically, students with high trigonometry pretest scores benefitted the most from the computerized instruction while students with high algebra pretest scores benefitted the most from conventional instruction.

Research by Behr (1970) did find a significant interaction between intellectual aptitude and type of mathematics instruction, but a follow-up study (Behr and Eastman, 1975) could not replicate those results. The two treatments under study were figural and verbal methods of programmed instruction, and the aptitude variable was based on Guilford's structure-of-intellect model. In the earlier study, students scoring high in verbal aptitude performed significantly better under the verbal treatment than under the figural treatment. In addition, students high in figural aptitude took significantly less time to use the figural treatment than did those who were low in figural aptitude. However, no similar significant interactions were found in the later study. These contradictory results may have been due to the use of very short treatment periods (only 50 minutes) and/or the presence of invalid aptitude measures, i.e., high correlations between tests supposedly measuring two completely different aptitudes.

Field Dependence-Independence and Level of Instructional Guidance

Around 1974, researchers examining ATI in mathematics began to focus on field dependence-independence as one aptitude on which to individualize their instruction. Following Witkin's lead, they hypothesized that students who were field dependent would achieve better under instructional techniques having a high degree of structure and guidance. Field independent students, on the other hand, were thought to achieve best under conditions of low structure and guidance. The studies conducted to test these hypotheses largely used worksheets and programmed instruction to carry out the treatments.

An example of one of these studies was that done by Bien (1974). She developed two methods of instruction, one structured and one unstructured, which taught fraction word problems to fourth graders. On a posttest consisting of unstructured problems, field independent students solved significantly more problems than field dependent students, regardless of instructional method received. Field dependent students who received the structured instruction, however, could set up problems on the posttest as well as their field independent counterparts.

McLeod et al. (1978) also conducted research along the same lines. They developed two programmed instruction units which taught addition and subtraction of numbers in bases other than ten. One unit provided maximum guidance to the learner while the other provided very little guidance. The results of their experiment showed a significant interaction between level of guidance and field dependence-independence. Field dependent students who received maximum guidance performed better on a posttest than their field dependent counterparts who received only minimum guidance. In contrast, field independent students performed worse with maximum guidance than they did with minimum. These results supported Witkin's hypothesis (Witkin et al., 1962; Witkin et al., 1977) that field dependent students would need more structure in their learning experiences than field independent students.

A third study investigating the interaction between field dependence-independence and level of guidance in mathematics instruction was done by McLeod and Adams (1979). The topic of instruction was networks. Field independent students were found to perform slightly better than field dependent students under low guidance conditions, but the difference was not significant. Interaction was also tested between level of guidance and achievement on the Necessary Arithmetic Operations test, a measure of general ability. Although this interaction was also found to be nonsignificant, it did provide an important comparison with the first interaction.

Until now, the studies reviewed in this section have involved level of instructional guidance in general but not feedback in particular. However, three studies which did examine the specific interaction between feedback and field dependence-independence have been located. The first of these studies utilized social reinforcement as a type of feedback. Cooperman (1974) tested the ability of fifth graders to unscramble anagrams under conditions of positive, negative, and neutral verbal feedback (approval, disapproval, and silence, respectively). All feedback was predetermined and had no relation to actual performance. On a subsequent posttest, Cooperman found that field dependent subjects performed significantly better under conditions of positive feedback while field independent subjects performed equally well under either positive or negative feedback. These results supported Witkin's hypothesis (Witkin et al., 1962; Witkin et al., 1977) that field dependent individuals are more sensitive to criticism because of their greater reliance on external referents for self-definition. Field independent individuals, on the other hand, are thought to possess "internalized frames of reference to which they adhere as guides to self-definition and which they maintain as distinctly separate from external social referents" (Witkin et al., 1977, p. 19).

In a different study, Threadgill (1979) investigated the interaction between corrective feedback and field dependence-indepenence on achievement in the mathematics topic, traversability of graphs. One of the treatments used in the study provided immediate feedback to the learner and presented the material in a deductive manner. The other treatment gave no feedback and used a guided discovery, inductive mode of presentation which required students to derive rules from examples and sort relevant from irrelevant information. No significant interaction between treatments and field dependence-independence was found.

Statistically significant interaction between feedback and field dependence-independence was found, however, in a study by Renzi (1974). He developed two self-instructional programs, one with feedback and one without, which instructed undergraduates in the technique of drawing an ellipse. Although field independent subjects in general were found to perform significantly better on a posttest than field dependent subjects, field dependent subjects who received feedback performed significantly better than those who did not. Thus, on the basis of these and other findings, Renzi concluded that there was sufficient justification to continue the use of feedback in self-instructional programs.

Renzi's finding that feedback did not help field dependent subjects achieve as well as their field independent counterparts was more difficult to explain. Based on the results of several studies, Witkin had concluded that any correlations between field independence and general intelligence would be low and due primarily to the analytical factor of intelligence (Witkin et al., 1962; Witkin et al., 1971; Witkin et al., 1977). Taking that into consideration, Renzi proposed that the difference in performance between field dependent and field independent subjects might have been greater than expected because of the instructional sequencing strategy used in the treatments. Both treatments used a retrogressive sequencing strategy, which may have caused field dependent subjects to experience more anxiety than normal due to the unfamiliarity of the retrogressive sequence. The retrogressive strategy had been chosen in the first place, however, because it produced greater achievement in earlier research (Alden, 1973). Because of this contradiction, Renzi proposed that subject matter content and psychomotor abilities might have also affected the outcome of the study.

Summary

In this review, we have seen that although feedback in general had an unpredictable effect on mathematics achievement, this may have been due to its interaction with field dependence-independence. This was in contrast to the relative lack of significant interaction between feedback and aptitudes other than field dependence-independence. Only Tait, Hartley, and Anderson (1973) could find significant interaction between feedback and mathematics aptitude; a similar finding by Behr (1970) was suspect because it could not be replicated (Behr and Eastman, 1975).

While several studies did find a significant interaction between level of instructional guidance and field dependence-independence, it should be noted that not all of them dealt with feedback *per se*. Only Cooperman (1974) and Renzi (1974) found significant interaction between field dependence-independence and feedback, and Cooperman's study dealt with reinforcement rather than feedback. However, the results from the few studies that have been done were promising enough to encourage the present study. Many of the interactions which were not significant were in the direction predicted by Witkin, and thus by their consistency lent some support to his theory.

METHOD

Description of Subjects

There were two groups of subjects in the study. The first was a group of 96 adolescents, 55 males and 41 females, who were all 13 and 14 years of age. All of the subjects in this group were members of four sections of an eighth grade general mathematics class taught by the same instructor. Their scores on the mathematics section of the Stanford Achievement Test ranged from the 8th percentile to the 98th percentile. The school attended by these subjects was an urban, small-city Iowa school which had a predominantly middle-class enrollment. The school curriculum was diversified and progressive, and the instructor for the class from which the subjects came was an experienced teacher.

The second group of subjects in the study consisted of 13 adults aged 21 and up. Like the adolescents, this group also included both sexes, but only two subjects were male. The members of this group were university students who were enrolled in a graduate-level educational statistics course and who expressed a need for remedial help in solving algebraic equations. Their scores on the mathematics test of the Stanford Test of Academic Skills ranged from the 60th percentile to the 96th percentile. The university attended by the subjects was located in central Iowa and had a large enrollment of middle-class urban and rural residents from all over the Midwest.

Instructors for both the eighth grade and university classes volunteered to participate in the study, and subjects in both classes were likewise volunteers. Among the adolescents, only one person in all four sections chose not to volunteer for the study, and only one other person chose to drop out of the study once it had begun. Participation in the adult group, however, was not nearly as good. Several adults expressed a wish to be included in the study, but were prevented from participating because of transportation difficulties. As a result, only 14 out of 25 adult students volunteered for the study, and one of those 14 volunteers later became too busy to remain in the study.

Description of Measuring Instruments

A total of seven instruments were used to measure independent and dependent variables in the study. Three of these instruments, the Group Embedded Figures Test, the Stanford Achievement Test, and the Stanford Test of Academic

Skills, were commercially-made standardized tests. The other instruments were two teacher-made tests of equation solving, another teacher-made test of statistics, and an author-made survey measuring attitude toward computer-assisted instruction. These seven tests are described below.

The Group Embedded Figures Test (GEFT) is the group form of the Embedded Figures Test (EFT) described in Chapter 1. The main difference between these two tests is the method of scoring. In the EFT, a subject's score is based on the amount of time required to locate a simple figure in a more complex geometric pattern. The more time required to correctly locate the figure, the greater the degree of field dependence; the less time required, the greater the degree of field independence. In the GEFT, however, a subject's score is the <u>number</u> of figures correctly located in a specified length of time. Thus, the relationship between score and degree of field dependence for the GEFT is just the opposite of that for the EFT. That is, a high score on the EFT indicates a high degree of field dependence, while a high score on the GEFT indicates a high degree of field independence.

The reliability coefficient for the GEFT was computed by finding the correlation between the two sections of the

GEFT. Both sections have the same number of items, identical time limits, and similar degrees of difficulty. After correction by the Spearman-Brown formula, the reliability coefficient was found to be .82 (Witkin et al., 1971). According to the GEFT manual, this reliability estimate compared favorably with that of the EFT.

Validity of the GEFT was assessed by comparing it to other measures of field dependence-independence. These concurrent measures were the EFT, the Rod and Frame Test (RFT, described in Chapter 1), and the Articulation of Body Concept test (ABC). Correlations, for both males and females, were computed between the GEFT and each of these other measures. The coefficients ranged from -.34 for females on the RFT to -.82 for males on the EFT (coefficients are negative because the RFT and EFT are scored in reverse fashion from the GEFT). Based on this information, the GEFT manual (Witkin et al., 1971) concluded that

> the GEFT may prove to be a useful substitute for the EFT when individual testing is impractical. It must still be considered a research instrument, however, until more extensive direct and construct validation data are collected from a wider variety of groups (p. 29).

The Stanford Achievement Test, used to measure mathematics achievement for the adolescent sample, is a widely used instrument which needs little introduction. Buros

(1978) places it "among the best available for ongoing assessment of basic skills and academic achievement through the elementary, middle, and junior high school" (p. 105). For the Advanced Battery used in the present study, split-half and K-R 20 reliability coefficients are all .90 or above (Buros, 1978). According to reviewers, validity is also thought to be excellent. Defining the test's validity in terms of content validity, the manual states that the specific objective to be tested by each item was identified before the item was written.

The Stanford Test of Academic Skills (TASK), used to measure mathematics achievement for the adult sample, is newer and less well known than the Stanford Achievement Test but reflects the same high standards. The TASK includes two levels: grades 8-10 (Level 1), and grades 11-12 and junior/community college (Level 2). Only the mathematics test for Level 2 was administered in the present study; the reading and English tests were not given. As with the Stanford Achievement Test, split-half and K-R 20 reliability coefficients for the TASK are consistently above .90. Those for the Level 2 mathematics test are each .94 (Gardner et al., 1974). Similarly, validity is highly rated. Buros (1978) notes that the mathematics test "is a broad survey of standard mathematics skills and appears to be a good sample of core content typically covered by the end of junior high school" (p. 109).

The three other cognitive tests used in the study were all teacher-made and subjectively-scored classroom tests. The subjective scoring was necessary because the three tests measured problem solving performance. One of these tests, the posttest, was administered to both the adolescent and adult samples after they had completed the instructional treatment. The posttest was made up of equations which were of the same form and difficulty as those in the treatment. During the posttest, subjects were not only required to show their work in solving each equation, but had to also state the operation performed at each step in the solution. For example, if they subtracted three from both sides of the equation, they wrote "S3" beside that step in the equation. This two-part answer made it possible for the researcher to separate subjects' knowledge of how equations should be solved ("Operations") from their ability to actually solve them ("Computations"). The posttest is shown in Appendix A, and the procedure for evaluating the posttest is shown in Appendix B.

Two other tests were constructed to test subjects' ability to utilize their equation-solving skills in a transfer task. For the adult subjects, who were enrolled in a graduate statistics course, the transfer task involved solving statistical problems on a regular classroom test written by their instructor. For the adolescent subjects, the transfer task involved solving systems of simultaneous linear equations (two equations in two unknowns). The transfer test for the adolescents was based on equations appearing in the textbook from which the transfer task was taught. As with the posttest, the adolescent transfer test required subjects to (1) solve each system of equations and (2) state the algebraic operations performed at each step in the solution. Consequently, the adolescent transfer test, like the posttest, also provided both a "Computations" score and an "Operations" score. The procedure for evaluating the transfer test is shown in Appendix C.

After the above scoring had been completed, the results of the adolescent transfer test were further split into two additional scores. The first score indicated subjects' ability to perform operations concerned strictly with simultaneous equations, i.e., performing additions, subtractions, and substitutions to eliminate one of the equation variables. This first score was called the Simultaneous Equations Score. The second score indicated subjects' ability to finish solving simultaneous equations once one variable had been eliminated. Thus, the second score indicated ability in a previously learned area, simple equation solving, but it also indicated how well subjects could transfer their knowledge of equation solving to a new situation. The second score was therefore referred to as the Equation Solving Transfer Score.

One final instrument used in the present study was a survey measuring attitude toward (1) equation solving, (2) feedback, and (3) computer-assisted instruction. This survey, shown in Appendix D, was given to both the adolescent and adult subjects. The survey was developed by the author and used a five point Likert-type scale. On this scale, subjects could indicate how strongly they agreed or disagreed with the statements in the survey. Space was also provided for subjects to express additional opinions about computer instruction.

Research Design

The experimental design for the study was a posttest-only control-group design which investigated aptitude-treatment interaction (ATI). There were two aptitudes included in the study. One was field dependence-independence, as measured by the GEFT, and the other was mathematics achievement.

There were also two treatments administered to each sample in the study. Both treatments were presented through the medium of a microcomputer, the Commodore "PET." The PET is a small, portable computer that has a built-in cathode ray tube (television screen) and typewriter keyboard. Users view text and questions on the screen and then respond by typing letters and numbers on the keyboard. A built-in cassette tape recorder also enables users to load many different lessons into the computer.

The two treatments presented on the PET differed in the amount of feedback provided to the learner. Both treatments generated simple linear equation problems and both performed equation operations requested by the subject, but only one treatment provided feedback on whether the requested operations were the correct way to solve the equation. Thus, the treatment that performed the operations without giving feedback required subjects to determine for themselves whether their solution strategy was correct. In contrast, the treatment that performed operations <u>and</u> provided feedback allowed no incorrect attempts at solution and corrected all mistakes made by the subjects.

Implicit Feedback Treatment

The treatment requiring subjects to correct their own solution strategies will hereafter be referred to as the "implicit" feedback treatment. The term "implicit" was chosen because, although subjects were given no direct indication as to the correctness of their solution strategy, the fact that they could see the results of their operations gave them an indirect indication of whether their strategy was bringing them closer to a solution. While the implicit feedback treatment gave no corrective feedback, it did give error messages for some illegal and undefined operations. These included: (1) unrecognizable symbols, (2) multiplication and division by zero, and (3) attempts to raise the equation above the fourth degree (x^4). Furthermore, the implicit feedback treatment reduced all fractions to their lowest terms and checked equation solutions upon request. All of the above features were likewise provided by the second treatment, which will be discussed shortly.

A hypothetical example of the implicit feedback treatment is shown in Figure 1. Responses by the subject are underlined, and symbols used for these responses are explained in Table 1. In Figure 1, the subject looked at the initial equation, Equation 1, and requested the computer to subtract two from both sides, which resulted in Equation

2. Recognizing that this action was not successful in reducing the number of terms in the equation, the subject then realized that the correct action was to add four to each side. This action resulted in Equation 3, and subtracting "x" from both sides yielded Equation 4. The subject asked the computer to check whether Equation 4 was a correct solution; the response was negative ("not solved yet") and Equation 4 was reprinted. Undaunted, the subject next requested the computer to multiply through by x^2, yielding Equation 5, but then wisely reversed this action to regain Equation 6. Finally seeing the correct solution strategy, the subject divided through by two and asked for another solution check. This time the answer was affirmative and the subject was told to type "go" to see a new equation.

(1)[1] $3x - 2 = x + \frac{1}{4}$

S 2

(2) $3x - 4 = x - \frac{7}{4}$

A 4

(3) $3x = x + \frac{9}{4}$

S X

(4) $2x = \frac{9}{4}$

!

NOT SOLVED YET

$2x = \frac{9}{4}$

M X↑2

(5) $2x^{3} = \frac{9}{4}x^{2}$

D X↑2

(6) $2x = \frac{9}{4}$

D 2

(7) $x = \frac{9}{8}$

!

SOLUTION CORRECT. TYPE "GO"

---

[1]Numbers in parentheses are not seen in the actual treatment.

Figure 1: Example of implicit feedback treatment

TABLE 1

Symbols used to request equation operations

Symbol	Meaning
A	Add
S	Subtract
M	Multiply
D	Divide
↑	Exponent
!	Check solution

Explicit Feedback Treatment

Figure 2 shows a hypothetical example of the second feedback treatment, hereafter known as "explicit" feedback. Not only did the explicit feedback treatment provide more feedback than the implicit treatment, it also imposed more limitations on the types of operations it would perform. Technically, almost any operation (except multiplication and division by zero) may be performed on an equation as long as it is performed on both sides, and the implicit feedback treatment was constructed according to this principle. However, not every operation on an equation brings it closer to solution, and the explicit treatment restricted equation operations to only those that simplified the equation. It also would not perform requested operations that did not conform to suggested solution strategies found in standard algebra textbooks. Restrictions imposed by the explicit treatment are listed in Table 2.

The sequence of interaction between the subject and the computer in Figure 2 can be described as follows. As before, all subject responses are underlined. First, the subject tried to subtract two from both sides, but this operation was not allowed since it did not reduce the number of terms in the equation. Instead, the computer suggested that the subject subtract "1x," which resulted in Equation 2. Next, the subject tried to multiply by four, but this also was not allowed since the equation had not yet been reduced to two terms. The computer suggested that the subject "add or subtract," which the subject did. However, subtracting two did not reduce the number of terms, so a message was given to "subtract -2." After this was done, Equation 3 could be multiplied by four to eliminate the denominator in the fraction, but not multiplied by one since that would be a useless operation. Finally, the subject divided by eight and obtained Equation 5, which was judged to be a correct solution.

(1)[1] $3x - 2 = x + \frac{1}{4}$

S 2

SUBTRACT 1X

S 1X

CORRECT

(2) $2x - 2 = \frac{1}{4}$

M 4

ADD OR SUBTRACT

S 2

SUBTRACT -2

S -2

CORRECT

(3) $2x = \frac{9}{4}$

M 4

CORRECT

(4) $8x = 9$

M 1

ILLEGAL OR USELESS OPERATION

D 8

CORRECT

(5) $x = \frac{9}{8}$

!

SOLUTION CORRECT. TYPE "GO"

---

[1]Numbers in parentheses are not seen in the actual treatment.

Figure 2: Example of explicit feedback treatment

TABLE 2

Restrictions imposed by the explicit feedback treatment

Restriction	Purpose
Equations with three and four terms (e.g., 5x = 2x + 9; x - 7 = 3x + 4) had to first be reduced to two terms (e.g., 6x = 2). Zero by itself on either side of an equation was counted as one term.	To conform to the standard practice of first adding and subtracting to reduce the number of terms before multiplying and dividing to eliminate fractions and x-coefficients.
Would not perform operations that increased the number of terms in an equation.	To prevent actions which would complicate the equation.
Did not allow multiplication or division by +1.	To prevent useless actions.
Two-term equations could only be multiplied by -1 if the x-coefficient was negative.	To prevent actions which would make the equation more confusing.
Did not allow operations which raised the degree of the equation.	To prevent actions which would complicate the equation.
Did not allow multiplication or division by zero (the same restriction was applied to the implicit treatment).	To prevent an illegal operation.

Types of Equations

In order to allow subjects to progress from simpler to more complex equations during the treatments, six levels of equation types were designed. The content and sequence of these levels were based on those found in standard algebra textbooks. Both treatments had identical types of equations at each level. However, within each level the equations were randomly generated so that a specific equation was unlikely to appear more than once. There was a 60% probability that the denominator of each term would be +1, and there was a 20% probability that two- and three-term equations would be reversed (e.g., $4 = x - 1$ rather than $x - 1 = 4$). The six levels of equations are described in Table 3.

TABLE 3

Levels of equations

Level	Equation Form	Replacements for a, b, c, d
1	$x \pm b = d$ $(d = x \pm b)$	"b" can be any number (whole or fraction) except zero. "d" can be any number greater than zero. "d - b" must be greater than or equal to zero (to prevent negative solutions).
2	$ax = d$ $(d = ax)$	"a" and "d" can be any numbers greater than zero.
3	$ax \pm b = d$ $(d = ax \pm b)$	"a" and "d" can be any numbers greater than zero. "b" can be any number except zero. "d - b" must be greater than or equal to zero.
4	$\pm ax \pm b = \pm d$ $(\pm d = \pm ax \pm b)$	"a", "b" and "d" can be any numbers except zero.
5	$\pm ax = \pm cx \pm d$ $(\pm cx \pm d = \pm ax)$	"a", "c" and "d" can be any numbers except zero.
6	$\pm ax \pm b = \pm cx \pm d$	"a", "b", "c" and "d" can be any numbers except zero.

Research Procedure

The study was carried out in the following manner. First, all subjects took the Group Embedded Figures Test. To avoid observer contamination and insure subject privacy, all names on this and every other test were removed and replaced with coded numbers known only to the researcher and the classroom instructors. Next, the mathematics test of the Stanford Test of Academic Skills was administered to the adults, and Stanford Achievement Test scores were obtained from the cumulative record folders of the adolescents. Then the adult subjects received 90 minutes of conventional instruction on solving simple linear equations. This instruction for the adult subjects was presented by the researcher; the eighth grade subjects had already received instruction from their teacher prior to the beginning of the study.

The researcher now assigned subjects in each sample to a treatment group, using stratified sampling based on results of the GEFT. The treatment groups were formed in the following manner. First, GEFT scores were recorded for all subjects. Second, nineteen subgroups were formed on the basis of these scores, each subgroup being comprised of subjects who made the same score. Finally, subjects within each subgroup were assigned at random to one of the two treatment groups.

Once the treatment groups had been established, the researcher trained each subject to use the computer. The next step was to administer the treatments. During the treatment period each adolescent subject used the computer an average of one day in three for a total of six computer sessions over four weeks. Each session was fifteen minutes long, covered one level of equations, and took place during class. Adult subjects, on the other hand, used the computer once a week outside of class for thirty minutes at a time (completing two levels instead of one), a total of three computer sessions over three weeks. All subjects started at Level 1 of their treatment and progressed through Level 6; each level was seen only once for no more than fifteen minutes. The researcher monitored each subject's work with the computer, but only to answer questions about the computer and to assist in choosing the correct program and level. No help on solving equations was given, except to refer subjects to pages in the textbook where this help could be found.

After the treatments had been completed, the posttest and attitude survey were administered. Following this, adolescent subjects received regular classroom instruction on solving systems of two linear equations, and the adult subjects received instruction on performing statistical calculations. No computer sessions were included in this post-treatment instruction, which was provided by each group's regular instructor. Transfer tests were then administered to all subjects.

RESULTS AND DISCUSSION

Multiple regression techniques were used to analyze the data in the present study. The full regression model contained three main factors: (1) program (implicit or explicit treatment), (2) GEFT score, and (3) mathematics achievement. In addition, two interactions were included in the model. These interactions were: (1) program by GEFT, and (2) program by math achievement. As in all aptitude-treatment interaction research, the interactions were the central focus of the study.

Descriptive Data

Tables 4 and 5 present the descriptive data for all cognitive tests administered in the study. Included are the means and standard deviations for adolescents and adults in both treatment groups. Within each sample, t-test results showed no significant difference between the treatment groups on any of the tests. Looking across samples, however, the adults had higher mean scores on the GEFT than the adolescents, a phenomenon which is consistent with the findings of Witkin, Goodenough, and Karp (1967). The adult sample also had very high mean scores on the posttest, restricting its usefulness as a dependent measure.

TABLE 4

Means and standard deviations of all cognitive tests (adolescent sample)

Test	Max. Score	Implicit Fdbk. Mean	Implicit Fdbk. SD	Implicit Fdbk. N	Explicit Fdbk. Mean	Explicit Fdbk. SD	Explicit Fdbk. N
GEFT	18	10.35	4.55	48	9.96	4.59	48
Stanford Ach.-Math	120	80.15	17.77	46	77.60	18.82	43
Posttest							
Operations[1]	1.0	.72	.22	48	.72	.24	48
Computations[1]	1.0	.52	.27	48	.50	.30	48
Transfer-Simul. Eq.							
Operations[1]	1.0	.79	.25	46	.77	.27	44
Computations[1]	1.0	.71	.26	46	.67	.27	44
Transfer-Eq. Solv.							
Operations[1]	1.0	.73	.27	46	.70	.28	44
Computations[1]	1.0	.66	.28	46	.65	.27	44

[1]Raw scores transformed to proportions.

TABLE 5

Means and standard deviations of all cognitive tests (adult sample)

		Treatment Groups					
		Implicit Fdbk.			Explicit Fdbk.		
Test	Max. Score	Mean	SD	N	Mean	SD	N
GEFT	18	13.14	2.61	7	13.33	3.78	6
Task-Math	48	38.29	3.25	7	40.17	4.36	6
Posttest							
Operations[1]	1.0	.96	.05	7	.98	.02	6
Computations[1]	1.0	.85	.16	7	.91	.08	6
Transfer-Stat.	100	87.71	6.21	7	88.83	7.22	6

[1]Raw scores transformed to proportions.

The results of the attitude survey are shown in Tables 6 and 7. Again, t-test results for the adult sample showed no significant difference between the treatment groups on any of the survey items. However, a significant difference was found between treatment groups on two of the survey items for the adolescent group. On Statement 3 ("I think the computer should have given me more 'hints' when I didn't know how to solve an equation"), the explicit feedback group was significantly more negative about the item statement than the implicit group ($p < .01$). That is, the explicit group was reasonably satisfied with the feedback it had received, while the implicit group was somewhat undecided. Further support for this trend was provided by the response to Statement 6 ("I think the computer gave me too much help in solving the equations"), where it was the implicit group's turn to be significantly more negative in its response ($p < .01$).

Additional information about attitudes is revealed by a cross-sample comparison of the survey data. In Statement 3, for example, the adolescent response to the statement was affected by the treatment received, but the adult response was not; adults were relatively consistent in their opposition to more "hints" from the computer programs. On other items, however, adults and adolescents were in greater agreement. Both samples disagreed with the statement that "equations on the computer were too hard" (item number four). Likewise, both responded negatively to the statements that "using the computer was a waste of time" (item number nine) and that "working with the computer was frustrating" (item number twelve). This last result was especially gratifying. Adults are usually more intimidated by computers than are children, but this did not seem to be the case in the present study.

TABLE 6

Means and standard deviations of the attitude survey (adolescent sample)

		Treatment Groups					
		Implicit Feedback			Explicit Feedback		
Item[1]	Max. Score	Mean	SD	N	Mean	SD	N
Statement 1	5	3.35	1.14	48	3.54	1.07	48
Statement 2	5	3.46	1.09	48	3.77	1.02	48
Statement 3[2]	5	2.83	1.29	48	2.19	1.05	48
Statement 4	5	1.96	0.97	48	1.85	0.99	48
Statement 5	5	4.21	0.90	48	4.27	0.94	48
Statement 6[2]	5	1.98	0.81	48	2.56	1.24	48
Statement 7	5	3.98	1.00	48	4.23	0.72	48
Statement 8	5	3.73	1.16	48	3.83	1.23	48
Statement 9	5	1.71	0.85	48	1.69	0.85	48
Statement 10	5	2.27	1.11	48	2.17	0.95	48
Statement 11	5	3.35	1.08	48	3.38	1.08	48
Statement 12	5	2.02	0.98	48	1.96	0.92	48
Statement 13	5	1.96	0.94	48	1.94	1.04	48

[1]See Appendix D.
[2]Significant difference ($p < .01$) between treatment means.

TABLE 7

Means and standard deviations of the attitude survey (adult sample)

		Treatment Groups					
		Implicit Feedback			Explicit Feedback		
Item[1]	Max. Score	Mean	SD	N	Mean	SD	N
Statement 1	5	3.29	1.25	7	3.50	1.05	6
Statement 2	5	3.29	1.25	7	3.67	1.03	6
Statement 3	5	2.29	0.76	7	1.83	0.41	6
Statement 4	5	1.43	0.54	7	1.50	0.55	6
Statement 5	5	3.57	1.40	7	3.50	0.84	6
Statement 6	5	2.14	0.38	7	2.83	0.98	6
Statement 7	5	3.86	1.35	7	3.67	0.52	6
Statement 8	5	3.14	1.07	7	3.00	0.89	6
Statement 9	5	2.00	1.41	7	1.83	0.41	6
Statement 10	5	2.43	1.51	7	1.83	0.41	6
Statement 11	5	3.29	1.38	7	3.00	1.27	6
Statement 12	5	1.43	0.79	7	1.67	0.52	6
Statement 13	5	2.71	1.38	7	2.33	0.82	6

[1]See Appendix D.

Correlation coefficients between all cognitive measures administered in the study are shown in Tables 8 and 9.

TABLE 8

Correlation matrix for cognitive tests (adolescent sample)

Test	Correlation							
	1	2	3a	3b	4a	4b	5a	5b
1.GEFT	1.00	.46	.41	.36	.26	.28	.27	.30
2.Stanford-Math		1.00	.73	.75	.57	.63	.60	.61
3.Posttest a.Operations			1.00	.90	.69	.74	.76	.78
b.Computations				1.00	.69	.74	.77	.79
4.Transfer-Simul. Eq. a.Operations					1.00	.96	.90	.87
b.Computations						1.00	.93	.90
5.Transfer-Eq. Solv. a.Operations							1.00	.97
b.Computations								1.00

TABLE 9

Correlation matrix for cognitive tests (adult sample)

	Correlation				
Test	1	2	3a	3b	4
1.GEFT	1.00	.40	-.18	-.03	.42
2.TASK-Math		1.00	.37	.49	.48
3.Posttest a.Operations			1.00	.95	.28
b.Computations				1.00	.49
4.Transfer-Stat.					1.00

Interaction Data

In the following paragraphs, results are presented as they relate to each hypothesis in the study. Data are reported for both the adolescent and the adult samples.

> Hypothesis 1. There is no significant difference between type of feedback and degree of field dependence-independence in relation to an individual's ability to solve simple linear equations.

As shown in Tables 10 and 11, the results of the multiple regression significance tests do not allow us to reject this hypothesis. None of the posttest interactions between type of feedback and field dependence-independence (GEFT) reached significance in either sample. Not surprisingly, however, the effect of mathematics achievement was highly significant ($p < .0001$) for both the Operations and Computations portions of the posttest in the adolescent sample, and approached significance for the adult sample.

> Hypothesis 2. There is no significant interaction between type of feedback and degree of field dependence-independence in relation to an individual's ability to utilize their equation-solving skills in a transfer task.

Unlike the previous hypothesis, this hypothesis was rejected for both samples. In the adolescent sample (see Table 10), a significant interaction ($p < .05$) occurred between feedback and field dependence-independence (GEFT) in both the Operations and Computations portions of the Equation Solving score of the transfer test. A similar significant interaction ($p < .05$) also occurred in the transfer test for the adult sample (see Table 11). Furthermore, the effect of mathematics achievement was again highly significant ($p < .0001$) for all parts of the transfer test in the adolescent sample.

Tables 12 and 13 show the regression coefficients and y-intercepts for the regression of each cognitive dependent measure on the aptitudes of field dependence-independence (GEFT) and mathematics achievement. The graph for one of the significant interactions in the adolescent group, that

TABLE 10

Significance tests for all cognitive measures (adolescent sample)[1]

Dependent Variable	R^2 for Full Model	Source	F
Posttest			
Operations	.56	Feedback	2.33
		GEFT	1.07
		Math Ach.	67.87**
		Fdbk. by GEFT	0.45
		Fdbk. by Math Ach.	0.19
Computations	.57	Feedback	0.83
		GEFT	0.05
		Math Ach.	79.96**
		Fdbk. by GEFT	0.81
		Fdbk. by Math Ach.	0.00
Transfer-Simul. Eq.			
Operations	.33	Feedback	0.19
		GEFT	0.00
		Math Ach.	30.63**
		Fdbk. by GEFT	1.28
		Fdbk. by Math Ach.	0.50
Computations	.41	Feedback	0.24
		GEFT	0.04
		Math Ach.	43.24**
		Fdbk. by GEFT	1.53
		Fdbk. by Math Ach.	0.98
Transfer-Eq. Solv.			
Operations	.40	Feedback	0.26
		GEFT	0.00
		Math Ach.	39.24**
		Fdbk. by GEFT	5.14*
		Fdbk. by Math Ach.	1.64
Computations	.42	Feedback	0.01
		GEFT	0.05
		Math Ach.	40.96**
		Fdbk. by GEFT	5.76*
		Fdbk. by Math Ach.	2.57

[1]Due to missing data, N=85 for these calculations.
* $p < .05$
** $p < .0001$

TABLE 11

Significance tests for all cognitive measures (adult sample)

Dependent Variable	R^2 for Full Model	Source	F
Posttest			
Operations	.54	Feedback	0.24
		GEFT	0.56
		Math Ach.	3.00
		Fdbk. by GEFT	0.01
		Fdbk. by Math Ach.	3.56
Computations	.62	Feedback	0.13
		GEFT	0.18
		Math Ach.	4.61
		Fdbk. by GEFT	0.41
		Fdbk. by Math Ach.	5.72*
Transfer-Stat.	.79	Feedback	0.01
		GEFT	4.10
		Math Ach.	2.17
		Fdbk. by GEFT	6.57*
		Fdbk. by Math Ach.	14.51**

* $p < .05$
** $p < .01$

between feedback and GEFT on the Operations portion of the Equation Solving Transfer score, is shown in Figure 3. Figure 4 shows the similar interaction between feedback and GEFT in the adult group. In each case, the explicit feedback group has the steeper slope and the interactions are disordinal. Even for most of the nonsignificant interactions, the trend of steeper slopes for the explicit group is the same. That is, the GEFT regression coefficient for the explicit group in both samples is greater than that for the implicit group on all measures except the Posttest Operations score.

TABLE 12

Regression of cognitive dependent measures on aptitude tests (adolescent sample)

Dependent Variable	Treatment Group	GEFT Intercept	GEFT Regr. Coeff.	Math Ach. Intercept	Math Ach. Regr. Coeff.
Posttest					
Operations	Implicit	.52	.02	.00	.01
	Explicit	.53	.02	.09	.01
Computations	Implicit	.31	.02	-.35	.01
	Explicit	.26	.03	-.40	.01
Transfer-Simul. Eq.					
Operations	Implicit	.66	.01	.12	.01
	Explicit	.55	.02	.14	.01
Computations	Implicit	.56	.01	-.06	.01
	Explicit	.45	.02	.00	.01
Transfer-Eq. Solv.					
Operations	Implicit	.63	.01	-.02	.01
	Explicit	.41	.03	.01	.01
Computations	Implicit	.55	.01	-.12	.01
	Explicit	.36	.03	.00	.01

TABLE 13

Regression of cognitive dependent measures on aptitude tests (adult sample)

Dependent Variable	Treatment Group	GEFT Inter-cept	GEFT Regr. Coeff.	Math Ach. Inter-cept	Math Ach. Regr. Coeff.
Posttest Operations	Implicit	.98	.00	.52	.01
	Explicit	1.02	.00	1.06	.00
Computations	Implicit	.93	-.01	-.68	.04
	Explicit	.90	.00	.95	.00
Transfer-Stat.	Implicit	87.30	.03	17.95	1.82
	Explicit	70.64	1.36	81.99	.17

> Hypothesis 3. There is no significant interaction between type of feedback and mathematics achievement in relation to an individual's ability to solve simple linear equations.

This hypothesis and the next examine the interaction between feedback and the second aptitude variable, mathematics achievement. Referring to Tables 10 and 11, the data show that Hypothesis 3 was only rejected for one dependent measure, Posttest Computations, of the adult sample. For this dependent measure, a significant interaction ($p < .05$) occurred between feedback and mathematics achievement in the adult group. For all other dependent measures, however, the interactions were not significant. Thus, Hypothesis 3 was

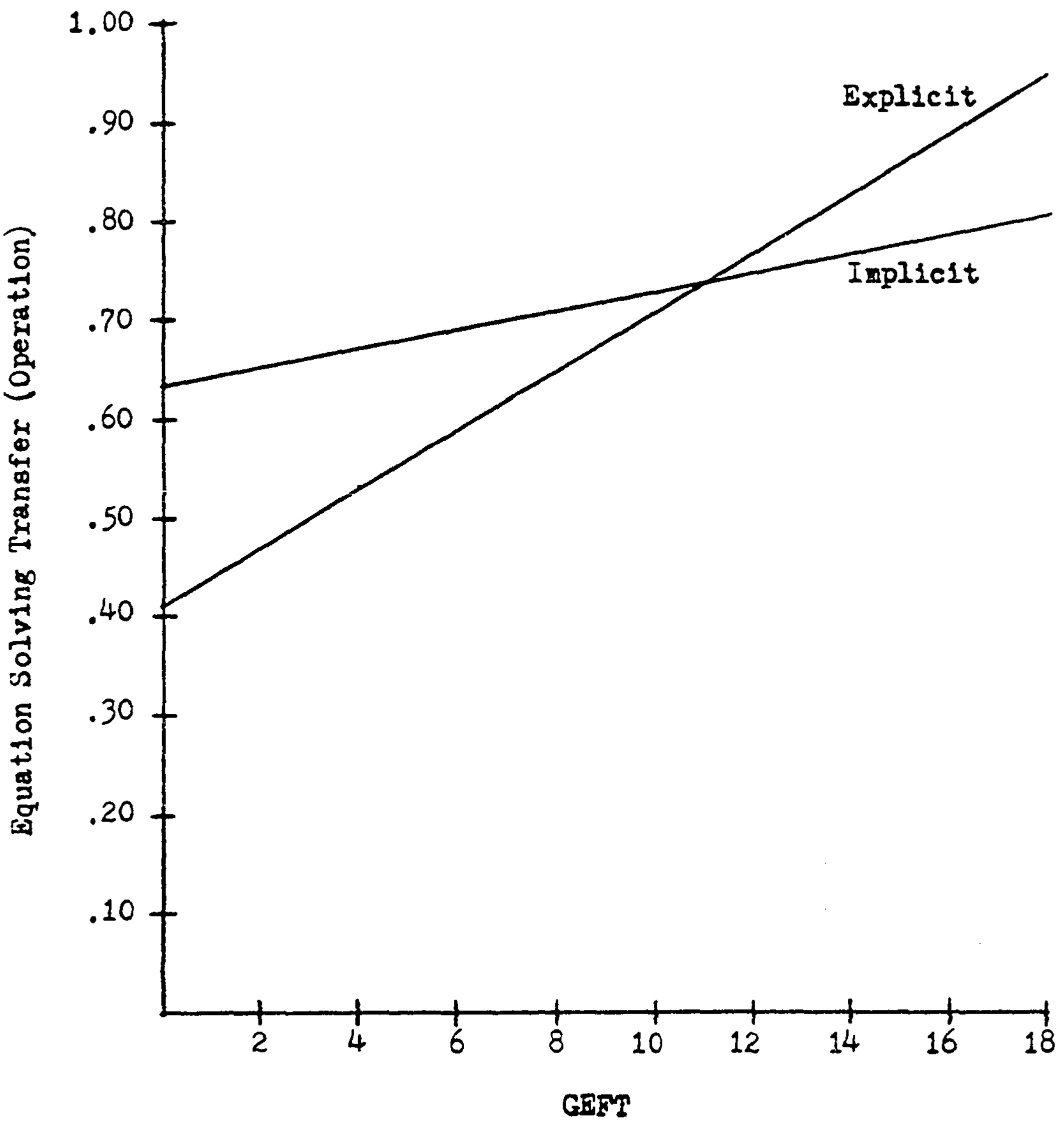

Figure 3: Regression of Equation Solving Transfer score, Operations portion, on GEFT (adolescent sample)

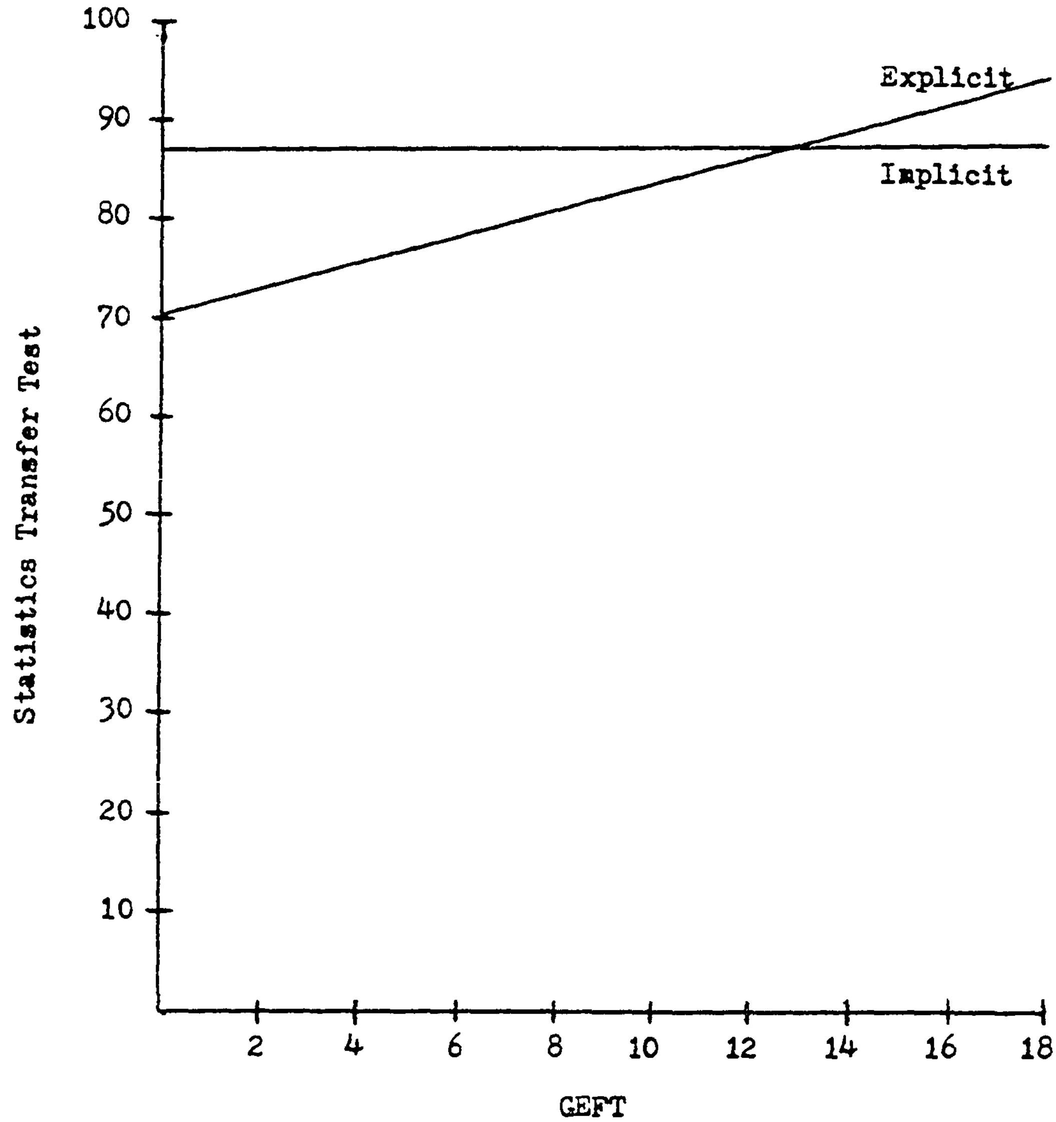

Figure 4: Regression of statistics transfer test on GEFT (adult sample)

not rejected for any dependent measure of the adolescent sample nor for the Posttest Operations measure of the adult sample.

A graph of the significant interaction between feedback and mathematics achievement is shown in Figure 5. As shown by the graph and by the regression coefficients in Table 13, the direction of this interaction is the opposite of that shown in Figure 3. That is, instead of the explicit feedback group having the steeper slope, it is now the implicit group which has the steeper slope. Further analysis of the two interactions in Figures 3 and 5 is given in the Discussion section.

> Hypothesis 4. There is no significant interaction between type of feedback and mathematics achievement in relation to an individual's ability to utilize their equation-solving skills in a transfer task.

Hypothesis 4, like Hypothesis 3, also examined the interaction between feedback and mathematics achievement, but for the transfer test rather than the posttest. As with the previous hypothesis, this one was also only rejected for the adult sample. Among the adults (see Table 11), a highly significant interaction ($p < .01$) occurred between feedback and mathematics achievement on the transfer measure. In the adolescent sample, however, no significant interactions

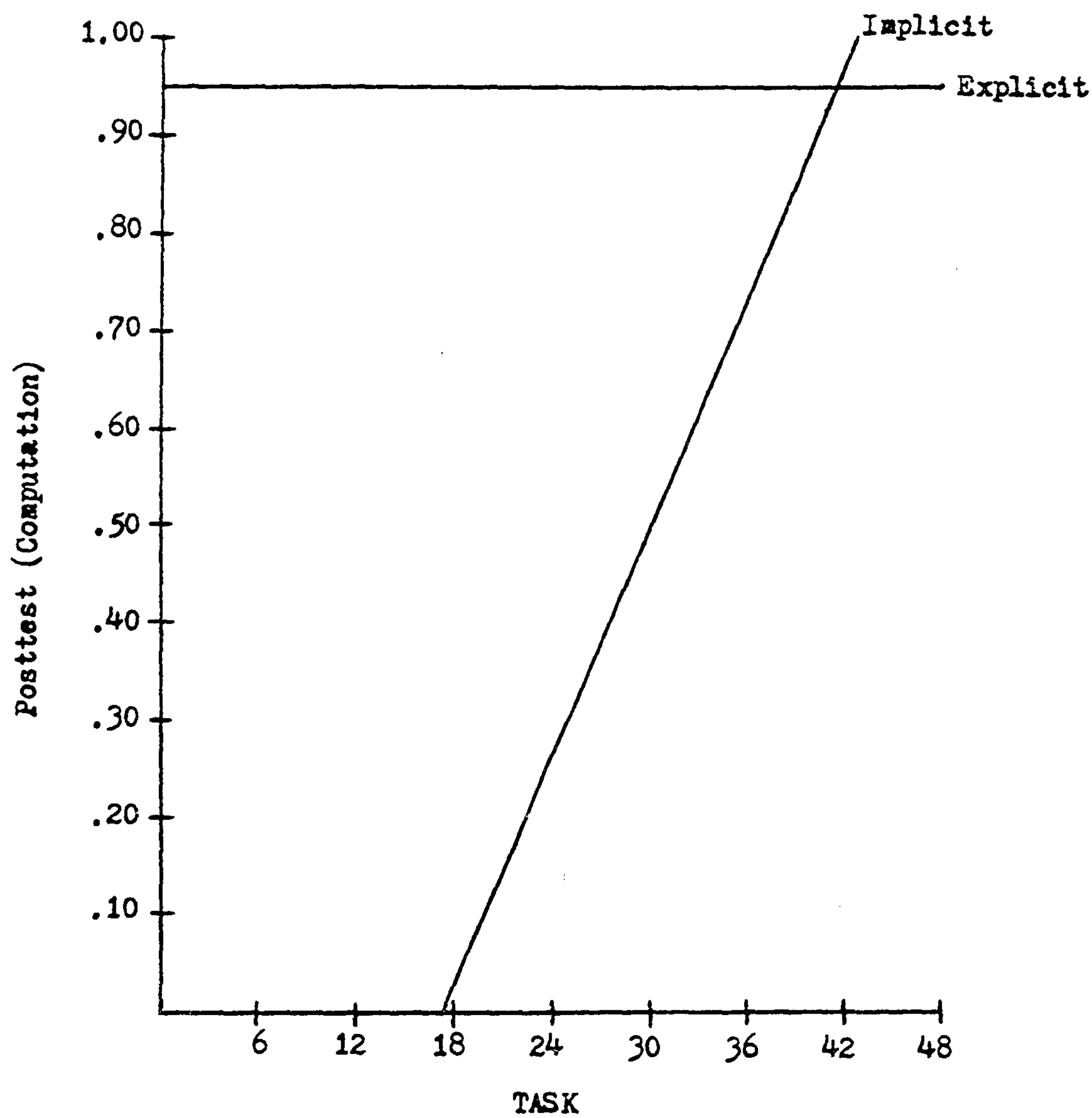

Figure 5: Regression of Posttest Computations score on math achievement (adult sample)

between feedback and mathematics achievement occurred on any of the transfer measures. The significant interaction found in the adult sample was similar in appearance to the one in Figure 5. Data in Table 13 show that for both the present interaction and the one in Figure 5, the implicit feedback group had a higher regression coefficient than the explicit group.

> Hypothesis 5. There is no significant interaction between type of feedback and degree of field dependence-independence in relation to an individual's attitude toward computer-assisted instruction.

Based on the results of the attitude survey significance tests shown in Tables 14 and 15, this hypothesis was not rejected for either the adolescent or the adult sample. None of the attitude survey interactions between type of feedback and field dependence-independence (GEFT) reached significance in either sample. However, for the adolescent sample, mathematics achievement was found to be a significant ($p < .05$) main effect for two of the survey items: Statement 4 ("I thought the equations on the computer were too hard") and Statement 12 ("Working with the computer was frustrating"). This result was not too surprising since the content of both of these statements was related to both computer-assisted instruction and mathematics.

TABLE 14

Significance tests for attitude survey (adolescent sample)[1]

		Source of Variance				
		Fdbk.	GEFT	Math Ach.	Fdbk.x GEFT	Fdbk.x Math
Item	R^2 for Full Model	F	F	F	F	F
Stmt. 1	.06	0.00	2.31	1.81	1.90	0.70
Stmt. 2	.03	0.25	0.77	1.37	0.67	1.15
Stmt. 3	.21	2.44	0.04	2.59	0.01	0.46
Stmt. 4	.28	1.83	0.71	7.56**	1.58	2.70
Stmt. 5	.00	0.04	0.03	0.04	0.00	0.04
Stmt. 6	.08	0.28	0.20	0.79	0.22	0.15
Stmt. 7	.05	2.14	0.02	1.34	0.15	1.84
Stmt. 8	.10	0.06	2.81	2.49	1.18	0.77
Stmt. 9	.02	0.00	0.00	0.02	0.08	0.03
Stmt. 10	.22	0.06	1.09	1.74	2.53	0.17
Stmt. 11	.05	0.06	0.24	0.74	0.03	0.09
Stmt. 12	.18	1.06	1.09	5.37*	2.16	2.64
Stmt. 13	.03	1.35	0.33	2.10	0.11	1.58

[1]Due to missing data, N=85 for these calculations.
* $p < .05$
** $p < .01$

TABLE 15

Significance tests for attitude survey (adult sample)

		Source of Variance				
		Fdbk.	GEFT	Math Ach.	Fdbk.x GEFT	Fdbk.x Math
Item	R^2 for Full Model	F	F	F	F	F
Stmt. 1	.28	0.01	0.68	1.85	1.00	0.04
Stmt. 2	.35	0.14	0.00	0.45	2.32	0.17
Stmt. 3	.34	0.71	0.07	1.16	0.14	0.40
Stmt. 4	.59	0.08	0.62	3.12	4.46	2.62
Stmt. 5	.26	0.07	0.20	0.46	0.27	0.92
Stmt. 6	.77	3.52	0.00	3.21	0.02	8.95*
Stmt. 7	.26	0.48	0.01	2.00	0.52	0.07
Stmt. 8	.48	0.82	0.82	5.30	1.80	0.02
Stmt. 9	.22	0.00	0.25	0.96	0.22	0.28
Stmt. 10	.59	0.30	0.78	4.00	1.79	2.85
Stmt. 11	.65	0.07	0.00	0.31	4.12	11.01*
Stmt. 12	.34	0.92	0.00	1.83	0.25	0.83
Stmt. 13	.37	0.07	0.31	0.83	2.31	0.85

* $p < .02$

Hypothesis 6. There is no significant interaction between type of feedback and mathematics achievement in relation to an individual's attitude toward computer-assisted instruction.

For the adolescent sample, this hypothesis was also not rejected for any of the statements in the attitude survey (see Table 14). For the adult sample, however, interactions between feedback and mathematics achievement for two of the statements were significant ($p < .02$), allowing us to reject the hypothesis in these two cases. The two statements which had significant interactions were Statement 6 ("I think the computer gave me too much help in solving the equations") and Statement 11 ("When the computer told me I had done something wrong, I had no trouble understanding what my mistake was").

Table 16 shows the regression coefficients for these two statements. In Statement 6, the explicit feedback group had the positive slope, indicating that the students with better math skills understandably felt that the explicit program gave them more help than they wanted. In Statement 11, on the other hand, the implicit group had the positive slope, while the explicit group had an equal slope in a negative direction. Thus, the more able students must have felt they understood their mistakes better when they were in the implicit rather than the explicit group. With a sample

TABLE 16

Regression of attitude survey on math achievement (adult sample)

	Treatment Groups			
	Implicit		Explicit	
Item	Intercept	Regr. Coeff.	Intercept	Regr. Coeff.
Stmt. 1	-1.80	.13	1.59	.05
Stmt. 2	-1.80	.13	6.49	-.07
Stmt. 3	6.25	-.10	3.88	-.05
Stmt. 4	.74	.02	-2.52	.10
Stmt. 5	-3.59	.19	7.52	-.10
Stmt. 6	4.13	-.05	-5.28	.20
Stmt. 7	-2.95	.18	.98	.07
Stmt. 8	-4.53	.20	.46	.06
Stmt. 9	8.64	-.17	3.88	-.05
Stmt. 10	13.81	-.30	3.88	-.05
Stmt. 11	-5.42	.23	12.32	-.23
Stmt. 12	6.77	-.14	3.64	-.05
Stmt. 13	3.58	-.02	7.56	-.13

size of thirteen it is difficult to speculate why this was so, but it is possible that the better math students were frustrated by the tighter restrictions of the explicit program. These restrictions required that operations not only be correct but also in a specified order, and the better students may have become disturbed when their correct operations were sometimes rejected.

Discussion

According to Witkin's theory of cognitive style, field dependent learners should achieve best under a high-structure instructional program while field independent learners should excel under a low-structure one. If "high structure" and "low structure" can be defined in terms of amount of feedback, then the results of this study tend to refute Witkin's theory. Instead of field dependent subjects achieving best under the high-structure explicit feedback program, they actually had higher test scores after using the low-structure implicit program. Conversely, field independent subjects performed better under the explicit rather than the implicit program. This interaction was statistically significant only for the transfer test (see Hypothesis 2), but the direction of the interaction was the same for most of the other tests as well. Furthermore, the trend was identical in both the adolescent and the adult samples.

The observed results might be attributed to the design of the two programs. The implicit program, on the one hand, put very few restrictions on the type and order of equation operations that could be performed. All requested operations were acceptable unless they were illegal. The explicit program, on the other hand, had several restrictions. It monitored all requested operations to see that they not only simplified the equation but appeared in the correct order as well (see Table 2). These restrictions were necessary in order to make feedback more manageable, but they may have caused the explicit program to be more difficult to understand. With the explicit feedback all students were able to correct their mistakes, but only the field independent students may have been able to understand the true nature of these mistakes. They alone may have had the analytical ability to interpret each mistake in relation to both the solution of the whole equation and the restrictions imposed in solving it. If this were true, only the field independent subjects would have received long-term benefits from the explicit program.

When using the implicit program, subjects had a greater opportunity to solve equations in their own idosyncratic ways. Any solution method, no matter how lengthy or unconventional, was acceptable as long as it did not contain illegal operations. For the field dependent subjects, this freedom to experiment may have promoted their intuitive understanding of equation solving. Thus, they were able to retain what they had learned better than their field dependent counterparts in the explicit group. But it would seem that an instructional program which developed intuitive understanding in some students would have developed it in all, including the field independent students. It is still not clear why they benefited less from the implicit program, but one explanation may be that they were confused by its purpose. Because of their greater analytical ability, the field independent students may have already developed an equation-solving strategy, and the opportunity to develop new strategies may have been unconsciously perceived as a waste of effort.

Although field dependence-independence had an unexpected interaction with feedback, mathematics achievement had a more predictable one. In this interaction (see Hypotheses 3 and 4), the implicit feedback program now had the greater slope. In other words, the higher ability students achieved better under the implicit program while the lower ability students excelled under the explicit one. This outcome was predicted by Cronbach and Snow (1977), who found that students of low ability generally benefitted more from instructional methods providing a high degree of support and guidance. However, the significant interactions found in Hypotheses 3 and 4 were only for the small adult group--the trend was not confirmed by the larger adolescent group. If the adult group had been larger, there might have been some basis for concluding that a true interaction had occurred. As it is, it is more likely that the difference was due to an aberration in the data, although the issue is certainly worth investigating again in future research.

SUMMARY AND CONCLUSIONS

Summary

The use of feedback in computer-assisted instruction has become increasingly widespread in the past twenty years, but a great deal still is not known about its true educational benefits. In some cases, feedback has been found to promote learning, but in others it has had a neutral or even a negative effect. One possible cause for these conflicting reports may be the presence of a mediating variable which is interacting with feedback. Recent research has indicated that one such variable which might interact with feedback is the aptitude of cognitive style.

The specific cognitive style examined in this study was the concept of field dependence-independence. Although field dependence-independence originally dealt only with the processes of visual perception, it was later extended to include the processes of problem solving as well. It was theorized that the difficulty encountered by a field dependent individual when imposing structure on an unorganized perceptual field might manifest itself as well when attempting to impose structure on unorganized learning material, such as problem solving tasks. Thus, it was proposed that field dependent individuals should be provided with a more structured learning environment (e.g., feedback) than should field independent individuals, who appeared to provide their own structure.

In the present study, the presence of an interaction between field dependence-independence and feedback was investigated in a computerized problem-solving situation. The specific situation chosen for this study was algebraic equation solving. The author developed two computer programs which presented simple linear equations to the learner and required him or her to solve them by specifying the equation operation the computer should perform. One program, "explicit feedback," provided corrective feedback for every mistake, while the other, "implicit feedback," provided no feedback but did perform all equation operations requested by the learner. The interaction between feedback and another aptitude, mathematics achievement, was also investigated in the study.

Two groups of subjects participated in the study. One was a group of 96 eighth graders and the other was a group of 13 adults. Both groups received instruction in solving algebraic equations, and then members of both groups were randomly assigned to one of the two feedback conditions. After using the computer programs for several weeks, both groups were given a posttest and an attitude survey. Later, after receiving instruction on a related topic, they were given a transfer test.

The main focus of the study was on the interactions between feedback and (1) field dependence-independence and (2) mathematics achievement. The results were as follows:

1. There was no significant interaction between feedback and field dependence-independence for either group of subjects on the posttest. However, a significant interaction did occur between these two variables for both groups on the transfer test. This significant interaction was opposite that predicted by previous field dependence-independence research. That is, instead of field dependent learners performing better under the high-structure explicit feedback program, they scored higher under the low-structure implicit program. Conversely, the field independent learners, who were expected to score best under the implicit program, actually performed better under the explicit.

2. A significant interaction also occurred between feedback and mathematics achievement. Significance was reached on both the posttest and the transfer test in the adult sample, but there was no corresponding interaction in the adolescent sample. In contrast to the previous significant interaction, the direction of this one was the same as that found in earlier research. Students high in mathematics achievement scored higher under the implicit feedback program, while those low in mathematics achievement excelled under the explicit program.

3. Finally, there was no significant interaction between feedback and field dependence-independence for either group on the attitude survey. However, a significant interaction did occur between feedback and mathematics achievement for two survey questions in the adult group. These interactions revealed that the better math students felt that the explicit program gave them too much help, and that they understood their mistakes better when they were in the implicit group.

Implications for Future Research

As is often the case in research, some of the more interesting findings are those that are not expected. This study was no exception. One "interesting result" found in the present study was the interaction between feedback and field dependence-independence. The unexpected direction of the interaction necessitated a closer look at the structure of the feedback treatments in order to understand how they operate. In the Discussion section of the previous chapter, it was proposed that the implicit feedback program promoted an intuitive understanding of the concept of equation solving. This opportunity to develop understanding seemed to help the field dependent students more than the field independent ones, who may have already understood the concept. But what if the implicit program was not administered after instruction, as was done in the present study, but was administered before instruction? Used in this way, the understanding developed by the implicit program might prepare the student for the classroom instruction that was to follow. After classroom instruction, the explicit feedback program could then be used to reinforce the student's newly acquired understanding. Results of a study such as this could have important implications for not only CAI but for many other types of instruction as well.

Another finding that requires more investigation is the interaction in the adult sample between feedback and the second aptitude, mathematics achievement. This time the interaction was in the expected direction, but it only occurred for a small group. Certainly, this finding needs to be replicated, but the difficulty encountered in finding adult subjects for the present study leads one to believe that replication would be a monumental task. An alternate proposal would be to change the subject content of the computer programs before running the study again. It was found that not many adults study introductory equation solving, and many of those who do are involved in erratic, drop-in remedial programs where they are difficult to contact. For that reason a different subject, one that is studied widely by both adults and children, would be more useful in another comparison study such as this one.

Conclusions

The results of this study point out the large amount of information still to be uncovered in the areas of field dependence-independence and computer-assisted instruction. Significant interactions exist between CAI feedback and field dependence-independence, but they may not always be in the predicted direction. In addition, these interactions may be similar for both adolescents and adults, but a great deal of research remains to be done before this can be confirmed. Even if we are not yet at the point where we can individualize instruction on the basis of field dependence-independence or some other aptitude, the results of aptitude-treatment interaction (ATI) research still have immediate utility. As noted by Snow (1977),

> the evaluation of instructional prescriptions, whether individualized or not, requires an ATI approach even where there is no intent ultimately to assign students to alternative instructional treatments. In describing any kind of instructional effect, one must always be able to say whether the description given holds for each student involved. Research on aptitude thus takes a place in more general efforts to build instructional theory (p. 54).

BIBLIOGRAPHY

Alden, J. 1973. The effects of overview and retrogressive vs. progressive sequencing on achievement and motivation in a serial task. Unpublished doctoral dissertation, Hofstra University.

Anderson, Richard C., Raymond W. Kulhavy, and Thomas Andre. 1971. Feedback procedures in programmed instruction. Journal of Educational Psychology 62(2):148-156.

Ausubel, David P., and Floyd G. Robinson. 1969. School learning: An introduction to educational psychology. Holt, Rinehart, and Winston, New York, New York.

Becker, Jerry P. 1970. Research in mathematics education: The role of theory and of aptitude-treatment-interaction. Journal for Research in Mathematics Education 1(1):19-28.

Behr, Merlyn J. 1970. Interactions between "structure-of-intellect" factors and two methods of presenting concepts of modular arithmetic--A summary paper. Journal for Research in Mathematics Education 1(1):29-42.

Behr, Merlyn J., and Phillip M. Eastman. 1975. Interactions between structure-of-intellect factors and two methods of presenting concepts of modulus seven arithmetic--A follow-up and refinement study. Journal for Research in Mathematics Education 6(3):150-157.

Berliner, David C., and Leonard S. Cahen. 1973. Trait-treatment interaction and learning. Pages 58-94 <u>in</u> Fred N. Kerlinger, ed. Review of research in education. Vol. 1. F. E. Peacock, Itasca, Illinois.

Bien, Ellen C. 1974. The relationship of cognitive style and structure of arithmetic materials to performance in fourth grade arithmetic. Unpublished doctoral dissertation, University of Pennsylvania.

Buros, Oscar K., ed. 1978. The eighth mental measurements yearbook, vol. 1. The Gryphon Press, Highland Park, New Jersey.

Cooperman, Marilyn L. 1974. Field dependence and children's problem solving under varying contingencies of predetermined feedback. Unpublished doctoral dissertation, Fordham University.

Cronbach, Lee J., and Richard E. Snow. 1977. Aptitudes and instructional methods: A handbook for research on interactions. Irvington Publishers, New York, New York.

Gardner, Eric F., Robert Callis, Jack C. Merwin, and Richard Madden. 1974. Manual for the Stanford Test of Academic Skills, Level II, Junior/Community College. Psychological Corporation, New York, New York.

Goldstein, Kenneth M., and Sheldon Blackman. 1978. Cognitive style: Five approaches and relevant research. John Wiley and Sons, New York, New York.

Jacobs, Paul I., and Sharadchandra Kulkarni. 1966. A test of some assumptions underlying programmed instruction. Psychological Reports 18(1):103-110.

Kogan, Nathan. 1971. Educational implications of cognitive styles. Pages 242-292 in Gerald S. Lesser, ed. Psychology and educational practice. Scott, Foresman, Glenview, Illinois.

Lang, Martin T. 1976. The effectiveness of using computer extended instruction to teach basic concepts of introductory calculus. Pages 277-282 in The 1976 AEDS International Convention Proceedings. Association for Educational Data Systems, Washington, D.C. (ERIC ED 125 659).

McLeod, Douglas B., and Verna M. Adams. 1979. Individual differences in cognitive style and discovery approaches to learning mathematics. The Journal of Educational Research 72(6):317-320.

McLeod, Douglas B., Thomas P. Carpenter, Robert L. McCornack, and Romualdas Skvarcius. 1978. Cognitive style and mathematics learning: The interaction of field independence and instructional treatment in numeration systems. Journal for Research in Mathematics Education 9(3):163-174.

Renzi, Nicholas B. 1974. A study of some effects of field dependence-independence and feedback on performance achievement. Unpublished doctoral dissertation, Hofstra University.

Roper, W. J. 1977. Feedback in computer assisted instruction. Programmed Learning and Educational Technology 14(1):43-49.

Salomon, Gavriel. 1972. Heuristic models for the generation of aptitude-treatment interaction hypotheses. Review of Educational Research 42(3):327-343.

Schoen, Harold L. 1973. A comparison of four types of feedback in a CAI unit. Catalog of Selected Documents in Psychology 3(1):MS 308.

Schwartz, Daniel W., and Stephen A. Karp. 1967. Field dependence in a geriatric population. Perceptual and Motor Skills 24(2):495-504.

Snow, Richard E. 1977. Research on aptitude for learning: A progress report. Pages 50-105 in Lee S. Shulman, ed. Review of Research in Education. Vol. 4. F. E. Peacock, Itasca, Illinois.

Tait, K., J. R. Hartley, and R. C. Anderson. 1973. Feedback procedures in computer-assisted arithmetic instruction. The British Journal of Educational Psychology 43(2):161-171.

Threadgill, Judith A. 1979. The relationship of field-independent/dependent cognitive style and two methods of instruction in mathematics learning. Journal for Research in Mathematics Education 10(3):219-222.

Witkin, H. A., H. B. Lewis, M. Hertzman, K. Machover, P. B. Meissner, and S. Wapner. 1954. Personality through perception. Harper and Brothers, New York, New York.

Witkin, H. A., R. B. Dyk, H. F. Faterson, D. R. Goodenough, and S. A. Karp. 1962. Psychological differentiation: Studies of development. John Wiley and Sons, New York, New York.

Witkin, Herman A., Philip K. Oltman, Evelyn Raskin, and Stephen A. Karp. 1971. Manual for the Group Embedded Figures Test. Consulting Psychologists Press, Palo Alto, California.

Witkin, H. A., C. A. Moore, D. R. Goodenough, and P. W. Cox. 1977. Field-dependent and field-independent cognitive styles and their educational implications. Review of Educational Research 47(1):1-64.

Witkin, Herman A., Donald R. Goodenough, and Stephen A. Karp. 1967. Stability of cognitive style from childhood to young adulthood. Journal of Personality and Social Psychology 7(3):291-300.

ACKNOWLEDGMENTS

A great many people helped to make this dissertation possible, and the author would like to now thank a few of them. First, Dr. Rex Thomas, for his untiring effort and genuine concern during the author's entire graduate career. Second, Dr. Roger Hiemstra, whose emphasis on quality is an asset to all of his students. Third, the other members of the author's committee: Dr. J. Stanley Ahmann, Dr. Gary Phye, and Dr. Charles Connolly, for their assistance and their advice.

The author would also like to thank the teachers and students who participated in the study, as well as the administrators who made their participation possible. Thanks is also expressed to Dr. Robert Strahan for assistance in statistical matters, and to Dr. Roger Lawrence for substituting on the author's committee. Finally, the author would especially like to thank her husband, Pete, whose faith and enthusiasm helped to keep the whole project going and made it enjoyable as well as worthwhile.

APPENDIX A. POSTTEST

Name ______________________________

Equation Solving Test

Solve the following equations for X. In the column to the left of each equation, describe what you did to both sides of the equation. For example, if you subtracted 4 from both sides, you would write "S4." Show all your work, and please make an attempt to do every equation. Leave fractional answers as fractions (not decimals).

1. $X - 7 = 2$

2. $X + 6 = 10$

3. $22 = X - 1$

4. $8X = 5$

5. $9 = \frac{1}{2}X$

6. $\frac{2}{3}X = 2$

7. $5X + 6 = 26$

8. $\frac{3}{4}X - 3 = 6$

83

9. $1 = \frac{1}{8}X - 1$

10. $2X + 4 = -5$

11. $-6X - 2 = -20$

12. $-\frac{1}{2}X + 1 = 6$

13. $9X = 6X - 2$

14. $3X + 10 = -2X$

15. $-6X = -4X - 10$

16. $5X - 1 = -9X - 14$

17. $-2X - \frac{3}{5} = 3X + \frac{2}{5}$

18. $-X + 12 = -\frac{1}{2}X + 8$

APPENDIX B. EVALUATION PROCEDURE FOR THE POSTTEST

Evaluation Procedure for the Posttest

1. All scoring was divided into Operation credit and Computation credit.

2. All operations which did not complicate, i.e., add terms to or increase the degree of, an equation were correct, unless they occurred after an incorrect operation. All others were incorrect, unless the student was able to successfully solve the equation.

3. Excess operations performed on an already-solved equation were incorrect.

4. Incorrect operations performed correctly were given Computation credit.

5. The total number of possible points for each equation was determined by the number of operations specified by the student. Points were deducted from both the Operation and Computation scores if an equation did not have a sufficient number of steps for the operations specified.

6. If an operation was done but not recorded in the box (or recorded incorrectly), Operation credit was given if it was clear that the correct operation had been carried out.

7. For unattempted equations, points were deducted based on the smallest number of possible steps for a correct solution.

8. Where an equation had been attempted but was completely wrong, students lost no more than the minimum number of points required for a correct solution.

9. The operations "M1" and "D1" were ignored unless they were computed incorrectly.

APPENDIX C. EVALUATION PROCEDURE FOR THE SIMULTANEOUS EQUATIONS TRANSFER TEST

Evaluation Procedure for the Simultaneous Equations Transfer Test

1. All rules for the Posttest Evaluation Procedure (see Appendix B) also applied in this evaluation.

2. Scoring on this test was further divided into Simultaneous Equations credit and Equation Solving credit.

3. Substitutions done with an incorrect value, such as one which resulted from a previous error, received full credit if there were no other errors.

4. No Equation Solving credit was given if the second variable was obtained by trial-and-error substitution, but no points were deducted if the answer was correct.

5. If a substitution was set up correctly but the answer was wrong, one point was deducted from the Computation portion of the Simultaneous Equations score.

6. If a substitution was not set up and only the answer was shown (regardless of its correctness), one point was deducted from both the Operation and Computation portions of the Simultaneous Equations score. This was done to discourage guessing.

APPENDIX D. ATTITUDE SURVEY

Name ____________________

Computer Attitude Survey

DIRECTIONS

Read the following statements and decide how much you agree or disagree with them. To indicate your decision, circle one of the numbers on the line next to each statement. Do NOT circle between numbers. A sample answer is shown below.

	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
SAMPLE I like to get up early in the morning.	(1)	2	3	4	5
1. I like math better when I learn it on a computer.	1	2	3	4	5
2. I feel that the computer helped me to become better at solving equations.	1	2	3	4	5
3. I think the computer should have given me more "hints" when I didn't know how to solve an equation.	1	2	3	4	5
4. I thought the equations on the computer were too hard.	1	2	3	4	5
5. I would like to learn other math skills (besides equation solving) on a computer.	1	2	3	4	5
6. I think the computer gave me too much help in solving the equations.	1	2	3	4	5
7. I enjoyed solving equations on a computer.	1	2	3	4	5
8. I would like to learn other subjects (English, social studies, etc.) on a computer.	1	2	3	4	5

	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
9. I think using the computer was a waste of time.	1	2	3	4	5
10. I got confused when I tried to solve equations on the computer.	1	2	3	4	5
11. When the computer told me that I had done something wrong, I had no trouble understanding what my mistake was.	1	2	3	4	5
12. Working with the computer was frustrating.	1	2	3	4	5
13. The 15-minute sessions on the computer were too long.	1	2	3	4	5

If you have any other comments about using the computer, please write them below:

APPENDIX E. HUMAN SUBJECTS FORM

INFORMATION ON THE USE OF HUMAN SUBJECTS IN RESEARCH

IOWA STATE UNIVERSITY

(Please follow the accompanying instructions for completing this form.)

1. Title of project (please type): Interaction of Field Dependence-Independence and Math Aptitude with Type of Feedback Used in Computer-Assisted Equation Solving

2. I agree to provide the proper surveillance of this project to insure that the rights and welfare of the human subjects are properly protected. Additions to or changes in procedures affecting the subjects after the project has been approved will be submitted to the committee for review.

Vicki A. Boysen	2/8/79	Vicki A. Boysen
Typed Named of Principal Investigator	Date	Signature of Principal Investigator

201 Curtiss	4-2219
Campus Address	Campus Telephone

3.

Signatures of others (if any)	Date	Relationship to Principal Investigator
Roger Hemstra	2/12/79	Major Professor
Ray H. Thomas	2/9/79	Co-Major Professor

4. ATTACH an additional page(s) (A) describing your proposed research and (B) the subjects to be used, (C) indicating any risks or discomforts to the subjects, and (D) covering any topics checked below. CHECK all boxes applicable.

- [ ] Medical clearance necessary before subjects can participate
- [ ] Samples (blood, tissue, etc.) from subjects
- [ ] Administration of substances (foods, drugs, etc.) to subjects
- [ ] Physical exercise or conditioning for subjects
- [ ] Deception of subjects
- [X] Subjects under 14 years of age and(or) [ ] Subjects 14-17 years of age
- [ ] Subjects in institutions
- [X] Research must be approved by another institution or agency

FEB 1979 RECE... GRADUATE CO... I.S.U.

5. ATTACH an example of the material to be used to obtain informed consent and CHECK which type will be used.

- [X] Signed informed consent will be obtained. (for children)
- [X] Modified informed consent will be obtained. (for adults)

6.

	Month	Day	Year
Anticipated date on which subjects will be first contacted:	3	15	79
Anticipated date for last contact with subjects:	10	15	79

7. If Applicable: Anticipated date on which audio or visual tapes will be erased and(or) identifiers will be removed from completed survey instruments: 10 (Month) 31 (Day) 79 (Year)

8.

Signature of Head or Chairperson	Date	Department or Administrative Unit
[signature]	2/12/79	Professional Studies

9. Decision of the University Committee on the Use of Human Subjects in Research:

- [X] Project Approved
- [ ] Project not approved
- [ ] No action required

George G. Karas	3/2/79	[signature]
Name of Committee Chairperson	Date	Signature of Committee Chairperson

Revised 6/78