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**THE EFFECTS OF TEST ANXIETY AND INSTRUCTIONAL TREATMENT ON
THE COGNITIVE PROCESSING OF INSTRUCTION**

City University of New York

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THE EFFECTS OF TEST ANXIETY AND INSTRUCTIONAL TREATMENT ON
THE COGNITIVE PROCESSING OF INSTRUCTION

by

Howard T. Everson

A dissertation submitted to the Graduate Faculty in
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ABSTRACT

THE EFFECTS OF TEST ANXIETY AND INSTRUCTIONAL TREATMENT ON
THE COGNITIVE PROCESSING OF INSTRUCTION

by

Howard T. Everson

Adviser: Dr. Sigmund Tobias

This study investigated the relationship between test anxiety and level of instructional support on achievement and cognitive macroprocessing. Aptitude x treatment interaction research suggests that anxiety affects achievement indirectly by affecting the cognitive processes engaged by instruction. This model of anxiety assumes the cognitive component of test anxiety (i.e., worry) interferes with the effective input of instructional material, in addition to affecting learning at other points. This "interference" model suggests that supportive instructional treatments are differentially beneficial to anxious learners because they reduce the cognitive demands of the task and minimize the

interference of worry. This model was tested by varying instructional support from high to low and examining the interactions of test anxiety and ability on achievement and on the use of a number of macroprocesses.

Individual differences in test anxiety, reading ability and prior knowledge were examined for three treatment groups: (1) text with inserted adjunct postquestions and feedback; (2) text with inserted adjunct postquestions but no feedback; and (3) a text only control group. Test anxiety was assessed using both trait and state measures. Reading ability was measured using the Nelson-Denny Reading Test. A pretest based on the instructional text measured prior knowledge. Achievement was measured by a posttest containing adjunct question relevant and incidental items. The macroprocesses were operationalized as the number of sentences previewed, the number of main and alternate text sentences reviewed, the frequency of use of headings, and the frequency of notetaking and reviewing notes.

Multivariate analysis of the posttest revealed main effects for treatment and prior knowledge on both the relevant and incidental posttest items, as well as a main effect for test anxiety on the incidental items. No anxiety x treatment interaction effects on achievement were found. Analysis of the macroprocessing data uncovered a main effect for treatment on both the use of the alternate text and notetaking, a main effect for test anxiety on the use of the alter-

nate text, an anxiety x prior knowledge interaction for both use of alternate text and use of headings, and a worry x prior knowledge x treatment interaction for use of the alternate text. These results are discussed within the framework of a limited capacity model of test anxiety with an emphasis on the prescriptive use of macroprocesses.

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Chapter I

THE NATURE OF THE PROBLEM

Ever since Freud (1936) identified its central role in the development of the personality, the concept of anxiety has been prominent in most subsequent theories of personality. For example, Sarason, Davidson, and Lighthall (1960) stated... "they are not aware of any systematic conception of personality, particularly with regard to its development, which does not give the concept of anxiety a role of great, if not central, significance" (p. 5).

One specific type of anxiety that has received considerable study in this country and elsewhere (van der Ploeg, Schwarzer, and Spielberger, 1984) is test anxiety. For the most part, this body of research views test anxiety as a special case of general anxiety (Sieber, 1980) and includes the phenomenological, physiological and behavioral responses to evaluative stress and/or fear of failure.

The proliferation of research in this area is not surprising. After all, test anxiety is not unfamiliar in our modern day achievement oriented society. For those seriously affected, simply the mere prospect of an exam produces an overwhelming flood of worry and emotion (Wine, 1980). Consequently, tests are fraught with discomfort for the highly test anxious person and are events to be avoided.

To some degree this fear of tests is justified. Typically, when under stress, the highly anxious student does not perform as well as the less anxious student, though it has been demonstrated repeatedly that, in general, highly anxious people are just as intelligent (Mandler and Sarason, 1952; Spielberger, 1966). What we find, then, is that test anxious students are caught in a vicious cycle of poor performance on exams, subsequent disappointment, and inadvertent reinforcement of the anxiety provoking aspects of test taking. Precisely because test anxiety is so consistently related to poor academic performance, understanding its role in the cognitive processing of instruction is of considerable importance.

The Problem

Current test anxiety theory suggests that the major effect of anxiety on learning is due to interference at the cognitive processing level. For example, Wine (1980) has formulated a cognitive-attentional model of test anxiety which asserts that attention in highly evaluative situations is distributed between task-relevant and task-irrelevant responses. According to this view, for individuals with high levels of test anxiety a significant amount of attention is devoted to task-irrelevant responses (such as worrying) which results in decreased attention to the task at hand and, consequently, reduced performance. In support of the

cognitive interference model, it has been suggested that anxiety does not directly affect instructional outcomes, but, rather, affects the cognitive processes engaged by the instructional treatment, and these, in turn, affect performance (Tobias, 1980).

This so called "interference model" of test anxiety has been challenged recently by an alternative "deficit model". The deficit hypothesis assumes that the poor performance of highly anxious students is attributable to poor study habits, or to deficits in test taking skills rather than to interference by anxiety. This shift in perspective is pivotal because it assumes that a skills deficit accounts for the poor performance, not interference in cognitive processing at either acquisition or retrieval as the information processing view would suggest.

Recently, Tobias (1984) has attempted to reconcile these alternative explanations in terms of a "limited capacity" model designed to account for the effects of test anxiety both in terms of cognitive interference and cognitive strategy deficits. Working within an information-processing analysis (J. Anderson, 1980; Biggs, 1971) framework, Tobias' arguments focus on the 'micro' and 'macro' process levels. The electronic computer serves as a useful metaphor for understanding the cognitive capacity model. A simply analogy is drawn: (1) something goes into the individual's brain (input data or perception); (2) a process occurs within the

individual (execute programs or thinking about perception, cognitive processing); and (3) the individual acts (output or performance).

In this way, then, learning is represented simply as the extent to which output is improved or modified, in terms of the instructional material presented as input and the operations the individual performs on the input, i.e., cognitive processing. On a 'micro' level these processes include registering, storing, and transforming information. The 'macro' process level refers to those higher-order strategies such as sorting, noting, reviewing and summarizing.

From a cognitive perspective, Tobias' (1977) information-processing model assumes that anxiety interferes with the effective input of instructional material, in addition to affecting learning from instruction at other points (during both the processing and the output stages, see, for example, Figure 1. It follows, then, that instructional treatments which provide high levels of support by inserting adjunct questions or advanced organizers, or by providing feedback will serve to decrease the cognitive capacity demands of the learning task and, hence, will be selectively beneficial to highly anxious learners. Moreover, by operationalizing specific processing dimensions (e.g., macroprocesses) assumed by the model, the cognitive strategy differences of high and low anxious learners can be examined objectively. The aim of this study was to examine those ATI's.

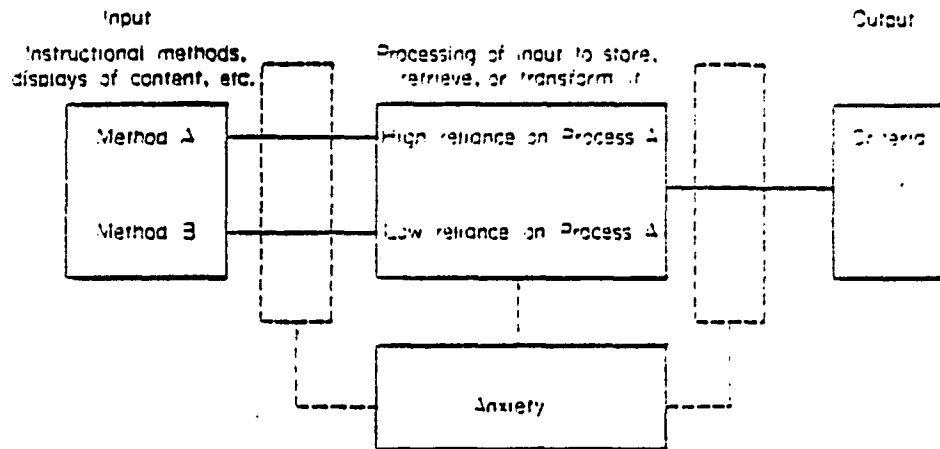


Figure 1. Model of anxiety-treatment interactions (Tobias, 1977).
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ATI Paradigm

Since the 1950's, many studies of test anxiety have been conducted in an effort to understand the nature of the relationship between anxiety, learning, and instruction. For the most part, these studies represent attempts at explaining and treating academic performance differences in test anxious students. Over the years, two distinct paradigms for studying test anxiety in an instructional context have emerged. Although different methodologically, both paradigms have addressed the need to attenuate the debilitating effects of anxiety on academic achievement.

One approach taken by researchers working in this area represents an effort to treat test anxiety symptomatically, and is characterized by the prototypical anxiety reduction program (see Meichenbaum and Butler, 1980). Typically, this research seeks an optimal program for reducing or diminishing the physiological sensations associated with elevated levels of anxiety.

In contrast, the other paradigm that has emerged attempts to further our understanding of the nature of the interaction between test anxiety and instruction. This body of research aims at adapting instructional methods differentially for high and low anxious learners. As such, it reflects the more general paradigm in psychology of studying the interactions between learner attributes (e.g., aptitudes, traits, etc.) and instructional treatments, otherwise known as at-

tribute (or aptitude) treatment interactions and commonly abbreviated as ATI research (Cronbach & Snow, 1977).

The logic propelling the ATI paradigm is straightforward: no one instructional method is presumed superior for all types of students. On the contrary, ATI research assumes that students with one set of characteristics, say higher ability or increased motivation, may be taught optimally using one instructional method, whereas others with different characteristics may be taught more effectively another way. In an effort to advance test anxiety theory, ATI research has attempted to demonstrate an interaction between anxiety and those instructional methods assumed to be differentially affected by anxiety (Tobias, 1980). From a theoretical perspective, such research holds the promise of clarifying both the cognitive processes controlling learning, as well as the ways in which anxiety affects learning from instruction. In a more applied sense, the study of ATI's offers the potential for developing instructional treatments which would enhance the achievement of highly anxious students. The ATI paradigm guided the design of this study.

Research Design

The aim of the present research was to renew interest in ATI research by exploring some hitherto neglected variables. In addition to investigating the achievement x treatment interactions of test anxious students receiving different lev-

els of instructional support, this research also attempted to identify the various types of cognitive macroprocesses students employed while engaged in meaningful learning. In that sense this study was designed to be exploratory as well as confirmatory. The study was conceptualized as a 3 x 2 factorial with three levels of instructional support (low, medium, and high), and two levels of achievement (relevant and incidental posttest items) with test anxiety represented as a continuous variable in a multivariate multiple regression analysis design.

The level of instructional support was manipulated from high to low by use of an adjunct postquestion design. The macroprocess construct was operationalized as those relatively molar cognitive processes students use, such as reviewing, previewing, seeking clarification, or notetaking, when learning from instruction. More specifically, the macroprocesses investigated included review (text lookbacks), previews, use of a less difficult version of text, notetaking, use of headings (text outline), and reviewing notes.

Operationally, this research used microcomputers to present the varying instructional treatments and collect a host of performance data. The computers were programmed to present the instructional treatments and provide feedback, as well as store data on subjects' responses to adjunct questions and frequency of use of the macroprocesses. In addition to measuring individual differences in test anxiety,

prior knowledge, and reading ability, achievement on both the relevant and incidental subscales of an immediate post-test was also assessed.

Goals of the Study

In general, prior research on anxiety and achievement suggests that the cognitive component of test anxiety, i.e. worry, generates a form of cognitive interference which serves to diminish the academic performance of anxious students. This expectation derives from a cognitive model of test anxiety (Tobias, 1984; Wine, 1980) which hypothesizes that the negative self-preoccupations typically associated with high anxiety absorb some portion of the individual's information processing capacity. Consequently, it follows, that only a reduced proportion of cognitive capacity remains available for processing task related information. Thus, it was reasoned that reducing the cognitive processing demands of the task by providing instructional support should be beneficial for high anxious learners. It also follows that engaging macroprocesses such as review, preview, and note-taking should be differentially beneficial for the achievement of highly anxious students when compared with their low anxious counterparts. Presently, little or no data exist which shed light on the nature of the interaction between test anxiety and these processes.

In an effort to provide an empirical test of the limited capacity model of test anxiety, the following issues were addressed in this study: (1) whether increasing instructional support serves to enhance the achievement of test anxious students; (2) whether differences exist between high and low test anxious students with respect to the frequency of use of macroprocesses; and (3) whether frequent use of the various macroprocesses serve to reduce the cognitive processing capacity demands of the learning task and increase performance of the highly anxious learners. In the following chapter a review of the related research is presented to establish the theoretical framework for studying between test anxiety and achievement. the interactions among test anxiety, instructional support, cognitive macro-processing, and achievement.

Chapter II

LITERATURE REVIEW

The research reviewed in this chapter is presented under three broad categories: the first, theory and research on test anxiety will serve to establish the cognitive perspective guiding the present research; second, a selective review of the adjunct postquestions research will enhance understanding of the instructional support strategies developed for this study; and third, research focusing of the use of study strategies will be reviewed in an effort to set forth the need for operationalizing the "macroprocess" construct.

This literature review is not meant to be exhaustive. However, the research in each area is reviewed selectively with the aim of establishing the theoretical perspective necessary, and so often absent, in ATI research.

Test Anxiety

Current interest in the construct of test anxiety can be traced to the seminal work of Mandler and Sarason (1952). Their innovative work is generally credited with introducing the construct of test anxiety into the psychological literature. For the most part their research focused on the role of drive states in testing situations, and stemmed from the

earlier work on drive states by Miller and Dollard (1941) and Hull (1943). In that study 33 subjects were administered a questionnaire intended to measure test anxiety, known as the Test Anxiety Questionnaire (TAQ). The scores on the TAQ were then compared to scores received on a standardized intelligence test. Results of the study indicated that the variance of the intelligence test scores was significantly larger for high-anxious compared to low-anxious students.

Interestingly enough, Mandler and Sarason (1952) explained their findings in terms of interference. This model predicts that highly anxious students will tend to exhibit task-irrelevant responses in a stressful situation, like test-taking, while the less anxious will engage in task-relevant responses. As a consequence, a differential effect on achievement as a function of anxiety level is expected. Although Mandler and Sarason began from a drive state perspective, what emerged was an early version of a cognitive interference model of test anxiety.

It is commonly accepted that academic performance is impaired by test anxiety. Although the literature in this area has been reviewed exhaustively by Spielberger (1966) and others (van der Ploeg, et al., 1984), a few brief examples will serve to underscore the relationship between test anxiety and academic achievement. In a study using Duke University undergraduates, Spielberger discovered that more

than 20% of a group of high-anxious students who dropped out of college cited academic difficulties as the reason, while only 6% of the low-anxious group who dropped out cited that same reason. Moreover, the negative relationship between anxiety and achievement was more striking among the lower ability students, where the failure rate of high-anxious students compared to low-anxious students was roughly two-to-one. Similarly, the relationship between anxiety and grade point average was found to parallel the relationship between anxiety and academic failure (Spielberger, 1962; Spielberger & Katzenmeyer, 1959). These studies reported that, in general, highly anxious students had lower grade point averages than low anxious students.

In a study using elementary school children as subjects, Lunneborg (1964) reported that high levels of anxiety were associated with low levels of achievement in both reading and mathematics. More recently, Gaudry and Spielberger (1971) reviewed a number of studies relating anxiety to academic achievement and concluded that the most consistent finding, at all levels of academic experience, was that high anxiety was associated with low academic achievement. Along these same lines research published recently on the achievement differences of high and low test-anxious Dutch school children reported the detrimental effects of high test anxiety on performance (van der Ploeg, 1984). Consequently, since high levels of anxiety have been consistently related

to poor academic performance, the construct of evaluative or test anxiety is of considerable educational importance.

Theory

Test anxiety theory and research, as noted above, had its beginnings with the work of S. Sarason and his associates in the early 1950's. In their paper introducing test anxiety, Mandler and Sarason (1952) presented a model based on two types of drives: task drives and anxiety drives. Task drives were viewed as learned drives which were a function of the demands of the task at hand. Task drives, moreover, were seen as including the need to achieve, about which more will be said later, and the need to complete the task. Similarly, task-relevant responses were defined as responses which lead to a reduction of the task drive and to completion of the task.

Anxiety drives, on the other hand, were also considered as learned drives which developed in response to anxiety reactions previously encountered in testing situations. The development of these anxiety drives, then, was characterized as resulting from prior testing experiences when anxiety was aroused. Two classes of responses which serve to reduce the anxiety drive were hypothesized. The first class included responses which tended to reduce the anxiety drive by facilitating completion of the task. These were viewed as functionally equivalent to the task-related responses discussed

earlier. The second, and more interesting theoretically, were a class of responses which Mandler and Sarason interpreted as self-directed. These included attempts to flee from the testing situation, increased physiological arousal, and reported feelings of helplessness. These responses do not facilitate task completion.

In terms of test anxiety theory, the Mandler-Sarason drive state model predicts that highly anxious students will tend to engage in frequent task-irrelevant behaviors when tested, while low anxious students will tend to exhibit task-relevant, task-facilitating, types of responses during testing. These task-irrelevant responses to the anxiety drive state were presumed to produce the achievement deficits in highly anxious students.

A similar, yet somewhat contrasting, view of test anxiety has been proffered by Atkinson (1964) and extended by Atkinson and Feather (1966). According to these investigators, test anxiety and achievement motivation are interrelated. For them, test anxiety is a manifestation of a motive to avoid failure, while achievement motivation is a manifestation of a motive to approach success.

Atkinson and Feather (1966) summarized their research with adult learners and concluded that it provided support for their basic hypothesis that people motivated more to achieve success than to avoid failure selected tasks of intermediate difficulty, persisted longer in achievement ori-

ented tasks, and, indeed, achieved more on those tasks than more anxious persons. Conversely, the more anxious individuals were motivated more to avoid failure than to achieve success and, therefore, selected either quite simple or extremely difficult tasks, with the latter chosen precisely because they are so difficult and, consequently, somewhat less threatening to fail.

In an attempt at extending the achievement motivation view of test anxiety, Hill (1972) argued that evaluative anxiety originates in early childhood. From this developmental perspective, Hill argued that parental standards serve to create motivation dispositions in the child which operate to obtain praise and avoid criticism.

Specifically, Hill has suggested that as children become more responsive to adult evaluations, guilt concomitantly increases. Further, he argues that with increasing anxiety, the drive or motive to receive praise becomes less dominant and the need to avoid criticism stronger. In this way, low-anxious children can be expected to exhibit comparatively stronger motives for obtaining praise than for avoiding criticism, while high-anxious children are expected to demonstrate the opposing tendency of a greater motivation for avoiding criticism. Thus, as the child grows older the parents are replaced by teachers and other significant people as the focus of evaluative criticism and feedback.

Support for the developmental view of test anxiety has been reported by both Hill (1972) and Crandall (1967). For example, Crandall (1967) found that low-anxious children are oriented more towards their internal evaluations of their performance and, consequently, are more attentive to their own performance in problem solving situations. In contrast, high-anxious children were found to be more susceptible to the evaluations of the adult experimenter. Moreover, both Allen (1966) and Crandall (1967) reported that low-anxious children apparently are more attentive to the information contained in the experimenter's reactions to their performance than to the social cues accompanying those reactions, while the high-anxious children reacted in the opposite manner.

A Cognitive Perspective. The cognitive view of test anxiety was advanced when Spielberger (1972) introduced the distinction between state and trait anxiety. Cattell (1966) also drew this distinction between what he referred to as characterological or trait anxiety, and anxiety as an emotional state. However, Spielberger (1966, 1972) presented a more formalized version of the state-trait conception.

According to Spielberger's model, A-Trait (trait anxiety)

"...refers to relatively stable individual differences in anxiety proneness, that is, to differences in the disposition to perceive a wide range of stimulus situations as dangerous or threatening, and in the tendency to respond to such threats with A-State reactions" (1972, p.39).

A-State (state anxiety), on the other hand, is defined as

"...a transitory emotional state or condition of the human organism that varies in intensity and fluctuates over time. This condition is characterized by subjective, consciously perceived feelings of tension and apprehension, and activation of the autonomic nervous system. Level of A-State should be high in circumstances that are perceived by an individual to be threatening, irrespective of the objective danger" (1972, p.39).

According to the state-trait model, then, the cognitive appraisal of a stimulus as dangerous or threatening elicits an A-State response. Thus, judging a stimulus as threatening is influenced, in part, by one's cognitive processes (i.e., perceptions, beliefs, learned responses) and sensory mechanisms.

Working from the fundamental assumption that state and trait anxiety are theoretically distinct, Spielberger created two scales to make them operationally distinct as well. Collectively, the two scales are known as the State Trait Anxiety Inventory (STAI). A complete description of the scales can be found in Spielberger, Gorsuch and Lushene (1970).

Another similar componential view of test anxiety has been proposed by Liebert and Morris (1967). Like Spielber-

ger, they conceptualized test anxiety as being separable into at least two major components, worry and emotionality.

"Worry refers to the cognitive elements of the anxiety experience, such as negative concerns about oneself, the situation at hand, and potential consequences. Emotionality refers to one's perception of the physiological-affective elements of the anxiety experience, that is, indications of autonomic arousal and unpleasant feeling states such as nervousness and tension" (Morris, Davis & Hutchings, 1981, p. 541).

This distinction has generated a considerable amount of test anxiety research. A thorough review of this research can be found in Morris et al., (1981).

For the most part, reviews of the test anxiety literature show the negative correlations between test anxiety and performance to be in the low to moderate range (-.10 to -.40). Positive relationships, however, have been reported, suggesting that test anxiety may, at times, facilitate performance or achievement. This inconsistency has been interpreted as an important basis for distinguishing between the cognitive and emotional or affective components of test anxiety. More clearly, such a distinction helps explain the 'facilitating' or arousal argument proposed in earlier work by Sarason, Mandler, and Craighill (1952) and Spence and Spence (1966). For example, Sarason et al. (1952) asserted that increased levels of anxiety do not necessarily lead to poor performance:

"When a stimulus situation contains elements which specifically arouse test or achievement anxiety,

this increase in anxiety drive will lead to poorer performance in individuals who have test-irrelevant anxiety responses in their repertory. For individuals without such response tendencies, these stimulus elements will raise their general drive level and result in improved performance." (p. 561)

More recently, worry and emotionality have been theorized to be independent in the sense that they have differential effects on intellectual and/or academic performance. The literature generally supports this position. For example, worry is the component of test anxiety reported as more consistently and more strongly related (inversely) to academic performance, whether examination scores or course grades are used as the dependent variable (Morris, Finkelstein, & Fisher, 1976; Morris, Kellaway, & Smith, 1978; Morris & Liebert, 1970).

Emotionality, at times, has been positively correlated with achievement, especially when situations are perceived as challenging rather than threatening (Schwarzer, van der Ploeg, and Spielberger, 1982). In this circumstance, emotionality has been interpreted as productive arousal (or motivation) rather than debilitating anxiety. In contrast, the cognitive or worry component of test anxiety appears to be a better predictor of academic achievement, particularly poor achievement, than the affective component of emotionality.

Deffenbacher (1977) reported a study of the performance differences of graduate students on the Miller Analogies

Test. In that study, emotionality interacted with worry to produce debilitating effects in the high-worry group. In another instructional context, one using computer-assisted learning, O'Neill, Judd, and Hedl (1977) found worry to correlate much more negatively ($r = -.45$ to $-.60$) with performance than either emotionality or state anxiety. These researchers concluded that the five-item state anxiety scale is a better index of perceived stress, but that the worry scale is a better predictor of academic performance.

Data reported from studies employing laboratory-like intellectual tasks (such as anagrams, standardized IQ scales, etc.) also indicated the presence of differential effects of worry and emotionality on performance (Morris & Perez, 1972). For example, Holroyd, Westbrook, Wolf, & Badhorn (1978) reported that the percent of time spent worrying correlated ($r = -.80$) with performance on an anagram task, while emotionality was uncorrelated with performance.

Deffenbacher (1978) employed the worry-emotionality distinction when examining the performance on an anagrams task under conditions of high and low-stress. Subjects were divided into high-anxious and low-anxious groups on the basis of their scores on the Test Anxiety Scale (I. Sarason, 1972). High-anxious individuals in the high-stress condition solved significantly fewer anagrams than high-anxious individuals in the low-stress condition ($x = 3.29$ vs $x = 5.65$). Although both worry and emotionality were related to

performance decrements, worry was reported to be the most debilitating factor. More important, the results reported by Deffenbacher (1978) and the others mentioned earlier are typical of the findings reported by a host of other investigators (e.g., Bloch & Brackenridge, 1972; Morris, Smith, Andrews & Morris, 1975; Morris & Perez, 1972; and Holroyd et al., 1978).

Deffenbacher's (1980) review of the worry-emotionality literature concludes by identifying a consistent pattern of emerging results: (1) worry and emotionality are significantly correlated; (2) worry consistently forms a negative or inverse relationship with performance; (3) emotionality is not as consistently related to performance as is worry; and (4) worry is the more important variable, accounting for more of the variance in relationships with performance.

More recently a cognitive-attentional reinterpretation of the Mandler-Sarason theory of test anxiety was proposed by Wine (1971, 1980). Wine's formulation explains the performance differences between high and low test anxious people by referring to the different ways in which these people are assumed to deploy their attention. According to Wine,

"...the low test anxious person is focused on task-relevant variables while performing tasks. The highly test anxious person is internally focused on self-evaluative, self-deprecatory thinking, and perception of his autonomic responses. Since the difficult tasks on which the test anxious person does poorly require full attention for adequate performance, he cannot perform adequately while dividing his attention between internal cues and task cues" (1971, p. 92).

High-anxious students, then, are thought to be dividing their attention between internal cues, such as self-derogatory thoughts and the perception of autonomic responses, and the cues derived from the task itself. Since the low-anxious students suffer lower levels of cognitive interference, their attention can be directed more fully toward the external task cues, thereby enhancing performance.

Subsequent to Wine's (1971) cognitive-attentional reinterpretation of test anxiety theory, I. Sarason (1972) published a review of a number of studies in which he reached a similar conclusion. Like Wine, Sarason noted that

"...what distinguishes the high test anxious individual are (1) the manner in which he attends to the events of his environment and (2) how he interprets and utilizes the information provided by these events" (1972, p. 383).

He noted that evaluative or achievement-oriented environments seem to have a negative effect on the performance of the high-anxious subjects, but a positive effect on the performance of low-anxious subjects.

Sarason (1972) argued, further, that low-anxious people in an achievement oriented situation are motivated to perform at high levels and tend to focus their attention more fully on the task at hand. In contrast, the high-anxious individual personalizes the situation and misinterprets informational cues and/or may experience attentional blocking. Sarason also noted that pre-performance variables (e.g., in-

structions, informational cues, and observations) may play a role in the way high-anxious people perform.

Thus, beginning with the work of Spielberger (1966) and developing further in the work of I. Sarason (1972) and Wine (1980), we see the emergence of cognition (attention and information processing abilities) as central to the formulation of test anxiety theory. It is generally agreed, for example, that people have a limited capacity as information processors (Broadbent, 1958). Working on this assumption, cognitive theorists have argued that during task performance, distracting thoughts concerning failure are channeled from long-term memory to those parts of the processing system dealing with the task at hand. Cognitive worry, then, competes with the task-relevant cognitive activities for space and time in a limited capacity system (Tobias, 1984b). Consequently, the degree to which test anxiety disrupts performance may be a product of both the amount of worry and the information-processing requirements of the task at hand.

Further support for this view of test anxiety can be found in the research on attention (Gopher & Kahneman, 1971; Keele, Neill, and deLemos, 1978), which suggests that individuals differ in the speed with which they switch attentional focus. Such research provides limited support for individual differences in attention that may, in fact, be related to individual differences in anxiety.

Research designed specifically to examine the cognitive-attentional view of anxiety was conducted by Sacks, Everson, and Tobias (1982). In this study the relationship among a number of components of test anxiety (e.g., state/trait and worry/emotionality) and attention was investigated using a dichotic listening task paradigm. Their results provide limited support for the cognitive-attentional view by suggesting that the cognitive component of test anxiety, worry, interfered with the ability to disperse and/or focus attention across listening tasks.

Cognitive Capacity Model. In general, the research discussed above, from the state-trait conception of Spielberger (1966) to the cognitive-attentional views of Wine (1980), has argued for a cognitive interference interpretation of the performance decrements associated with test anxiety. As noted earlier, this cognitive interference view has been challenged recently by researchers emphasizing a skills deficit hypothesis.

The deficit and interference models of test anxiety have been viewed as mutually exclusive by some researchers. For example, Kirkland and Hollandsworth (1980) suggested that the deficit view should be posited as an alternative to the interference model. Analysis of the research in this area (see Tobias, 1984a) indicates that it may be premature to place the skills deficit and interference models in opposition or to characterize them as mutually exclusive.

It has been suggested (Tobias, in press) that a limited cognitive capacity model may provide a useful account of the effects of both test anxiety and study skills. According to this view, the cognitive representation of test anxiety (i.e., worry) must absorb some of the student's information processing capacity, leaving only a reduced portion for handling the cognitive demands of the task at hand. In turn, this diminished capacity leads to less effective processing of the instructional input and, in terms of the anxiety model (Tobias, 1977, 1979) shown in Figure 1, reduction of output or achievement. High levels of anxiety make further demands of the cognitive processing capacity by dividing the attention of test anxious students between task-relevant and task-irrelevant concerns (I. Sarason, in press; Zatz & Chassin, 1983). In evaluative situations both the cognitive representation of anxiety and the anxious student's division of attention absorb a relatively large portion of cognitive capacity and produce performance and achievement decrements.

The cognitive capacity model (Tobias, 1984b) suggests that test anxiety and study/test-taking strategies have inverse effects. That is, high test anxiety is expected to increase the demands made on cognitive capacity, while effective study or test-taking skills are assumed to reduce the capacity demands of the task. Thus, optimal performance is expected of students with efficient study skills and/or test-taking strategies and low test anxiety, since they are

expected to have greater proportions of the cognitive capacity available for processing task-related demands. Students with high levels of test anxiety and ineffective study skills, on the other hand, have a diminished capacity for dealing with the task.

As Tobias (1984b) recently suggested, there are a number of advantages to reconciling both deficit and interference models of test anxiety in terms of cognitive capacity. First, the effects accounted for by these competing theories can be viewed as complementary rather than contradictory. Second, as noted earlier, such a view suggests a fruitful area of research using the ATI paradigm to investigate these phenomena. That is, from the vantage point of cognitive capacity, students high in test anxiety are expected to profit from instructional treatments that provide external means for organizing and processing instructional material, since it is assumed that such treatments, like other effective study strategies, will decrease the capacity demands of the instructional task and enhance the performance of highly test anxious students. A brief review of selective ATI research focusing on the interaction between achievement and instructional method follows below. This presentation will clarify the role of instructional support as it has been conceptualized in this study.

Anxiety-Treatment Interaction Research

The study of the interactions between learner attributes and instruction can be traced to Cronbach's (1957) call for detente between the experimental and correlational camps in psychology. The study of attribute treatment interactions (ATIs) is important to education from both a theoretical and a practical point of view. Theoretically, further clarification of how individual learner attributes interact with instructional methods will contribute to effective instruction. More pragmatically, an instructional prescription suggesting that that one individual should be instructed one way while another individual with differing attributes is instructed another way implies the existence of well established ATI's. The study of ATI's has been seen by some as an important element in a science of instruction (Tobias, 1979).

In general, research on the interaction between anxiety and instruction has used two distinct instructional contexts: (1) individualized instruction - using programmed instruction, computer-assisted instruction, or computer-managed instruction; and (2) classroom-based instruction. The overall research strategy includes assigning high- and low-anxious students differentially to a number of instructional treatments (either individualized or classroom-based) which vary along the dimension of "support" (e.g., requiring overt responses, providing feedback, allowing for review, etc.)

provided the learner. The presence of main effects and/or interactions is determined using multiple regression techniques or analysis of variance.

Although elusive, reports of anxiety x treatment interactions are found in the literature. In studies using classroom-based instruction (Dowaliby & Schumer, 1973; Domino, 1974) it has been shown that well organized, teacher led instruction produced higher levels of achievement for high-anxious students when compared to more loosely organized, student-centered instruction.

Peterson (1977), in an extension of the work of Dowaliby and Schumer (1973), and of Domino (1974), randomly assigned ninth grade students to a 2x2 matrix of instructional treatments with two levels of structure and two levels of student participation. Level of structure was defined as the degree of explicitness of the lesson, while student participation varied from high to low. In addition to anxiety, other individual difference measures (e.g., achievement via conformity or independence, and verbal ability) were included in this research design. The dependent measures, a multiple choice test and an essay, were designed to assess recall of the material presented in the lesson. The tests were administered immediately after the lesson, and again three weeks later.

Peterson (1977) reported a number of significant interactions among anxiety, ability, and the instructional treat-

ments. For example, students who were either high or low on both ability and anxiety performed most poorly in the low structure/ low participation treatment. However, students who were high on one attribute variable and low on the other performed best under that treatment and most poorly when assigned to the high structure/low participation treatment. No significant interactions were reported for student attitudes. Retention tests administered three weeks later produced reduced interactions.

In a replication of her study, Peterson (1978) used the same research design on four classes of college students enrolled in a five week psychology course. The replication was unsuccessful. Strikingly opposite interactions were reported for the ninth graders and the undergraduates. Although the low structure/low participation treatment produced the highest achievement for both groups, in the college sample the low structure/low participation treatment resulted in the highest achievement for students either high or low on both ability and anxiety. In contrast to the ninth graders, the college students high in ability and low in anxiety, or vice versa, performed poorest in the low structure/low participation treatment. These somewhat paradoxical findings were attributed to the overall higher ability levels of the college sample.

A study by Porteus (1976) provides limited support for the interactions reported by Peterson (1977). Porteus stud-

ied the achievement of high school students (N=56) in two subject areas: Economics and Philosophy. Two instructional treatments were included in the design: a teacher-centered and a student-centered method. Although a number of individual difference measures were used, for present purposes the anxiety measure (the TAS, see Spielberger, 1966) and the verbal ability measure will be discussed. The achievement measures included three multiple choice tests given throughout the course and an essay test. Not unlike the ninth graders studied by Peterson (1977), the students in Porteus' study who were high on both anxiety and ability or low on both did best in the teacher-centered treatment. Students who were high on one and low on the other tended to do well in the student-centered instructional method.

Using programmed instructional treatments, Crawford (1976) investigated the effects of a number of variables on achievement, among them were anxiety, motivation, and scholastic aptitude. An instructional program on physiological psychology was presented to undergraduates in a form requiring either constructed responses with feedback, or a reading only format. In addition, the program was designed to use three levels of difficulty for constructed responding, and two difficulty levels for the reading only mode. Half the students were given a pre-task designed to familiarize them with the instructional material and the other half received no pre-task.

It was reported that students high in test anxiety and low in achievement motivation achieved the highest post-test scores in the less difficult version of the material. Students high in achievement motivation and low in test anxiety, in contrast, achieved best on the more difficult versions of the material. However, when the interaction between test anxiety and instructional treatment was examined without regard for achievement motivation, no significant interactions were found. Conversely, when the interactions between achievement motivation and instructional treatment were studied in the absence of test anxiety no significant interactions emerged. This study lends some support to the Atkinson and Feather (1966) perspective on test anxiety discussed earlier and, further, it suggests the utility of studying the effects of test anxiety on the cognitive processing of instruction.

The literature also contains a few studies examining ATI's directly related to Tobias' (1977) information-processing model of test anxiety (see Figure 1). For example, Oosthoek and Akers (1973) reported that the performance of anxious students who could rewind an audio tape was facilitated compared with students assigned to a treatment without the rewind capacity. More importantly, the anxious students in this study tended to use the rewind option more frequently than the less anxious students. This suggests, in contrast to Wine (1980), that the highly anxious students in

this study had an awareness of their ineffective processing of the instructional input and attempted to reprocess the material by frequent use of the review option.

In a series of related experiments, Mayer (1976) studied the interactions between anxiety and instruction that varied the sequence and the pacing of the experimental treatment. In one particular experiment (#3), Mayer studied forty (40) subjects in a design that incorporated self-paced versus experimenter-paced groups. Subjects performed both rote memory tasks and cognitive tasks. Unlike his earlier study, in this study the low-anxious students outperformed those with high anxiety. However, the same pacing by anxiety interaction was found. Thus, the performance of the high-anxious students was greater in the self-paced condition compared to the experimenter-paced condition. No differences between experimental conditions were reported for the low-anxious students. With respect to the different tasks, an anxiety x task interaction was reported in which the low-anxious students outperformed their high-anxious counterparts on the cognitive tasks. No differences were reported between high and low-anxious students on the tasks for rote memory.

Deutsch and Tobias (1980) studied the ATI's in the relationship between anxiety and an instructional method which permitted a rewind or review of a video tape. In this study, 112 undergraduate students drawn from five classes in

Educational Psychology were assigned to either: (1) a group presentation of four video models without the option to review or replay the videotape; and (2) an individualized presentation of the same four video modules with the option to review the videotape freely. The results reported lend support to the hypothesis that being able to review instructional content is especially beneficial to students high in anxiety. Moreover, these findings imply that highly anxious students may benefit from instructional methods that serve to reduce the cognitive capacity demands of the task by providing students with a number of macroprocessing options such as reviewing, previewing, use of headings, etc.

In a study of the effects of test anxiety on learning at varying levels of processing, Weinstein, Cumberly, and Richardson (1982) reported a significant interaction between test anxiety and level of processing on a paired associate learning task. Ninety (90) female students were classified as either high or low test anxious on the basis of their scores on the Test Anxiety Scale (I. Sarason, 1978) and then randomly assigned to either a superficial or deep level processing group. The superficial processing group used a learning strategy in which they associated words within a pair by using only one aspect of the physical structure of the two words. In contrast, the deep processing group employed a strategy in which they associated the words in terms of meaningful similarity between them, or by using an

additional word that related the two words in each pair. The posttest consisted on a paired-associate learning task.

The mean performance of the subjects in the deep processing group ($X = 16.95$) was significantly higher than the performance of the subjects with superficial processing ($X = 4.83$). Moreover, the interaction of anxiety level and processing level was also significant, with the regression lines crossing within the range of level of processing (a disordinal interaction). The shape of the interaction suggests that the performance of the high-test anxious students using a deep processing strategy was significantly better than the performance of similar students using the superficial processing strategy.

In addition, the achievement of the low test-anxious students using a deep processing strategy was significantly greater than their high test-anxious counterparts using the same strategy. The performance of the students using the shallow level of processing, in contrast, was not significantly different across anxiety levels. Again, these results provide confirmation of the hypothesis that providing anxious students with instructional methods or processing strategies that serve to effectively reduce the cognitive capacity demands of the learning task will lead to increased achievement (Tobias, 1979, 1984a).

Achievement-Treatment ATIs. Most ATI researchers seek interactions between instructional methods and cognitive ap-

titudes such as intelligence or verbal ability. Tobias (1977a) suggested that examining the interaction between prior achievement, rather than aptitude, and instructional method may be more relevant to instructional research for a number of reasons. First, correlations between aptitudes and achievement from instruction vary dramatically over time, a finding most recently demonstrated by Federico (1983) and by Burns (1980). ATIs found at the beginning of an instructional program, then, may be irrelevant once the instructional sequence is underway. Second, it may be difficult to construct alternative methods of instruction by relying only on aptitude differences. Third, the specific psychological processes engaged by a particular content area can be sampled using an achievement oriented pretest, whereas more general aptitude measures may not provide such potentially useful information.

These concerns, among others, led to the hypothesis that the level of prior achievement is inversely related to the amount of instructional support required to facilitate achievement. That is, students with low levels of prior achievement in a particular content area are expected to require substantial instructional support to accomplish objectives. Conversely, those higher in prior achievement are expected to need little instructional support. Operationally, prior achievement is readily defined by students' pretest scores. Instructional support can be defined as the

assistance provided to the learner in terms of organizing the instructional content, eliciting responses, providing feedback regarding those responses and so on (Tobias, 1979). There is considerable research support for this hypothesis (Tobias, 1977a; 1981; 1982).

For example, it has been demonstrated that students with limited prior achievement learned most under conditions of maximal instructional support, whereas this effect was less marked for students with higher levels of prior achievement. Ott and Macklin (1975) studied the interaction between instructional method and prior achievement on achievement in a college level Physics course. A pretest designed on course content along with a measure of mathematical aptitude were used as an index of prior achievement. Instruction consisted of an audio-tutorial, mastery based method or the traditional lecture/recitation/laboratory method. Interactions were reported for the math aptitude measure and the pretest such that at the upper levels of aptitude and achievement the traditional lecture/recitation method led to superior achievement. The mastery based strategy was superior for students at the lower end of the aptitude-achievement scale.

Further support for the achievement x treatment hypothesis comes from a study by Skanes, Sullivan, Rowe, and Shannon (1974). These investigators reported interactions between pretest and the amount of instructional support in the form of type of practice on a letter series reasoning task.

Lower ability students performed better when training and posttest were identical when compared with a treatment in which similar but not identical training was provided; the opposite was found for higher ability students.

Additional support was provided by Tobias and Ingber (1976) in a study of the interaction between prior achievement and instructional support in programmed instruction. A linear program requiring constructed responses that had to do with Jewish rituals was given to a sample of 104 students from both Hebrew and Catholic schools. Instructional support was varied by assigning students to two treatments: (1) a constructed response with feedback; and (2) a reading only group. An interaction between pretest score and instructional support was found in which the superiority of constructed response treatment over the reading only treatment decreased with increases in pretest score. A more detailed review of this literature can be found elsewhere (see Tobias, 1977a; 1981).

It should be noted, though, that support for the prior achievement-instructional support hypothesis has been accompanied by some conflicting evidence (Tobias, 1982) suggesting that other, more subtle variables may be involved. This disparate evidence suggests that external differences between instructional methods may be less important than the way students process the instructional material. These findings led to a reformulation of the ATI hypothesis.

It was reasoned that for novel content all forms of instructional support would probably enhance students' active attempts to comprehend and organize the subject matter. For such content, providing support should enable students to process the content more deeply than they otherwise could. In such situations instructional support, such as providing objectives, advance organizers, or similar techniques may improve the ability of students to organize the material. Other support, such as eliciting overt responses, providing feedback, and using adjunct questions may facilitate achievement by making it easier for students to fix their attention on complex, novel content.

On the other hand, on familiar material high levels of instructional support may be unnecessary for a variety of reasons. It is assumed that familiarity reduces the difficulty of the material to be learned, despite its intrinsic complexity. Support to improve the organization of easy material may then be unnecessary, since students' knowledge of the subject matter may impose an organizational structure. Similarly, the high degree of attention required for novel material is unnecessary when students' have had considerable prior experience with similar or related content areas. For these reasons instructional support is not expected to improve achievement for students with high levels of prior knowledge. Such an analysis suggests that external differences in instructional methods are significant only to the

degree that they influence the cognitive processes used by students while engaged in instruction. As noted earlier, if external differences in instructional methods serve to reduce the cognitive capacity demands of the task, the achievement levels of highly anxious students should be enhanced.

Research examining the interaction between the level of instructional support and use of macroprocesses may shed light on this issue. Tobias' (1977a) review of ATI research revealed few replicable interactions between instructional variations and anxiety in individualized instruction. However, main effects for anxiety were generally found, indicating the achievement of low-anxious students was greater than for those higher in anxiety. Tobias (1977b, 1980) noted, though, that many of the experiments reported instructional variations that may not have been as directly relevant to anxiety as originally assumed.

Summary. The findings of the ATI research reported above are somewhat contradictory with respect to the information-processing research model presented by Tobias (1977b, 1980). In those experiments that manipulated variables not unlike those proposed in the model, the results were generally supportive. On the other hand, when the experimental manipulations were at variance with, or unrelated to, the parameters of the model, the results generated were non-significant. Not surprisingly, for those experiments examining a host of

individual difference measures and/or achievement variables, some related to the model and some not so relevant, the meaningfulness of the results was difficult to establish. Consequently, Tobias (1980) recommended the design of future ATI studies include methods for systematically varying the parameters of his research model.

Progress in ATI research, as the studies reviewed above clearly demonstrate, has been hampered by the absence of sound theory relating anxiety specifically to instructional treatments. Interference theories, introduced more than three decades ago, are re-emerging within a more cognitive framework which uses the language of the information processing theorists. Similarly, the current componential view of test anxiety (i.e., state/trait and worry/emotionality constructs discussed earlier) has served to enhance test anxiety theory and provide useful empirical methods to further research in this area.

Contemporary research efforts in the area of test anxiety must avail themselves of these emerging constructs. The present research, based on a limited capacity model, will incorporate the componential view of test anxiety into an ATI paradigm. Within this design, the level of instructional support provided to the learner was varied using a computer-based instructional program. As noted earlier, this was accomplished by manipulating the use of adjunct questions inserted in the text, and by allowing subjects to ex-

ercise a variety of macroprocessing options while engaged in meaningful learning.

In the following section a brief review of the research examining the use of adjunct questions in learning from prose will be presented and discussed. Indeed, the abbreviated nature of this review is stressed, since a more thorough review of the hundreds of studies on the use of adjunct questions is beyond the scope of this study. However, the more contemporary issues in adjunct question research will be discussed and prototypical studies will be presented in an effort to develop the conceptual framework for using adjunct questions as an instructional support variable.

Adjunct Questions Research

Experimental investigations of the effects of questions on learning from text date back more than fifty years (Washburne, 1929) and represent, perhaps, one of the most widely studied areas in educational psychology (see Anderson & Bidle, 1975; Rickards, 1979). In general, the adjunct question paradigm consists of interspersing questions in a passage of text contiguous to the material to which they relate. In a typical study one or two adjunct questions are inserted either before (prequestions) or after (postquestions) a segment of text - usually one or two pages of text. Adjunct questions and the related text segments are presented separately, and the reader is usually not permitted to

review the text once it has been presented. Upon completion of the entire passage, a posttest is administered to determine the amount of questioned (relevant) and non-questioned (incidental) material retained by the readers.

For the most part, studies of this sort have consistently reported that the prequestion group retains about the same amount of material directly questioned (relevant) as the postquestion group, and that both adjunct question groups retain more of the questioned material than a reading only control group (see Anderson and Biddle, 1975 for a more thorough review). This has been called the "direct instructive effect" (Rothkopf, 1966) or the "direct effect" (Anderson & Biddle, 1975). More important, however, these studies have demonstrated consistently that a postquestion group recalls more of the text material not actually questioned (an indirect effect) when compared with a prequestion group or a reading only control group.

From the standpoint of instructional support, a design using adjunct postquestions, as opposed to prequestions, was expected to reduce the cognitive capacity demands of the instructional task by facilitating more intensive cognitive processing of the text. Specifically, it was reasoned on the basis of both theory and research on the use of adjunct postquestions that postquestions would induce the 'macro' level processes of reviewing, sorting, and organizing the instructional material. By virtue of inducing these hypoth-

esized macroprocesses, adjunct postquestions would reduce the cognitive demands of the task and facilitate achievement.

Support for this aspect of the experimental design comes from Frase (1967) who reasoned that the direct and indirect effects of adjunct postquestions were the result of either "backward" or "forward" processing. For example, Frase wrote...

"The first (backward) hypothesis states that placing test questions after passages requires S's to review implicitly content which has just been read, therefore retention of the preceding material is facilitated. This hypothesis asserts that questions work in a backward manner, organizing and repeating previous prose content... The alternative hypothesis asserts that questions act in a forward manner optimizing mathemagenic behaviors on passages following the questions" (p.270).

Subsequently, Frase (1970) revised this position and suggested that both a backward and a forward process might be produced by adjunct postquestions. Nonetheless, including adjunct postquestions in the experimental design provided a means for manipulating instructional support levels and induced the use of macro level cognitive process strategies.

Theory

The theory surrounding the use of adjunct questions was based initially on a behavioristic view (Rothkopf, 1965). For Rothkopf and others (Frase, 1968a, 1968b; Rothkopf &

Bisbicos, 1967) the mathemagenic hypothesis proposed that adjunct questions function as discriminative stimuli for attentional responses to text, and the effects of selective attention account for the observed differences in reading outcomes. If the reader correctly answers an inserted post-question, it functions as a reinforcer with respect to the reader's prior processing (mathemagenic) activities.

Studies attempting to test the mathemagenic hypothesis aimed at identifying the processes initiated by a variety of adjunct question treatments. Verbatim questions were shown to influence general attention to text and to mediate selective attention to specific features of the text. Inspection time data and eye movement studies (Corrozi, 1970; Morasky, 1972), for example, provide objective data that adjunct questions affect attentional responses to text.

Numerous studies have reported support for the conclusion that mathemagenic positive and negative outcomes with verbatim prequestions are consistent with the effects of selective attention. For example, in ten of the fourteen adjunct prequestion studies reviewed by Anderson and Biddle (1975), prequestion groups scored higher than a control group, provided the test items tapped information directly related to the adjunct questions. Verbatim prequestions, it has been reasoned (see Frase, Patrick, & Schumer, 1970), serve to increase attention to questioned items while inhibiting responses to incidental content.

Verbatim adjunct postquestions, in contrast, have been associated with a general facilitation of text retention (Rickards, 1979). These postquestions may function as "test-like events" which focus attention to the text and facilitate both backward and forward text processing. Frase (1968) has proposed that backward review is initiated in order to answer a postquestion. Moreover, since the postquestion confirms the use of appropriate reading activities, it also exerts a forward influence on subsequent text processing.

As Rickards (1979) noted in his review of the adjunct postquestions literature, the paradigm shift to a more cognitive view of learning has served to modify the earlier neobehaviorist notions of mathemagenic activities and the associative model of learning. This paradigm shift is evidenced in the number of studies that have used adjunct postquestions to assess the "depth of processing" or conceptual level necessary to respond correctly (Duell, 1974; Rickards, 1976, and Rickards and DiVesta, 1974).

Initially proposed as a framework for understanding human memory (see Craik & Lockhart, 1972), the depth of processing metaphor has come to represent a useful way of analyzing reading comprehension. Within this framework, the "deeper" (i.e., more semantic) the processing, the better the comprehension. Thus, one sees the emphasis shifting to the processes underlying learning from prose, and a decrease in the

manipulation of variables such as position, frequency, and response mode that characterized earlier studies in this area. A more thorough discussion of this paradigm shift, including a review of those studies aimed at identifying the cognitive processes engaged by adjunct questions is presented by Rickards (1979).

Again, with respect to the present study the research and theorizing on adjunct questions is quite clear on their general role of facilitating a more intensive processing of the instructional text. Building on that body of research, adjunct postquestions were employed in the present study to enhance text processing and to permit manipulation of the cognitive capacity demands of the learning task across instructional treatments.

ATIs & Adjunct Questions

Despite the relative abundance of studies using adjunct postquestions, few investigations have been directed at the effects of individual differences on the effectiveness of adjunct postquestions inserted in text. For the most part, those adjunct question studies that have examined individual differences employed the ATI paradigm. Rothkopf (1972), for example, reported that low ability students (i.e., those with ineffective reading skills) achieved more under the adjunct questions conditions when compared to the no adjunct question group. The less proficient readers, he argued,

were aided in terms of increased inspection rates (attention to text) produced by the insertion of adjunct postquestions.

Hiller (1974) varied two sets of inserted postquestions designed to have significantly different levels of readability. Hiller also examined individual differences in verbal ability, anxiety and self-confidence as they interacted with four treatment levels: (1) relatively easy inserted postquestions; (2) relatively difficult inserted postquestions; (3) passive reading; and (4) idiosyncratic study. The scores on the immediate retention test for the difficult postquestion group reading the difficult lesson were correlated significantly with self-confidence. In contrast, significant negative correlations for test anxiety and the immediate retention test score for the same group of subjects were reported. Thus, learning was correlated with anxiety and self-confidence for the two treatments in which the text had lower than average readability, but not in the average readability level treatment.

Two factors have been advanced to account for these results: (1) immediate retention achieved by the difficult question group studying the moderately difficult lesson was significantly related to intellectual self-confidence; and (2) the deficits might be attributable to the fact that students experiencing difficulty with the postquestions may have attended more to the material directly related to the postquestion. This latter explanation suggests that diffi-

cult postquestions may serve to increase the cognitive capacity demands of the task and diminish achievement. Such an account is at least plausible given the reported negative correlations between test anxiety and achievement for this group in Hiller's study.

Shavelson, Berliner, Ravitch, and Loeding (1974) attempted to extend the study of the interactions between individual differences in aptitudes and instructional treatments by manipulating the position and type of questions inserted in prose material. Five aptitude measures were administered: (1) vocabulary; (2) hidden figures test for general ability; (3) letterspan or recall for letters; (4) Taylor Manifest Anxiety (Taylor, 1953); and (5) memory for semantic implications. To determine if aptitude x treatment interactions were present, total and incidental learning scores were regressed on the aptitude measures. No interactions between memory ability, as measured by the letterspan and semantic implications tests, and treatments were found. Moreover, anxiety and the hidden figures test did not interact with the treatments. The vocabulary score did interact with the treatments on both the immediate and the delayed retention test indicating that higher order adjunct questions placed after the text facilitated the performance of subjects with low vocabulary scores.

The majority of studies using adjunct questions have included instructions to the subjects not to review the text.

However, Gustafson and Toole (1970) permitted review and allowed their subjects to study a passage for as much time as they wished. Their results were, in general, consistent with the basic findings of a mathemagenic effect reported by Rothkopf (1966, 1972). The ability to attend selectively to, and presumably review, the questioned material produced a substantial improvement in intentional learning and a small improvement in incidental learning for the adjunct question group.

The selective attention dimension of adjunct postquestions was investigated in a series of studies conducted by Reynolds (see Reynolds, Standiford, and Anderson, 1979; Reynolds and Anderson, 1982). In the most recent investigation (Reynolds and Anderson, 1982), college students were asked varying types of questions after every four pages of a forty-eight page text on oceanography. The authors assumed that adjunct postquestions cause readers to selectively attend to question-relevant information. In addition to investigating attention, a pacing vs no pacing factor was examined as well.

Two operational measures of attention were used: (1) the amount of time a subject spends reading segments of the text; and (2) reaction time in a secondary task (i.e., while reading, the subject was instructed to depress a particular key as quickly as possible whenever a predetermined tone was sounded). Each of the twelve 4-page zones was divided into

24 segments of about 33 words in length. The text was rewritten so that each segment contained information that directly pertained to only one type of question. In other words, if a segment introduced a technical term, it did not contain any proper names. The text was edited so that each zone contained the same number of segments relevant to each type of question. Each zone was arranged so segments containing the same type of target information were always separated by segments with information of other types.

Probe reaction times were found to be significantly delayed when subjects were reading segments of the text containing question-relevant information. Furthermore, in the self-paced group, reading times were significantly longer on text segments containing question-relevant information. They concluded that readers were allocating more attention to the targetted information. Again, the reaction time paradigm used in these studies by Reynolds and his colleagues fortify the supposition that adjunct questions provide increased instructional support and deeper levels of cognitive processing.

Feedback as Instructional Support. A number of studies have provided feedback to adjunct questions in an effort to understand its role in instruction. In a study of the interaction between test anxiety and programmed instruction that varied the feedback provided to the students, Campeau (1965) looked at the achievement of eighty (80) fifth grad-

ers. Using analysis of covariance and controlling for both prior knowledge and IQ, Campeau reported that for the girls in her study the anxiety x feedback interaction was significant. High-anxiety girls achieved more than a low-anxiety group in a constructed response with reinforcement condition. When reinforcement was removed, however, the achievement of the lower anxiety subjects was higher. For boys, however, no significant effects were found in either the immediate or the delayed retention measure.

It should be noted, though, that the data for the boys and the girls were analyzed separately and, consequently, no conclusions can be drawn regarding the presence of main or interactive effects for sex as an explanatory variable. Moreover, cutoff scores for both the high and low-anxious students were used which corresponded to the upper and lower quartile of the distribution of the TASC (S.Sarason, et al., 1960). Using only the scores of these extreme groups weakens the analysis somewhat, since approximately 30% of the variance in the TASC remains unanalyzed (Cohen, 1968; Cronbach & Snow, 1977).

In a more recent study, Oner (1977) used one hundred sixty (160) 6th graders in an experiment that required learning material on the use of decimals in mathematics. Instructional treatments were varied with respect to providing feedback as to correctness of responses and the level of teacher support available. A main effect for anxiety was

reported with low-anxious students outperforming their high-anxious counterparts. However, the predicted interactions between test anxiety and level of teacher support, as well as test anxiety and feedback, were not found.

In a study designed to assess the effects of feedback and review on learning from text, Kulhavy, Yerkovich, and Dyer (1979) presented 120 undergraduates with a 25 frame instructional program on heart disease (see Tobias, 1968). The subjects either did or did not receive feedback after each adjunct postquestion response. Half of the subjects in the feedback groups were allowed to see the programmed text while responding to adjunct questions. It was reported that the presence of feedback led to higher posttest recall and reduced program errors.

Further, it was reported that subjects who did not receive text while responding spent more time reading per frame. Apparently, when students know they can refer only once to the text, they read more carefully and with a consequent increase in retention. These results, however, may be confounded by the fact that subjects were apparently able to "peek" at the instructional text while responding to the adjunct postquestions. Future studies need to be concerned about the possibility of subjects previewing, reviewing, or "peeking" at the text in advance.

In their review of the literature on feedback and programmed instruction Hyman and Tobias (1980) noted that ex-

periments that have varied feedback when using programmed materials have reported somewhat inconsistent findings. These inconsistencies may be attributed to the experimental designs used which, invariably, did not control for the students ability to preview or review the instructional material in an effort to provide themselves with feedback. Moreover, prior achievement was not controlled for in any systematic way.

The results of their study, along with the review of prior research regarding the effects of feedback, led Hyman and Tobias (1980) to conclude that feedback is more likely to lead to increments in learning, particularly with respect to the degree with which feedback engages students to attend to the material, understand it more thoroughly, and determine the relationships between the content of the subject matter and their prior experiences.

In a meta-analysis of studies using feedback in programmed instruction Schimmel (1983) reviewed research that employed two types of feedback: simple confirmatory feedback, which informs the learner whether a response to an adjunct question was correct or incorrect, and feedback which provides the correct answer. Schimmel reported that learners receiving either type of feedback out performed learners receiving no feedback in the fifteen studies he subjected to analysis.

Research on the role of feedback or knowledge of correct response suggests that providing feedback as to the correctness of a response may be yet another means of varying the level of support of an instructional treatment. Schimmel's (1983) meta-analysis of feedback research supports this notion. In studies using computer-assisted instruction, for example, Schimmel reported that feedback was considerably more effective in promoting learning than an instructional program providing no feedback to the student.

This limited body of research, however, is inconsistent with respect to the presence of interactions between feedback and level of anxiety. In the present research feedback was used in the experimental design of the instructional support variable. In this way instructional support could be varied from high (adjunct postquestions and feedback), to medium (adjunct postquestions with no feedback), to low (a reading only control group), and the relationship between feedback and test anxiety could be examined empirically.

Summary

The adjunct question studies presented above have varied with respect to the individual difference dimensions investigated. Despite these variations, one salient point has emerged: the more support the adjunct question treatment provides to the learner, the greater the achievement. When students are asked questions that are directly relevant to

the material to be learned, their achievement increases. When adjunct postquestions lead to increased attention, that treatment, in turn, produces increased learning. More important, the assertion that adjunct questions apparently serve to reduce the cognitive processing demands of the instructional task finds support in this body of research. In addition, it appears that providing feedback as to the correctness of a response to an adjunct question will facilitate achievement by reducing further the cognitive processing demands of the task. Both of these methods were used in the present study to test those assertions.

Study Strategies Research

In the past instructional research has followed the routine of offering evidence for the effectiveness of a "new" instructional method by comparing it with more "conventional" methods. In addition to the more general problems of fidelity of treatment, implementation, and evaluation (see Montague, Wulfeck & Ellis, 1981), this type of comparative research ignores the hypothesis that learning from instruction is a function of the frequency and intensity with which students cognitively process the instructional material (Tobias, 1982).

The underlying assumption is that the "new" method induces more intensive cognitive processing. And in turn, these processing differences produce improved achievement for stu-

dents taught by the "new" method. A major problem, however, is that we know little about the types of cognitive processes students employ in meaningful learning. Moreover, we also know little about whether variations in the external characteristics of a method lead to differences in the type or frequency of cognitive processing. Thus, it has been hypothesized (Tobias, 1982) that alternate instructional methods will lead to different outcomes only if they induce effective macroprocessing activities. Implicit in the notion of macroprocesses are behaviors on the part of the learner such as planning, reviewing, checking, and monitoring.

Macroprocesses

A common distinction in physics is between micro- and macro-properties of systems, i.e., the small and the large scales. The micro and macro distinction is useful in the study of cognition and human learning, as well. In the main, the body of research under the rubric of cognitive psychology or cognition has made great use of the micro-process level by studying the information-processing constructs of encoding, storing, and retrieving (J. Anderson, 1980). On the cognitive macro-process level, however, little or no research has been conducted. The research effort described in the chapters that follow represents our initial attempt at investigating the cognitive macroprocesses used by students engaged in meaningful learning.

For purposes of this research, the term macroprocesses is defined as those relatively molar cognitive processes students use when learning from meaningful instruction, such as previewing, reviewing, seeking clarification, and the like. These activities, of course, could be referred to as study skills or metacognitive strategies and it would be useful to distinguish macroprocesses from these other terms. The term study skills as used by Weinstein (1978), and by Dansereau (1978) and others, (Brown & Smiley, 1978) imply both cognitive activities such as encoding and storing information and affective states such as anxiety, motivation, and attitudes. Macroprocesses, on the other hand, denote only the molar cognitive process activities used by students to learn from instruction. Moreover, metacognitive strategies (Brown, 1980) imply a degree of self-monitoring of one's knowledge that the term macroprocesses does not.

Tobias (1982) presents the concept of macroprocesses in the following way:

"In the case where comprehension and review questions are embedded in text, and when feedback is provided, what do students do when they have been informed that their answer is wrong? Do they pause to figure out why they were wrong? Do they review previously learned material? If material is reviewed, do students spend equal amounts of time skimming over every part of it, or do they search for a particular set of materials? When students are supplied with objectives do they consult them frequently while studying or look at them only once? Do they skim for context related to the objectives and ignore other material?" (1982, p.8).

Macroprocess Research

Since macroprocesses are concerned with students' processing of meaningful instruction, the research on study skills such as previewing, reviewing, and notetaking is clearly relevant. For the most part study strategies research has been concerned with improving achievement from instruction by advocating a number of varying techniques. Thomas Anderson (1980) reviewed the literature concerning the effectiveness of a variety of study strategies. This review included comparisons of student generated study strategies and adjunct study aids. The student generated aids included notetaking, underlining, imaging, outlining and paraphrasing, among others. Adjunct aids included the use of adjunct questions and advanced organizers. Anderson concluded that, in general, the adjunct study aids produced the strongest evidence of effectiveness. He reasoned that

these particular strategies serve to induce deeper and more specific forms of cognitive processing of the instructional material than student generated strategies.

Research on the use of adjunct questions has shown little concern with the types of cognitive processes subjects engaged in during instruction. Much of the information regarding the types of macroprocesses used by students has been inferential (Winne, 1981). That is, investigators infer the type of cognitive processing from the results of the research. For example, the "forward" and "backward" effects of adjunct questions reviewed earlier are inferred from the types of adjunct questions subjects answer correctly after reading the text.

With few exceptions (Gustafson & Toole, 1970; Hiller, 1974; Schumacher, Moses, & Young, 1983; Washburne, 1929), research on the use of adjunct questions has prevented subjects from rereading or reviewing the text once an adjunct question has been presented. This reviewing constraint, as Schumacher et al., (1983) noted, may seriously alter study strategy behavior and, therefore, calls into question the inferences drawn from the mathemagenic theory of adjunct questions, since the use of inserted questions in more natural educational settings (i.e., when using textbooks) may have lessor effects and would not necessarily force mental review when students can readily look back into the text.

In a series of studies designed to monitor the reviewing activities employed by subjects when presented with adjunct questions, Schumacher et al., (1983) used the eye movement paradigm to observe reviewing and text searching activities. The results of these studies provided equivocal evidence that adjunct questions influence studying processes. For example, these investigators reported a positive effect for adjunct questions on relevant posttest items only. No indirect effect was found. More important, although the adjunct questions produced more reviews or "lookbacks", this active interaction with the text did not lead to significantly better performance on relevant posttest items in their study. This finding is not surprising, since the theoretical link between eye movement behavior and higher level cognitive processing remains to be established (Rayner & Carroll, 1984). It has been argued, for example, that if eye movements are rhythmic or random or if the fixation duration is a function of the visual characteristics of the text, their use as indices of language comprehension or cognitive processes may be severely limited.

There have been a number of studies recently that have used the self-report and/or the experimenter-observer paradigms to examine the relationship between achievement and strategy use. Peterson, Swing, Braverman and Buss (1981) studied student macroprocesses by video taping lessons on probability taught to fifth and sixth graders (N=72). Sub-

jects were subsequently interviewed, using a stimulated recall procedure, regarding their cognitive processes during instruction. The cognitive processes identified included such things as attending, understanding, and relating instructional material to prior knowledge. The results of a correlational analysis indicated that subjects' reports of their cognitive processes were, in general, significantly related to a set of outcome measures. The strength of these relationships, using Kendall's tau, were in the .2 to .3 range. Moreover, the correlation of reported cognitive processes with scores on the Sequential Test of Educational Progress (STEP) and the Raven's Progressive Matrices were also significant.

Garner and Reis (1981) investigated reading "lookbacks", i.e., reviewing previously read material, among good and poor readers in grades 4 thru 10 using an experimenter-observer procedure. Reviewing was explicitly encouraged, and the investigators monitored the lookback behaviors. Their results indicated that only the older good readers used the reviewing strategy with any frequency or degree of success.

In a further study, Alexander, Hare, and Garner (1984) investigated review strategies among older (undergraduates), proficient readers. Prior to instruction subjects were asked what strategies they would use on a task that required reading a passage and answering subsequent questions. After the instructional task, subjects were then asked what strat-

egies they actually used. It was reported that those who said they used a particular strategy (e.g., underlining or reviewing), actually did so and, conversely, very few subjects used a strategy that they had not previously reported. However, the rather surprising result of this study was that more than half (29 out of 52) of these older, proficient readers failed to review the text at all. The authors noted that this may be an artifact of their design, since many students reported that they thought they were not permitted to look-back or review the material. However, there is some evidence that even experienced, good readers do not routinely use certain strategies thought to be in their repertoire (Alexander, Hare & Garner, 1984).

Alvermann and Van Arnam (1984) used an ATI paradigm to examine the relationship between reading ability and induced review. Their results suggest that poor readers were assisted by increased levels of instructional support (i.e., the use of graphic organizers). Moreover, the inducement of review or "lookbacks" was reported to have resulted in superior performance for poor readers.

In a pilot study for the present experiment we asked students to generate a list of all of the study strategies they used when learning from text. Student responses were submitted to content analysis and the single most prominent strategy appeared to be reviewing, followed by underlining, preparing summaries taking notes, skimming, obtaining extra

help by use of dictionary, and consulting title headings. A number of these student identified strategies were included in the design of the present study and operationalized under the more general category of macroprocesses.

In a more direct study of macroprocesses Tobias and Sacks (1983) assigned students to one of three conditions: (1) adjunct questions; (2) adjunct questions plus review; and (3) a reading only control group. This design, which served as a field test for the instructional material used in the present investigation, required subjects to record the time spent on reading, time spent answering adjunct questions, as well as time and frequency of reviews. Prior knowledge and test anxiety were used as covariates, as well.

Regression analysis produced no interactions. However, main effects for prior knowledge were found on both relevant and incidental posttest items. Contrary to expectations, the optional review group, the group hypothesized to process the instructional content more thoroughly, did not demonstrate greater achievement than the other two groups. Observation of student behavior and further analysis of the results suggest that the review option may not have been used effectively because of the inconvenience of doing so. That is, subjects using the review option in this design were required to record each use of the review option as well as the time it took to use it. These requirements, may have served as disincentives for reviewing the text.

Summary of Research

As is evident from the preceding review of the literature, there are a number of converging lines of evidence supporting the general hypotheses of a limited capacity model outlined earlier. These include research on the interactions among a variety of individual difference measures and instructional method, research on the effect of adjunct questions, and research on a variety of study strategies used by students engaged in meaningful learning.

Research has also indicated that adjunct questions are an important source of instructional support in that they typically improve the achievement of students on material relevant to the content of the questions. For example, instructional programs using adjunct questions, and in particular adjunct postquestions, have consistently demonstrated greater achievement when compared to reading-only instructional programs (see, for example, Ellis, Konoske, Wulfeck, & Montague, 1982). Although the ATI literature is less than conclusive about the role of feedback in the achievement of high-anxious students, it is reasonable to assume that feedback as to the correctness of a response to an adjunct question may, indeed, facilitate achievement by decreasing the cognitive capacity demands of the learning task and thereby enhancing the level of instructional support to the student.

There is a good deal of evidence to suggest that the level of instructional support provided to the learner inter-

acts with individual differences. Research on individual differences in anxiety and studies examining the effect of adjunct postquestions converge on this point. Studies manipulating the "depth of processing" of highly anxious learners (Weinstein, et al., 1982), for example, provide clear support for the notion that instructional support interacts with learner characteristics. ATI research relating prior achievement and instructional support has, in general, supported the hypothesis of an inverse relationship between these variables. That is, generally, students with little relevant prior experience typically profited most from instructional methods offering substantial instructional support, whereas such support was often of little benefit to students with high levels of relevant prior experience.

While there has been a good deal of speculation about the mechanisms by which adjunct questions achieve their effect, little direct evidence regarding the underlying processes is available. Conflicting findings in this area, and in ATI research in general, have led to an emphasis on the cognitive processes engaged by instructional methods and by student characteristics. Recent efforts to investigate cognitive processing strategies have relied on two methods: (1) the eye movement paradigm; and (2) verbal report methods. However, both procedures have severe limitations.

With respect to the verbal report methods, the criticisms, in general, revolve around the historical issues as-

sociated with introspective techniques, reliance on verbal reports and the verbal ability of the subject, and the tendency of students to report the use of strategies they believe they ought to have used. The eye-movement paradigm has come under criticism on three fronts (Rayner & Carroll, 1984). The first concern has to do with perceptual span or useful field of vision during an eye fixation. This goes directly to the question of how much information a reader gathers and uses during a single fixation. The second issue, alluded to earlier, has to do with eye behavior reflecting ongoing mental activity. The question remains unanswered as to the relationship between eye fixations and cognitive processing. The third issue is a practical problem having to do with how eye movement is tracked and the difficulties attending the analysis of such data.

The study presented here attempted to address the issues of whether anxiety interacts with the level of instructional support provided to the learner. Moreover, the newly emerging concept of "macroprocesses" was incorporated into the design to explore the specific behaviors (e.g., previewing, reviewing, notetaking, etc.) engaged by learners who vary with respect to level of test anxiety, prior knowledge, and instructional support. Microcomputers were used to present the instructional treatments and to collect data on the frequency of use of a variety of macroprocesses. Such a paradigm, though new and relatively untested, was used with the

hope of avoiding the methodological problems associated with studying cognitive processes using self-report or eye-movement procedures.

In this investigation the macroprocesses used by subjects were defined in terms of the instructional options selected while studying text. For example, all subjects had the option to do any of the following: preview text, preview headings, take notes on the computer system, review text, and review their own notes. Additionally, a number of investigators (Leinhardt, Zigmond & Cooley, 1981; Tobias, 1982) have suggested that identifying the point where students become confused is important for understanding strategy use. In an attempt at that, the instructional program contained an option for reading and reviewing an alternate, easier version of the text. Subjects were encouraged to use this macroprocess when they experienced confusion or comprehension failure. Thus, the present study set out to examine the macroprocessing differences between instructional methods and, hopefully, begin the investigative process of specifying the effective, as opposed to nominal, characteristics of different instructional methods.

Chapter III

HYPOTHESES

The thrust of the present study was to determine whether different instructional methods, such as providing text augmented with adjunct questions, or adjunct questions with feedback, reduce the cognitive capacity demands of an instructional task and enhance the achievement of highly test anxious students. In a parallel fashion we also investigated whether students' use of a variety of macroprocessing options affected achievement. Using a computer-based instructional program which varied in terms of instructional support, we tested the following hypotheses:

Hypothesis 1

All subjects, regardless of their level of test anxiety, when assigned to an instructional treatment providing adjunct postquestions would demonstrate greater achievement on both adjunct question relevant and incidental posttest items than students assigned to a reading only treatment. This was a direct test of the hypothesis that adjunct questions reduce the cognitive capacity demands of the learning task (Rothkopf, 1972). Thus, a main effect for instructional treatment was expected. The rationale for this hypothesis comes from prior research on adjunct postquestions discussed

earlier which documented both the direct and indirect instructional effects of adjunct questions.

Hypothesis 2

Subjects assigned to the optimal support treatment will demonstrate greatest achievement on both relevant and incidental posttests. Thus, it was expected that subjects assigned to an instructional treatment providing both adjunct questions and feedback would demonstrate greater achievement on both adjunct question relevant and incidental posttest items than either the adjunct question or reading only groups. The rationale for this hypothesis was based on research suggesting that feedback reduces the cognitive capacity demands of the task by enhancing the direct effect of adjunct postquestions (Rothkopf & Billington, 1974).

Hypothesis 3

An interaction between test anxiety and treatment was predicted such that less anxious subjects assigned to the reading only treatment would demonstrate greater achievement on an immediate posttest than highly anxious subjects in the same group, while no achievement differences were expected between high and low anxious subjects assigned to treatments providing increased instructional support. This hypothesis represented a clear test of our research model (Tobias, 1980) and stemmed from the assumption that anxiety's cogni-

tive dimension, worry, interferes with effective processing of instruction and treatments designed to reduce the cognitive capacity demands of the instructional task would be selectively beneficial to highly anxious subjects since they are presumed have less capacity available for processing for task demands (Tobias, 1984a).

Hypothesis 4

High-anxious subjects were expected to review the instructional material more frequently than low-anxious students, regardless of the level of instructional support provided. As such a main effect for anxiety (i.e., worry) was expected with respect to the number of sentences reviewed. Again, this hypothesis attempts an explicit test of Tobias' (1977b, 1980) research model, and stems from the assumption that worry interferes with effective processing of instructional material and highly anxious subjects, when presented with a review option, will engage that option to reduce the effects of cognitive interference.

Hypothesis 5

Frequency of use of the macroprocesses was predicted to be positively correlated with achievement on the posttest for all subjects. This hypothesis was based on the study strategies research reviewed earlier which suggested that effective use of learning strategies produces increased levels of achievement (T. Anderson, 1980).

Chapter IV

METHOD

Subjects were randomly assigned to read an instructional text displayed by microcomputer in one of three different methods. In each condition subjects could use a variety of options to facilitate study of the text. Individual difference data, including measures of reading ability, prior knowledge, and anxiety were collected along with data on subjects' use of the macroprocessing options. Achievement was measured by an immediate posttest.

Subjects

Volunteers for this experiment were recruited from the student population of the City College of New York. A total of 120 subjects participated in the study. The sample was comprised of 68 males and 52 females and their average age was 21. Subjects were screened for their familiarity with computers and/or their knowledge of programming languages. Potential participants indicating familiarity with computers and/or programming did not take part in the study. The rationale for the screening of participants stemmed from the experimental need to control for prior experience with microcomputers and to ensure increased levels of learning attributable to the instructional material. Examples of the

Subject's Consent Form and Identifying Information Form appear in Appendix A. Subjects were paid \$12 for their participation in the study.

Experimental Groups

Subjects were randomly assigned to one of three different instructional treatments: (1) an adjunct postquestion plus feedback group which represented the highest instructional support treatment; (2) an adjunct postquestion group which represented a mid-level instructional support treatment (no feedback); and (3) a reading only control group that received no adjunct postquestions and represented the lowest instructional support treatment.

In both adjunct postquestion treatments subjects were required to respond to one adjunct postquestion at the end of each of the 22 CRT screenfuls of text (i.e., every two paragraphs). For the treatment group receiving feedback subjects' responses were evaluated by the computer and three classes of feedback were provided: (1) subjects were informed that their response was identical to the answer provided in the text; (2) the response was similar to, or equivalent to one provided in the text; and (3) the response appeared to be incorrect and the correct response was provided.

Materials

Anxiety Measures

Two measures of anxiety were used in this study. The Test Anxiety Scale (I. Sarason, 1978) is a commonly used measure of "trait" anxiety or anxiety-proneness in an academic testing situation. The Worry-Emotionality Scale (Morris, et al., 1981) is a "state" measure of aroused anxiety (situational anxiety) developed for evaluative situations. Spielberger, et al. (1970) address the issue of the validity of state measures of anxiety in terms of their ability to reflect stress. Validation data of this type can be found in the test manual for the state-trait anxiety inventory (Spielberger, Gorsuch, & Lushene, 1970).

Test Anxiety Scale (TAS). - the TAS (I. Sarason, 1972) is a 37-item instrument for measuring self-reported anxiety. The TAS is a pencil and paper measure based largely on the items from the Mandler and Sarason (1952) Test Anxiety Questionnaire and re-written in a true/false format. The TAS was developed from the earlier Test Anxiety Questionnaire (TAQ) but avoids the cumbersome scoring techniques used in the original TAQ (Levitt, 1967). Test-retest reliability coefficients in the range of .80 to .87 have been reported using the TAS (Wagaman, Cormier, and Cormier, 1975; I. Sarason, 1978).

Since the TAS is a measure of trait anxiety, it was administered prior to pretesting. The TAS was presented as a

scale of attitudes toward test taking rather than as a measure of anxiety. The TAS along with the instructions for administering it may be found in Appendix B.

Worry-Emotionality Scale. - the revised worry-emotionality scale (see Morris, et al., 1981) contains ten statements designed to measure a subject's state anxiety by evaluating the worry and emotionality components of test anxiety. These items were developed from items on the Test Anxiety Questionnaire (Mandler & Sarason, 1952). Alpha reliability coefficients for the Worry-Emotionality Scale were reported as .83 and .76 for emotionality and .68 and .69 for worry (Deffenbacher, 1980).

Each of the 10 statements is rated on a 1 to 5 scale indicating how much the feelings, attitudes, or thoughts apply to the subject at the time of testing. Thus, the range of scores for each subscale can vary from 5 to 25, with increasing scores indicating more worry or emotionality. The Worry-Emotionality scale was administered at three distinct points during the experiment: upon completion of the pretest, midway through the computer-based instructional treatment, and immediately following the posttest. An example of the Worry-Emotionality Scale can be found in Appendix C.

Nelson-Denny Reading Test. This standardized reading test is composed of two subtests, vocabulary and comprehension (see Appendix D). The vocabulary subtest consists of

100 multiple choice items, each with five answer choices, and has a 15 minute time limit. The comprehension subtest contains eight reading passages and a total of 36 multiple choice type questions, each with five answer choices. This subtest has a 20 minute time limit. The median alternate-form reliability coefficient for the vocabulary subtest is reported to be .92, and for the comprehension subtest the alternate-form reliability coefficient is reported as .77.

Raw scores were obtained for each subtest by following the directions for scoring the test (Brown, Bennett, & Hanna, 1981). The raw scores on both subtests were used in subsequent analyses.

Pretest. The pretest was designed to measure prior knowledge of the fundamentals of the computer programming language BASIC. It was a pencil and paper exam consisting of fifty items in a multiple choice format with four answer choices. The pretest had an Alpha reliability (Cronbach, 1951) coefficient of .75. Subjects correctly answering 31 or more (i.e., 62%) of the pretest items were screened-out and did not complete the remainder of the study. A cut-off score of 31 or more correct was used as an objective means of assuring a subject pool with a limited amount of prior knowledge of computer programming languages (see Appendix E).

Instructional Text. The instructional material consisted of 173 sentences making up roughly forty-nine paragraphs of expository text. The text presented some major concepts of data processing, computer programming, and a sample of illustrative commands of the BASIC programming language. The text was estimated to require a 14th grade reading level (Fry, 1969). The following paragraph is a representative sample of the text:

A computer is a tool for representing and manipulating information. There are many different types of computers, ranging in size from hand-held calculators to large and complex computing systems filling several rooms or even entire buildings. In the recent past, computers were so expensive that they could be used only for business or scientific computations. At present costs have decreased by many orders of magnitude and personal computers available for use in the home are in the same price range as color television sets.

Each of the 173 sentences in the text was numbered and exposed one at a time. When a sentence was read and the space bar on the computer's keyboard depressed, it was erased though the space it occupied and its number remained.

In addition, an alternate, easier to read version of the instructional text was also available for optional use by subjects. This version of the text had the same content as the main text in every paragraph, but used an easier vocabulary (i.e., the 10th grade level according to Fry's formula). The following is a sample of the alternate, less difficult version of the text available to all subjects:

Computers are useful because they can store and process information. There are many kinds of computers. Some are small enough to hold in your hand, others are so large that they take up many rooms and even whole buildings. Computers used to cost so much that only large companies or scientific organizations could afford them. Now costs have come down and computers for use in homes cost only about as much as color television sets.

The alternate text was structured so that superordinate concepts and sentences preceded subordinate ones to a greater extent than in the main text (see Appendix F).

Adjunct Postquestions. As noted earlier, in both adjunct question treatment groups subjects were required to answer one adjunct postquestion at the end of each screenful of text. One adjunct question was inserted after every two paragraphs of text. The adjunct questions were designed to facilitate retention of the instructional material by asking subjects to recall facts, apply rules, and synthesize information. A complete list of all 22 adjunct questions appears in Appendix G.

Posttest. The posttest used in this study was pencil and paper test designed to measure the subjects' achievement from the instructional treatment and was based entirely on the instructional text. The posttest consisted of 44 items requiring constructed responses (see Appendix H). Seven of these items required multiple responses. Scores on the

posttest ranged from 6.5 to 48. Moreover, for use in subsequent analyses the posttest was divided into two subtests: adjunct postquestion relevant items and adjunct postquestion incidental items. The posttest, then, was comprised of 22 relevant items and 22 incidental items. The posttest had an Alpha reliability (Cronbach, 1951) coefficient of .92.

Procedures

As Figure 2 illustrates, the experimental procedures were administered in two sessions. In the first session subjects were administered the following: (1) the Test Anxiety Scale (Sarason, 1978). (2) a pretest covering the instructional material; (3) the Worry-Emotionality Scale (Morris, et al., 1981) with instructions to the subjects to complete it in terms of the way they felt at the moment; and (4) the Nelson-Denny Reading Test (Brown, et al., 1981). These materials were administered in group settings ranging from three to 35 subjects.

EXPERIMENTAL PROCEDURES

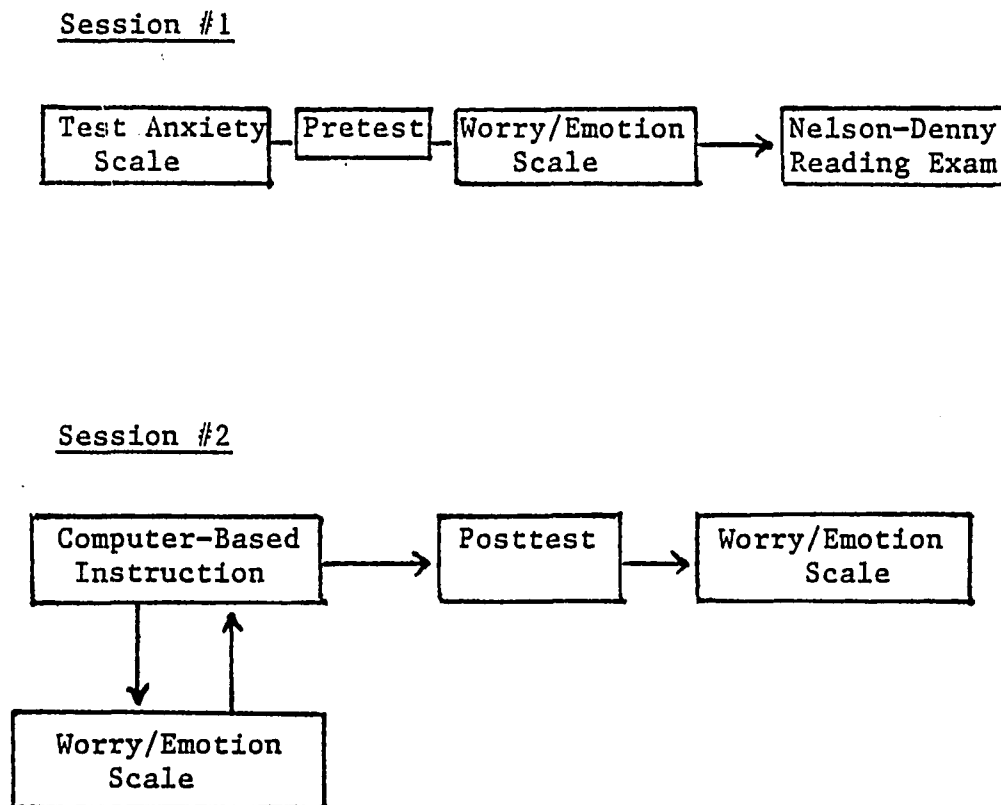


Figure 2. Flow Chart of the Experimental Procedures

In the second session subjects were assigned to microcomputers to study the text. When each subject completed one half the instructional material the Worry-Emotionality Scale (Morris et al., 1981) was administered by the computer with instructions to respond the way they felt while studying the material. Upon completion of the instructional material, each subject completed a paper and pencil version of a constructed response posttest described earlier and another version of the Worry-Emotionality Scale with instructions to report how they felt while working on the posttest.

The instructional materials were presented using Apple II microcomputers. The time subjects spent reading each text segment, along with their responses to all adjunct questions, were recorded automatically by the computer. In addition, the computer recorded each subject's use of the macroprocessing options described below.

All subjects could choose any of these options while reading the text: they could (1) review, or; (2) preview any sentence, or group of sentences; (3) consult the alternate version of the text after completing a paragraph; (4) the alternate text could be reviewed, or; (5) previewed; (6) subjects were able to take notes on the computer system; (7) and review their notes; (8) an organizational display could be requested containing all the headings in the main and alternate texts, the sentence numbers covered by each heading, and the number of the sentence the subject was presently

reading; and (9) a menu of the options available, and how they could be invoked could also be requested.

The macroprocessing options described above could be invoked by subjects at any time during the course of the presentation with two exceptions: (1) the adjunct question groups could invoke the options only after they had responded to the question; and (2) the alternate version of the text could be requested only after a complete paragraph had been read. A beep was sounded by the computer at the end of a paragraph signaling that the alternate version of the text could be consulted.

Prior to the beginning of the instructional presentation, a description of each of the options was provided. The description required subjects to use each option at least once to ensure familiarity with the procedures prior to instruction. The options available for use by subjects were presented at the bottom of each and every screenful of text. After the first few introductory remarks, the descriptive material followed the same structure as the ensuing instructional material, i.e., each sentence was numbered and presented one at a time and the space bar on the computer's keyboard had to be depressed to produce the next sentence. A text of the instructions for using the computer-based options is presented in Appendix I.

Feedback. Subjects assigned to the adjunct question and feedback treatment received evaluative feedback as to the

correctness of their response to the adjunct question. Once the subject responded to the question the computer evaluated the answer and, in turn, informed the subject that his or her answer was (1) identical to the one provided in the text; (2) similar to the one provided in the text; or (3) incorrect. The subjects' responses to the adjunct postquestions, along with the evaluative score, were stored by the computer for subsequent analysis.

Chapter V

RESULTS

This chapter presents the results of the study. The first section presents analyses of the individual difference data with particular emphasis on the relationship between anxiety levels and achievement for each experimental group, including the the results of both multivariate and univariate multiple regression analyses (Hull & Nie, 1981) of the relevant and incidental posttest items. The second section describes the results of both multivariate and univariate regression analyses of the macroprocesses. These data focus on the effects of prior achievement, worry, and instructional method on the use of the various macroprocesses. The third and final section in this chapter presents correlational data examining the relationships among the use of the various macroprocesses and achievement on the posttest for each experimental group.

Individual Difference Data

Test Anxiety. Observed scores on the TAS ranged from a low of 1 to a high of 31 with a mean of 18.2 and a standard deviation of 7.08. The three Worry subscales (i.e., Worry 1, Worry 2, Worry 3) of the Worry-Emotionality Scale had a range of scores with a low of 5 and a high of 24. The three

Emotionality subscales (E1,E2,E3) ranged from a low of 5 to a high of 24. An examination of the means for both subscales suggests that, in general, subjects' worry scores tended to increase throughout the experimental session with the mean worry score reaching its peak following the posttest. Subjects' emotionality scores, on the other hand, remained relatively constant throughout the investigation. Table 1 displays the means and standard deviations of the individual difference variables, the macroprocessing options, and the posttest scores for each experimental group.

The correlation of the TAS (trait) and Worry (state) measures of anxiety ranged from .35 to .48, while the correlation of TAS with the Emotionality measures had a slightly lower and more restricted range of .27 to .37. The correlations among the subscales of the Worry-Emotionality Scale were, as expected, quite strong ranging from .27 to .83. Table 2 presents the intercorrelations of the various trait and state test anxiety measures, pretest, and reading ability subtests for the entire sample.

Table 1. Means and Standard Deviations of Major Independent and Dependent Variables by Group.

<u>VARIABLE</u>	<u>Adj.Q's/Feedback</u>		<u>Adj.Q's</u>		<u>Control</u>	
	(N=38)		(N=39)		(N=43)	
	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>
Test Anxiety	17.00	6.46	17.97	8.28	19.44	6.35
Worry 1	8.16	3.67	8.61	4.28	8.67	3.84
Emotion 1	7.39	3.85	8.05	4.66	6.67	2.23
Worry 2	9.24	3.91	9.61	4.65	9.32	4.04
Emotion 2	7.53	3.68	7.02	2.58	8.05	3.56
Worry 3	8.59	3.36	9.76	4.61	11.86	5.57
Emotion 3	7.22	3.54	7.50	3.87	7.78	3.56
Vocabulary	41.18	21.13	41.45	23.10	38.23	22.27
Comprehension	29.60	14.69	30.74	18.32	27.28	16.27
Pretest	19.45	7.41	20.77	5.77	19.12	5.45
Previews	1.05	2.51	1.74	3.54	1.63	3.04
Reviews	9.55	20.06	16.23	22.24	9.93	18.19
Alt.Text	4.74	13.04	37.49	47.32	15.39	27.48
Review Alt.	2.27	10.36	4.29	9.94	3.46	9.75
Notes	3.79	5.98	5.54	7.67	9.10	10.97
Review Notes	0.29	0.96	0.68	1.09	0.92	1.64
Headings	0.58	1.11	0.92	1.53	1.38	1.93
Posttest R	17.56	5.29	17.91	5.99	13.91	5.15
Posttest I	13.14	5.40	14.84	5.86	11.99	5.05

Table 2. Intercorrelation of Test Anxiety,
Pretest and Reading Scores.

	TAS	Pretest	ND Voc	ND Comp	W/E1	W/E2	W/E3
TAS	1.00						
Pretest	-.16	1.00					
ND-Voc.	-.04	.10	1.00				
ND-Comp.	.05	.03	.77	1.00			
W/E1	.40	.03	-.16	-.13	1.00		
W/E2	.42	-.06	-.26	-.19	.53	1.00	
W/E3	.37	-.05	-.23	-.13	.81	1.00	

Correlations among the anxiety measures and posttest scores across treatment groups were more varied. The TAS, for example, a trait measure, produced low negative correlations with the posttest scores across experimental groups. These correlations ranged from $-.02$ to $-.24$. In contrast the correlations among Worry 3 and the posttest scores were quite low for both the feedback group ($r = -.03$, $r = -.06$) and the control group ($r = -.15$, $r = -.2$), while the correlations were somewhat stronger for Worry 3 and the relevant and incidental posttest scores ($r = -.37$ and $r = -.39$, respectively) for the no feedback group.

Prior Achievement Measures. The pretest scores ranged from a low of 1 to a high of 30, with a mean of 19.76 and a standard deviation of 6.22. The Nelson-Denny vocabulary subtest ranged from 5 to 97 with a mean of 40.2 and a standard deviation of 22.05. The Nelson-Denny comprehension subtest had a range with a low of 1 and a high of 64, with a mean and standard deviation of 29.12 and 16.48, respectively.

The correlations among pretest and posttest scores were essentially the same across experimental groups. That is, pretest produced moderate, positive correlations with both relevant and incidental posttest scores for for all three groups. The correlations between pretest score and the relevant items of the posttest ranged from $.35$ to $.57$, while the correlations with the incidental subscale ranged from $.39$ to $.49$.

Posttest Data. As expected, significant differences were found in the posttest achievement scores among the three experimental groups. For example, both groups receiving adjunct postquestions had significantly higher scores on the relevant subscale of the posttest than the control group (see Table 1). However, the pattern of achievement on the incidental subscale revealed no differences between the means of the adjunct question/ feedback group and the control group, while a significant difference was found between the means of the adjunct question/no feedback group and the control group. Surprisingly, no differences were found between the means of either adjunct question group on the relevant or incidental subscales of the posttest.

To examine further the hypothesized relationships among the individual difference variables, treatment conditions, and posttest achievement, the scores on both the relevant and incidental subscales of the posttest were analyzed using both multivariate and univariate multiple regression techniques to estimate the effects of pretest score, worry, and treatment, as well as their interactions, on achievement.

Regression Model

The general regression model used to explore the statistical relationships among the independent and dependent variables, both in the multivariate and univariate form, included main effects for pretest, worry, and treatment group,

as well as all their interactions. The univariate regression model was of the general form:

$$Y_i = B_0 + B_1X_1 + B_2X_2 + B_3X_3 + \dots + B_7X_1X_2X_3 + e$$

which expresses the i th observation of the dependent variable Y as a linear function of the independent variables (X 's), and the error term " e " (Cohen, 1968; Pedhazur, 1982).

The multivariate extension of this model is:

$$Y_i = B_0 + B_1X_1 + B_2X_2 + B_3X_3 + \dots + B_7X_1X_2X_3 + e$$

where $Y_i = (Y_{i1} \ Y_{i2} \ \dots \ Y_{iq})$ is a vector of q response variables for observation i , the X 's are independent variables, the B 's are $q \times 1$ vectors containing the regression parameters, and the " e " vectors are the errors (which are assumed to be independent and have a q -variate normal distribution with mean 0 and covariance matrix E).

It should be noted, here, that deviation scores for both the anxiety and pretest scores were computed and used in this model. The use of deviation scores has been recommended to reduce the effects of multicollinearity among predictor variables (Cronbach and Snow, 1977; Kenny, 1979).

Achievement Data. The results of the multivariate regression analyses, presented in Table 3, indicate that, as expected, both treatment condition, $F(1,100) = 5.12$, $p < .01$, and pretest score, $F(1,100) = 15.83$, $p < .001$, contributed significantly to achievement on the posttest. The cognitive component of anxiety, worry, had a main effect on achievement on only the incidental items of the posttest, $F(1,100) = 4.09$, $p < .05$, suggesting that, regardless of level of instructional support provided, the less anxious subjects, on the whole, learned more of the instructional material than their highly anxious counterparts. Further, these regression analyses revealed no significant interactions among pretest, treatment and worry on either the relevant or incidental posttest items.

Table 3. Results of Multivariate & Univariate
Regression Analyses of Posttest Scores

N=112	1		
	<u>WILKS</u>	<u>UNIVARIATE F's</u>	
		<u>PostRel</u>	<u>PostInc</u>
Treatment	5.12*	8.12*	3.36°
Pretest	15.83**	29.95**	25.51**
Worry 3	2.03	2.28	4.09°
Trt * Pretest	-	-	-
Trt * Worry 3	-	-	-
Pre * Worry 3	-	-	-
Trt*Pre*Worry	-	-	-

1. Approximate transformation to the F distribution.

F values less than 1 not reported.

** signif LE .001 * signif LE .01 °signif LE .05

Macroprocess Data. The means and standard deviations of the use of the various macroprocesses for the entire sample are presented in Table 4. These data indicate a great deal of variability in frequency of macroprocess use among the subjects. In order to reduce the effects of outliers on these data the frequency measures for subjects whose use of any of these options exceeded more than three standard deviations above the mean was set at the third standard deviation value. Despite that, it is evident that the variability was still very large. As noted earlier, these data were analyzed using the general regression model developed for the posttest analyses. The results of both the multivariate and univariate regressions are displayed in Table 5.

Table 4. Means and Standard Deviations of Macroprocesses

<u>Variable</u>	<u>Mean</u>	<u>SD</u>
Previews	1.48	3.05
Reviews	15.21	23.93
Alt. Text	19.20	34.87
Notes	6.26	8.79
Rev. Notes	.64	1.29
Headings	.98	1.60

Table 5. Results of Multivariate & Univariate
Regression Analyses of Macroprocesses

N=120	1									
	WILKS	Rev.	Alt.	Rev.	Alt.	Notes	Rev.	Notes	Hdgs.	Prev.
Treatment	2.88**	1.4	11.54**	-	-	4.06°	2.42	-	2.87	-
Pretest	-	-	1.46	-	-	1.62	3.12	-	2.5	-
Worry 2	1.8	2.73	3.67°	2.90	-	-	-	-	2.76	1.95
Trt*Pre	1.3	2.0	-	2.49	-	-	-	-	2.08	2.11
Trt*Worry	-	-	-	-	-	-	-	-	-	-
Pre*Worry	2.04°	-	10.78**	-	-	1.10	-	-	4.06°	1.87
T*Pre*Worry	1.33	2.56	4.47°	-	-	2.39	-	-	2.86	1.77

1. Approximate transformation to the F distribution.

F values less than 1 not reported.

** signif LE .001 * signif LE .01 ° signif LE .05

These multivariate regression analyses indicated a difference among the three treatment groups for the frequency of overall option use, with significant univariate effects for use of the alternate text ($F(2,109) = 11.54, p < .01$) and notetaking ($F(2,109) = 4.06, p < .05$), in particular. In general, the group receiving adjunct postquestions and feedback used the macroprocessing options least frequently, while the adjunct postquestions only group used the options most. A main effect for worry was found for the alternate text option ($F(1,109) = 3.67, p = .05$) indicating that the more anxious students used the alternate, easier version of the text more frequently than less anxious students.

Moreover, these regression analyses of the macroprocesses revealed a number of significant interactions. For example, a significant pretest by worry interaction was found for use of both the alternate text ($F(1,109) = 10.78, p < .001$) and frequency of use of headings ($F(1,109) = 4.06, p < .05$). These interactions are displayed using a cuboctahedron response surface design (Meyer, 1963) in Figures 3 and 4.

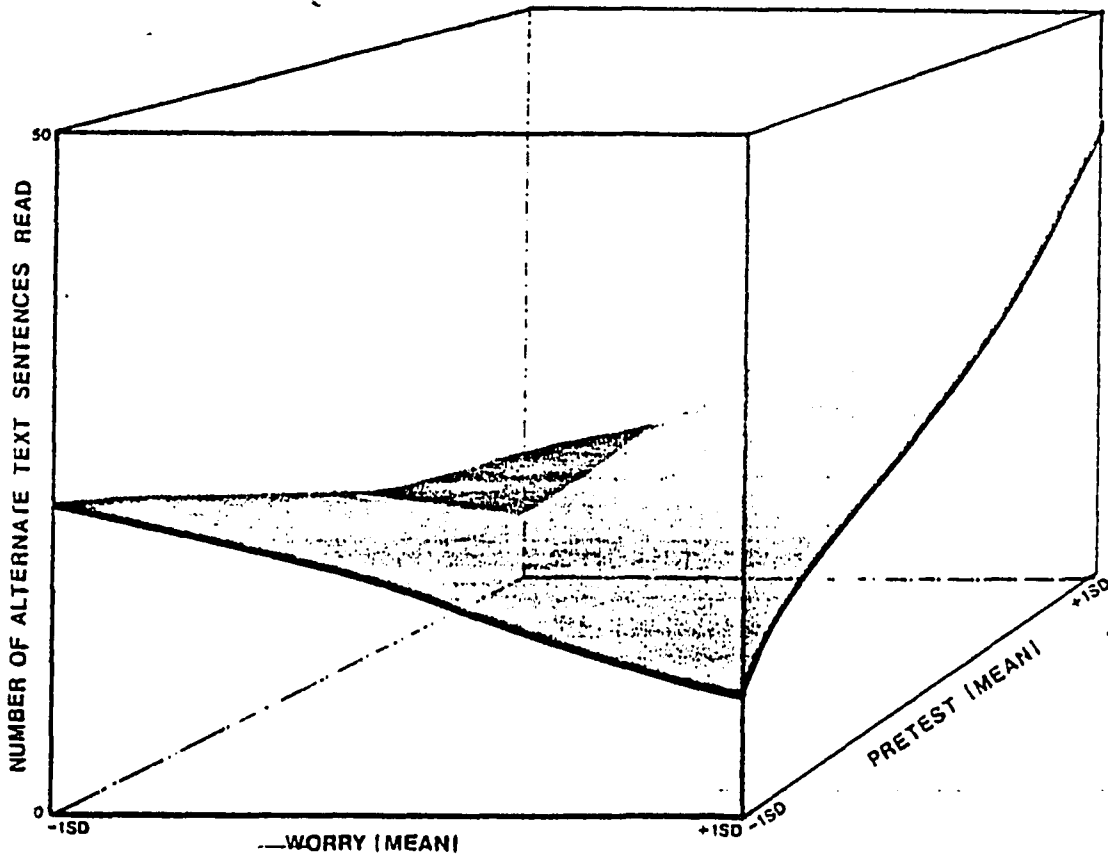


Figure 1. Response Surface Plot of the Interaction of Worry and Prior Knowledge on the use of the Alternate Text.

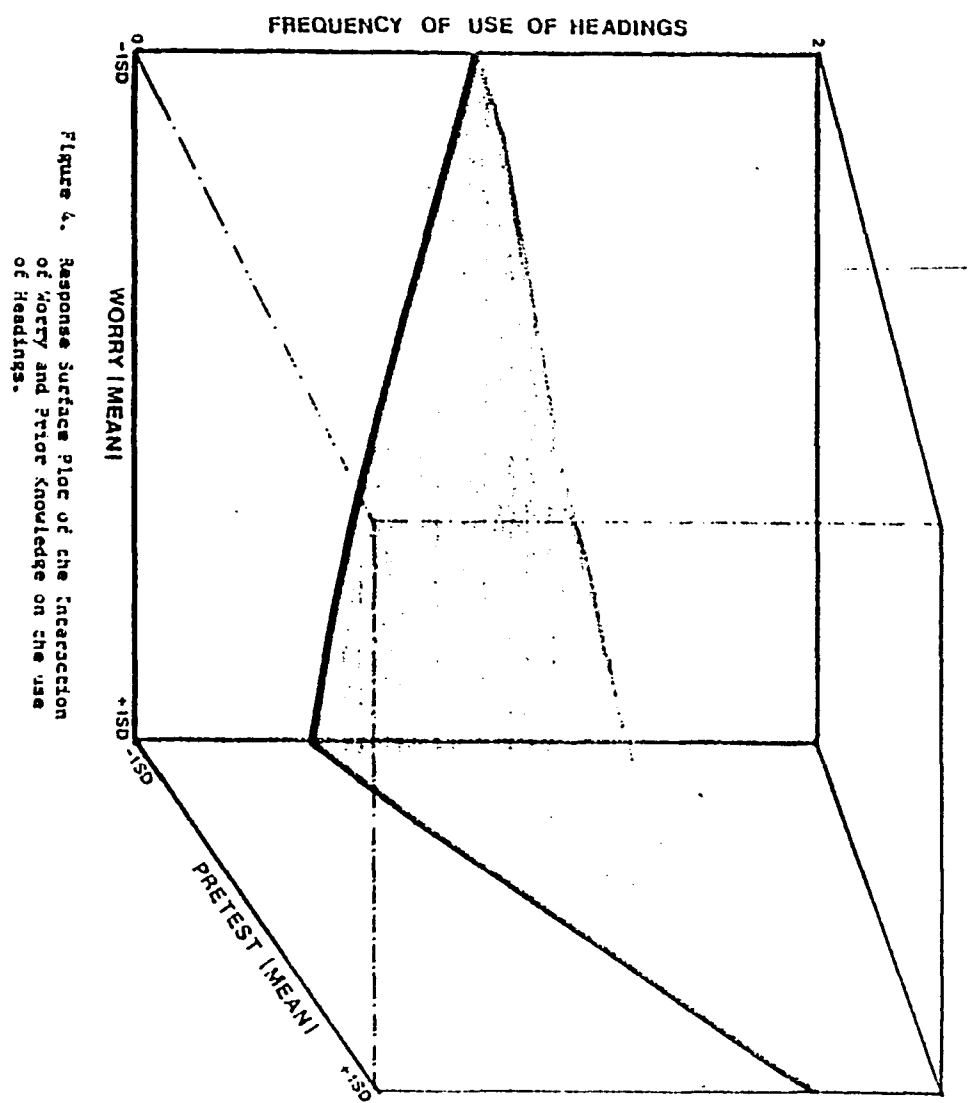


Figure 4. Response Surface Plot of the Interaction of Worry and Prior Knowledge on the use of Headings.

In general, subjects with high pretest scores and high levels of worry read more of the alternate text. However for subjects reporting low levels of worry the slope of the interaction was different. For the less anxious, those with low pretest scores used the alternate text more frequently. The shape of the pretest x worry interaction for use of headings was similar. The high worry subjects with high pretest scores used the headings most frequently, while the highly anxious subjects with low pretest scores used them least. For the less anxious subjects the interaction with pretest score was negligible.

In addition, a significant triple interaction of treatment x pretest x worry was found for the alternate text option ($F(1,109) = 4.47, p < .05$). Again, using the response surface design, the worry x pretest interactions for each treatment group are presented separately in Figures 5a, 5b, and 5c.

Interestingly, the relative slopes of the response surfaces for the worry x pretest interaction are widely divergent for each group. The surface for the group receiving adjunct questions/no feedback (see Figure 5b) reveals that the slope of the interaction is greatest at the higher levels of pretest, with those both high on prior knowledge and worry using the alternate text more frequently. For the group receiving feedback (see Figure 5a) the use of the alternate text appears to be more a function of anxiety level,

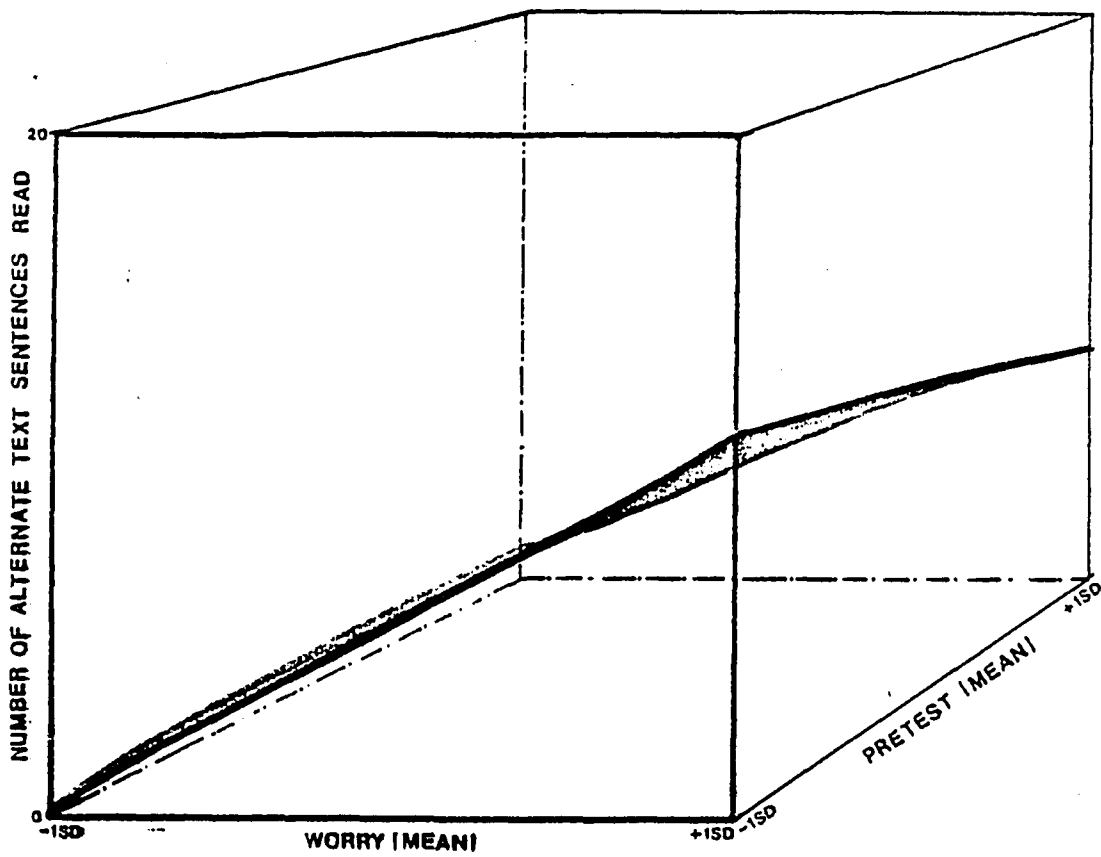


Figure 5a. Response Surface Plot of the Interaction of Worry and Prior Knowledge on the use of the Alternate Text for the Adjunct Question/No Feedback Group.

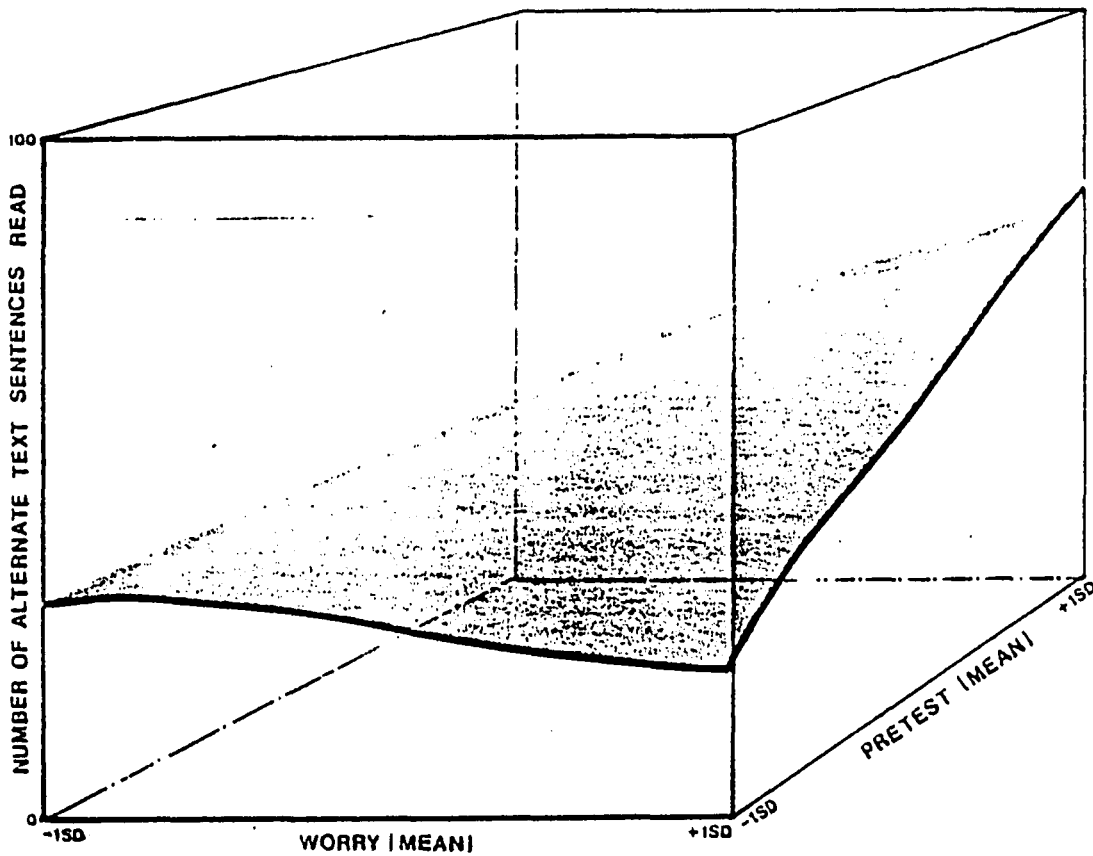


Figure 5b. Response Surface Plot of the Interaction of Worry and Prior Knowledge on the use of the Alternate Text for the Adjunct Question/Feedback Group.

with those reporting high levels of worry using the alternate text more frequently. The shape of the worry x pretest interaction for the control group (see Figure 5c) was quite similar to the shape of the overall worry x pretest interaction displayed earlier in Figure 3. Again, in this group those with high pretest scores and high levels of anxiety (worry) used the alternate text most frequently.

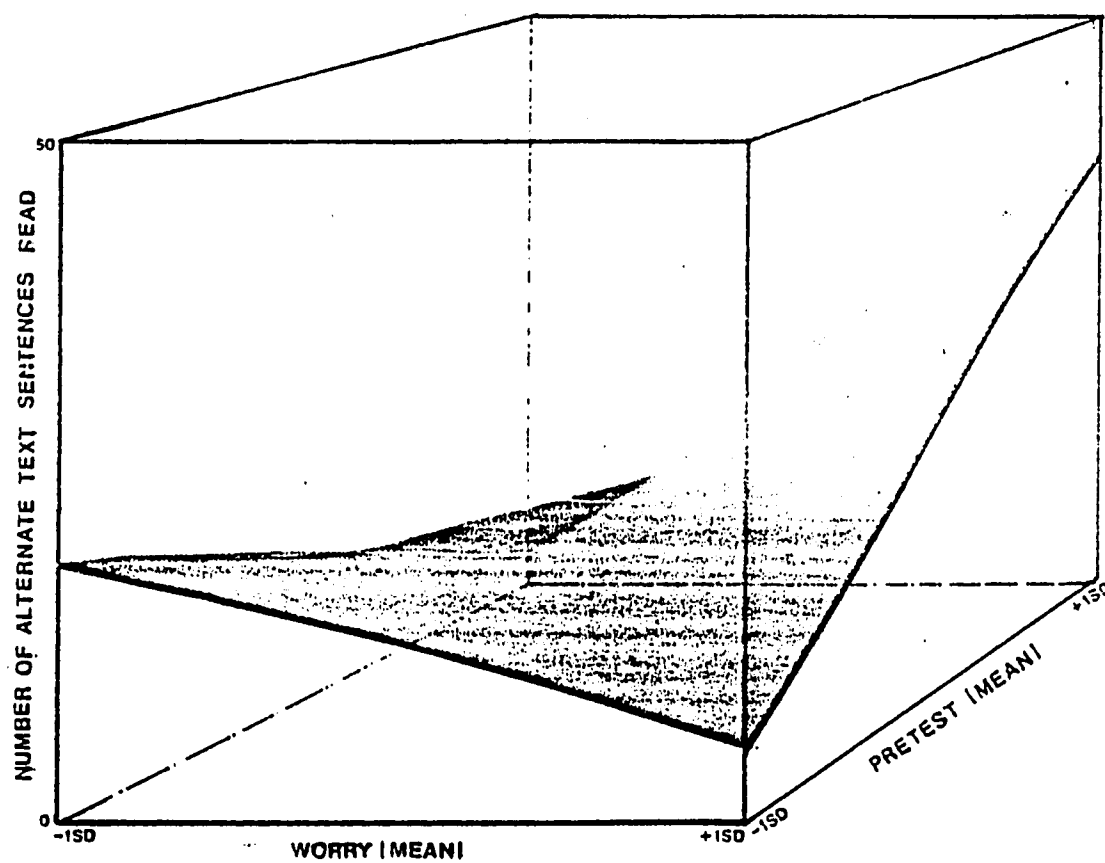


Figure 5c. Response Surface Plot of the Interaction of Worry and Prior Knowledge on the use of the Alternate Text for the Reading-Only Control Group.

Correlation of Macroprocesses and Achievement

The correlational data presented here focuses on the nature of relationship between use of the various macroprocesses and achievement on the relevant and incidental posttest items for each treatment group. Tables 6a thru 6c present the correlations for each experimental group.

Beginning with the group receiving feedback, we see that the strongest correlations with posttest achievement are found with frequency of notetaking ($r = .31$) and reviewing notes ($r = .26$ and $.32$). The preview option, on the other hand, seemed to facilitate achievement somewhat on the incidental posttest items ($r = .27$) and hinder achievement on the relevant items ($r = -.39$). Surprisingly, use of the review option was essentially uncorrelated with achievement on the posttest for this group ($r = .00$ and $.05$).

In both the adjunct question/no feedback and control groups use of the review of the main text had an apparently facilitating effect on posttest achievement, producing correlations in the .37 range. Notetaking had a somewhat lower correlation with posttest achievement for these two groups than for the group receiving feedback.

Lastly, an examination of the correlations between correctness of response to an adjunct question and use the macroprocesses indicated that, in general, the subjects who reviewed either the main or alternate text frequently answered more of the adjunct questions correctly ($r = .35$).

Table 6a. Intercorrelations of Macroprocesses and Posttests
for Adjunct Question/Feedback Group

	<u>Prev.</u>	<u>Rev.</u>	<u>Alt.</u>	<u>Rev.Alt.</u>	<u>Hdg.</u>	<u>Notes</u>	<u>Rev.Notes</u>	<u>Post R</u>	<u>Post I</u>
Previews	1.00								
Reviews	.45	1.00							
Alt.Text	.58	.34	1.00						
Rev.Alt.	-.09	-.06	.08	1.00					
Headings	.12	.17	-.07	.56	1.00				
Notes	.03	-.09	.19	.48	.10	1.00			
Rev.Notes	.02	.00	.17	.78	.35	.77	1.00		
Posttest R	-.39	.00	-.19	.20	-.14	.31	.26	1.00	
Posttest I	.27	.05	-.21	.26	-.07	.31	.32	.80	1.00

Table 6b. Intercorrelations of Macroprocesses and Posttests
for Adjunct Question/No Feedback Group

	<u>Prev.</u>	<u>Rev.</u>	<u>Alt.</u>	<u>Rev.Alt.</u>	<u>Hdg.</u>	<u>Notes</u>	<u>Rev.Notes</u>	<u>Post R</u>	<u>Post I</u>
Previews	1.00								
Reviews	.50	1.00							
Alt.Text	.34	-.02	1.00						
Rev.Alt.	.61	.48	.25	1.00					
Headings	.61	.37	.46	.58	1.00				
Notes	.12	.40	-.06	.04	.02	1.00			
Rev.Notes	.25	.64	-.07	.31	.18	.64	1.00		
Posttest R	.14	.35	.13	.15	.05	.18	.18	1.00	
Posttest I	.13	.37	.14	.12	.19	.24	.25	.87	1.00

Table 6c. Intercorrelations of Macroprocesses and Posttests
for Reading Only Control Group

	<u>Prev.</u>	<u>Rev.</u>	<u>Alt.</u>	<u>Rev.Alt.</u>	<u>Hdg.</u>	<u>Notes</u>	<u>Rev.Notes</u>	<u>Post R</u>	<u>Post I</u>
Previews	1.00								
Reviews	.06	1.00							
Alt.Text	-.02	.25	1.00						
Rev.Alt.	-.08	.01	.07	1.00					
Headings	.24	.38	.21	.03	1.00				
Notes	.45	.56	.15	.03	.32	1.00			
Rev.Notes	.00	.82	.23	.09	.39	.59	1.00		
Posttest R	.07	.36	.08	-.27	-.09	.17	.29	1.00	
Posttest I	.03	.38	.17	-.23	-.12	.20	.24	.72	1.00

Chapter VI

DISCUSSION

The study presented in Chapter IV was designed to investigate the general hypothesis that test anxiety contributes to achievement decrements by absorbing a portion of the student's cognitive processing capacity and, therefore, instructional methods designed to reduce the capacity demands of the learning task should be beneficial to highly anxious students. The results of this study provide limited support for this hypothesis. In addition students' use of a variety of macroprocessing options was also investigated.

This chapter is divided into two major sections. The first presents a summary of the experimental results organized around the specific hypotheses examined in this investigation. The second section discusses the implications of the findings for educational practice as well as future research.

Summary of Results

The results of this investigation are summarized in response to the five hypotheses stated earlier.

Hypothesis 1

Earlier it was hypothesized that all subjects assigned to an instructional treatment providing adjunct postquestions would demonstrate greater achievement on both adjunct question relevant and incidental posttest items than students assigned to a reading only treatment. This was a direct test of the hypothesis that adjunct questions reduce the cognitive capacity demands of the learning task by facilitating both a backward and forward processing of the instructional material (Rothkopf, 1972). This hypothesis was confirmed. The univariate regression analyses performed on both subscales of the posttest indicated a main effect for treatment on both relevant ($F(2,100) = 8.12, p < .01$) and the incidental posttest items ($F(2,100) = 3.36, p < .05$). Thus, both adjunct question groups outperformed the reading only control group on the immediate posttest.

Hypothesis 2

The second hypothesis predicted that subjects assigned to an instructional treatment providing both adjunct questions and feedback would demonstrate greater achievement on both the relevant and incidental posttest items than either the adjunct question or reading only groups. The rationale for this hypothesis was based on research suggesting that feedback reduces the cognitive capacity demands of the task by enhancing the direct effect of adjunct postquestions (Roth-

kopf & Billington, 1974). The data do not support this hypothesis. As noted earlier, no differences were found between the adjunct question/feedback and the adjunct question/no feedback groups on either the relevant or the incidental posttest items. The presence of feedback, moreover, apparently depressed use of the various macroprocessing options for this group and that function, in turn, may have contributed to the absence of differences between these two adjunct question groups.

Hypothesis 3

An interaction between test anxiety and treatment was predicted such that less anxious subjects assigned to the reading only treatment would demonstrate greater achievement on an immediate posttest than highly anxious subjects in the same group, while no achievement differences were expected between high and low anxious subjects assigned to treatments providing increased instructional support. This hypothesis stemmed from the assumption that anxiety's cognitive dimension, worry, interferes with effective processing of instruction and treatments designed to reduce the cognitive capacity demands of the instructional task would be selectively beneficial to highly anxious subjects since they are presumed have less capacity available for processing for task demands (Tobias, 1984b). The results of the multivariate and univariate regression analyses discussed earlier did

not confirm this hypothesis. No significant interactions between worry and instructional method were found, although a main effect for worry on achievement on the incidental posttest items did occur. An inspection of the correlations between worry and both posttest scores for each group reveals that the interfering effects of anxiety were diminished somewhat for the group receiving feedback ($r = -.03$ and $r = -.06$), while for the control group the debilitating effects of worry were more moderate ($r = -.15$, $r = -.20$). For the experimental group receiving adjunct questions but no feedback, the interfering effect of worry was greatest. This is evidenced in the relatively strong negative correlations between worry scores and achievement on the relevant ($r = -.37$) and incidental ($r = -.39$) subscales of the posttest.

Further evidence for the attenuating role of feedback in this study is found in the correlations between worry and the correctness of a response to an adjunct question. For example, this correlation for the group receiving feedback is relatively strong, $r = .29$, when compared with the correlation between anxiety and posttest performance for the same group, i.e., $r = -.06$. While for the no feedback group the correlation between worry and performance on the adjunct questions is virtually identical to the correlation of worry and performance on the posttest, i.e., $r = .39$. Providing feedback apparently reduced some portion of the cognitive

demands of the learning task, and this, in turn, may have served to diminish the effect of anxiety on posttest achievement.

Hypothesis 4

High-anxious subjects were expected to review the instructional material more frequently than low-anxious students, regardless of the level of instructional support provided. Thus, a main effect for anxiety (i.e., worry) on the number of sentences reviewed was predicted. This hypothesis represented an explicit test of Tobias' (1977b, 1980) research model, and was based on the assumption that worry interferes with the effective processing of instructional material and highly anxious subjects, when presented with a review option, will engage that option frequently to reduce the effects of cognitive interference. This hypothesis received partial support.

Although an overall, i.e., multivariate, main effect for worry ($F = 1.8$) did not reach statistical significance, a significant main effect for worry was found for the frequency of use of the alternate, easier version of the text indicating that the more anxious students attempted to reduce the cognitive demands of the instructional task by referring frequently to the less difficult version of the text (see Table 4). Despite the enormous variability in the frequency of use of the various macroprocessing options both within

and across treatment groups, the results of the univariate multiple regression analyses (again, see Table 4) indicate that a main effect for worry on the use of the review options approached statistical significance ($F(1,109) = 2.90$, $p < .10$).

Hypothesis 5

Frequency of use of the macroprocesses was predicted to be positively correlated with achievement on the posttest for all subjects. This hypothesis was based on the study strategies research reviewed earlier which suggested that effective use of learning strategies produces increased levels of achievement (T. Anderson, 1980). In general, the frequency of use of the various macroprocesses had little relationship to achievement on the posttest. In both the adjunct question/no feedback group and the reading only control group, use of the review option was positively correlated with posttest scores on both relevant and incidental items (i.e., correlations were in the +.36 range). However, it is prudent to note again that the incredible variability in the frequency of use of the macroprocessing options casts doubt on the validity of any inferences drawn from these correlations.

Interaction of Prior Knowledge and Anxiety

The interaction between prescore and anxiety on the number of alternate text sentences read indicates that the more anxious students tended to read more alternate sentences than those lower in anxiety. This finding was expected from Tobias' (1984) formulation suggesting that anxiety absorbs some portion of cognitive capacity, leaving less capacity for task solution. Use of the alternate, easier text may well have been less demanding of cognitive capacity for these subjects, hence, as anxiety increased they attempted to reduce the cognitive demands the main text passage called for by consulting the less demanding alternate passage. The number of alternate sentences consulted had an essentially flat relationship with prescore, indicating little variability attributable to the amount of prior knowledge. A similar interaction was found for frequency with which the headings were used, though the magnitude of this interaction was substantially smaller than that involving the alternate text.

A triple interaction was also found for the number of alternate text sentences read by students. This interaction involved anxiety, prescore, and instructional method. In general, the number of sentences read were unrelated to prescore for the control and feedback groups. For the adjunct postquestion group, however, as prescore increased the tendency to use the alternate text also increased. Presum-

ably, students in this group were uncertain regarding the correctness of their answers to the adjunct postquestions and, hence, felt some need to consult the alternate, easier text. Surprisingly, the more knowledgeable the student about the subject matter, as reflected in the prescore, the more likely they were to consult the alternate text. The interaction involving anxiety had a similar slope for all three instructional groups, i.e., as anxiety increased there was a tendency for the number of alternate text sentences read to increase as well.

Implications of the Study

The significant differences on both the relevant and incidental items of the posttest confirm prior findings that adjunct postquestions facilitate achievement on material which is both incidental and relevant to the content of the question. In this study the two groups receiving questions outperformed the reading-only control group both on relevant and incidental items of the posttest. Of some interest was the fact that the adjunct question group had slightly, though not significantly, higher scores than the group receiving feedback. Perhaps the presence of feedback led this group to process the text less thoroughly than the adjunct question only group.

The most surprising aspect of the macroprocessing data reported in this study was the incredible variability with

which the macroprocessing options were employed. The percentage of students who did not use an option at all varied from 18% to 88%. Despite this low frequency, a number of subjects used these options very often indeed. The standard deviations of the frequency data were often two and three times higher than the mean! Further, this enormous variability may have served to mask some of the results of our statistical analyses. Reading times, for example, did not vary a great deal across groups as one might expect given the variability in the use of macroprocesses. The mean reading time (i.e., total time the main text sentences were displayed on the computer screen) was 33.23 minutes for the feedback group, 28.54 minutes for the no feedback group, and 30.46 minutes for the control group. The group using the macroprocesses most frequently spent the least amount of time with the sentences presented on the screen. Thus, in general, reading time was negatively correlated with frequency of use of the macroprocesses.

In contrast to the relative similarity of the reading times, there were clearly differences among the groups in terms of the frequency with which options were used. In general, the group receiving feedback used the options least often, and the adjunct question group most frequently. These results appear to suggest that the group receiving feedback may have had little need to use the options due to the information provided by the feedback. That is, it may

have been unnecessary for these students to use the review option, for example, in order to determine the correct answer, since it was supplied to them. The large mean differences on use of review supports this. Presumably, these students were less motivated to employ the other options. These results confirm Tobias' (1982) expectation that it is instructionally unsound to do for students what they could do for themselves, i.e., supply their own confirmation as to whether answers are correct. By providing feedback these students were less active in their reading of the text, at least as determined by the frequency of macroprocessing use.

Future Research

Research relating teacher behavior to student achievement (Brophy, 1979) uses careful observations of classroom behavior as an essential methodology. ATI research could adopt such a method as well. Instead of initiating research by generating a prediction as to what students are likely to do in an instructional setting where a variety of alternatives are available, it may be more fruitful to observe what students of varying individual difference characteristics actually do, and what instructional options they select. As Tobias (1981) has suggested...

"one wonders whether all of the research relating mode of responding to instructional materials to anxiety might not have most profitably begun by watching students of known anxiety characteristics select available options, and ask students to pro-

vide reasons for their selection, rather than begin by hypothesizing outcomes in an area in which few instructionally relevant prior studies had been conducted. Conceivably a lot of findings of non-significant differences could have been avoided this way in the past..." (1981, p. 118).

A surprising finding was the fact that, in general, students use of macroprocessing options had only limited relationships to their posttest scores and similarly limited relationships to reading ability. It was assumed that students would invoke some or all of the options to help them learn the material more efficiently, and that use of these options would be positively related to outcomes. Instead, the findings suggest that option use frequently was not in the service of increasing comprehension. Moreover, future research efforts in this area would benefit from a focus on the human-computer interaction aspect of this type of study. Perhaps this troublesome variability in option use may have more to do with the novelty of interacting in a microcomputer learning environment and less to do with the functional nature of the macroprocesses themselves.

Additionally, there are at least two other plausible interpretations of the macroprocessing data reported here. The first of these is that students may not have been particularly motivated to do well on this task. This interpretation would suggest that students used the options out of curiosity regarding how they worked, rather than to improve their learning. The mean achievement scores tend to contra-

dict this interpretation. The total possible number of points on the posttest was 50. The percentage correct for the two postquestions groups was approximately 70%, a reasonably high score on a difficult test. It is conceivable that a highly motivated group may have done much better, though these data do not suggest an absence of motivation as a major interpretation of these results.

The alternative interpretation has to do with the fact that students may not know which instructional strategies are especially effective for improving their performance. The high variability of option use, and the low relationship with posttest scores and reading ability tend to support this interpretation. Students are rarely instructed, at any educational level, regarding how to improve their learning and studying. While students indicated frequent use of review in our pilot study, the data for number of sentences reviewed tell a different story. The feedback and control groups reviewed approximately 5% of the sentences, while the adjunct question/no feedback group reviewed about 9% of the sentences. This was not a high percentage of reviews, in view of the fact that the mean posttest score indicated a good deal of room for improvement.

In future research it may be useful to assist students with option selection. It would appear that students should review the preceding text in those instances when their answers to an adjunct question are wrong. In that way they

may be able to correct their misconceptions prior to moving on to succeeding text. A future study, for example, might examine the effect on the learning outcomes of some students, say those with low pretest scores, of prescribing use of the review option. If use of review in these situations does, in fact, raise achievement, one can then envision a succeeding study in which students are taught this general strategy while their performance is monitored on tasks similar to those used in this experiment.

Educational Practice

An interesting question arising from this research is what would be an ideal use of the various macroprocessing options? That is, how frequently should high or low ability students use these macroprocesses? The present data do not answer this question satisfactorily, since the median correlation between the total frequency of option use and total posttest score was only $-.03$ for the feedback group, and $.14$ for both the adjunct question and reading-only group. Clearly, such correlations do not warrant recommendations regarding ideal use of instructional options.

This study, however, does offer the potential for developing a theoretically sound determination of optimal macroprocessing. Though there was variation among the treatment groups, in this investigation the frequency of options use correlated positively with the total posttest score. Analy-

ses of these correlations may be useful in building a model of ideal option use. That is, if option use is highly correlated with achievement, then such use should be recommended. Furthermore, the presence of data regarding students' prior achievement, reading ability, and anxiety permits the computation of partial correlation coefficients in which the contributions of these variables can be studied in further research. It follows, then, that the use of correlational analysis is potentially powerful for developing sound educational prescriptions regarding ideal option use.

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These consist of pages:

123-127, Appendix B: Test Anxiety Scale.

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Worry-Emotionality Scale

Directions: To the left of each of the following statements indicate your feelings, attitudes, or thoughts as they are right now in relation to this study. Use the following numerical scale:

1. The statement does not describe my present condition.
2. The condition is barely noticeable.
3. The condition is moderate.
4. The condition is strong.
5. The condition is very strong; the statement describes my present condition very well.

_____ I feel my heart beating fast.

_____ I feel regretful.

_____ I am so tense that my stomach is upset.

_____ I am afraid that I should have studied more for the
_____ the material I will be reading.

_____ I have an uneasy, upset feeling.

_____ I feel that others will be disappointed in me.

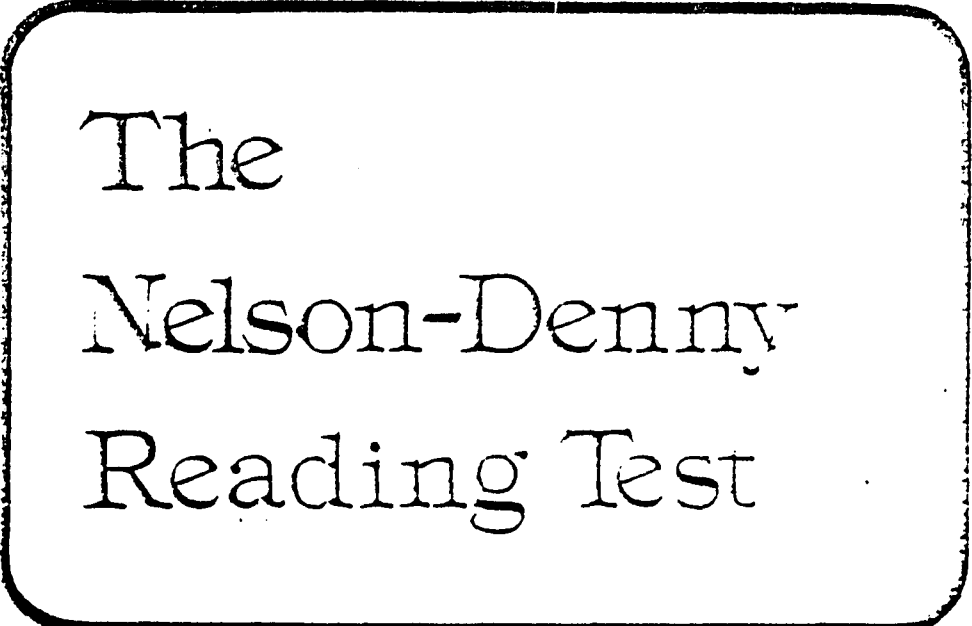
_____ I am nervous.

_____ I feel I may not do as well as I should on the tests
_____ I will be taking.

_____ I feel panicky.

_____ I do not feel very confident about my performance on
_____ the tests I will be taking.

APPENDIX D



The
Nelson-Denny
Reading Test

James L. Brown, Ph. D.
University of Minnesota

J. Michael Bennett, Ed. D.
University of Minnesota

Gerald Hanna, Ed. D.
Kansas State University

VOCABULARY
COMPREHENSION
READING RATE



Pretest

Please make no marks on the test and record all your answers on the answer sheet.

Circle the letter of the best choice.

- 1) The costs of personal computers are similar to the costs of:
 - a. hand calculators.
 - b. portable radios.
 - c. color televisions.
 - d. none of the above.
- 2) A computer's cost depends on:
 - a. whether it is equipped with machine language.
 - b. the number of operations carried out in a fixed time period.
 - c. whether it is equipped with BASIC.
 - d. whether it has any input capability.
- 3) Which of the following defines a constant value for X?
 - a. $X = 3/C$.
 - b. $X = 10$.
 - c. INPUT X.
 - d. $X = Y$.
- 4) Which CPU component compares information? The
 - a. logical unit.
 - b. arithmetic unit.
 - c. control unit.
 - d. output unit.
- 5) We have listed a number of differences and one similarity between calculators and computers. On which one are they similar? Both
 - a. compare numbers.
 - b. have a logical unit.
 - c. make decisions.
 - d. have input.
- 6) Using machine language programs with large groups of data is
 - a. laborious.
 - b. simple.
 - c. easier than in BASIC.
 - d. easy to program, but slow to run.
- 7) The advantage of programming languages like BASIC is that programs:
 - a. are identical to English.
 - b. are the same in machine language.
 - c. can be run on other machines.
 - d. are expressed in arithmetic formulas.

- 8) In BASIC the symbol * stands for:
- a. addition.
 - b. subtraction.
 - c. multiplication.
 - d. division.
- 9) In BASIC data are always referred to by:
- a. names.
 - b. addresses
 - c. locations.
 - d. numerical values.
- 10) In BASIC, the best name for a variable like price would be:
- a. I
 - b. P
 - c. C
 - d. R
- 11) Which of the following is not an advantage of magnetic storage devices? Magnetic devices
- a. reduce the space required for output.
 - b. permit faster output.
 - c. permit faster data retrieval.
 - d. require more computer time.
- 12) If a program has missing steps,
- a. the computer will insert them.
 - b. BASIC will insert them.
 - c. the machine will pause.
 - d. the program will not execute.
- 13) Which of the following can be considered alphanumeric information?
- a. Graphs.
 - b. Pictures.
 - c. Movies.
 - d. Letters.
- 14) Which part of the computer performs operations such as multiplication and division. The:
- a. logical unit.
 - b. arithmetic unit.
 - c. control unit.
 - d. all of the above.
- 15) Which of the following instructions are not available in BASIC?
- a. Input/Output.
 - b. Data interpretation.
 - c. Data manipulation & comparison.
 - d. Control or transfer operations.

- 16) The instruction signaling the conclusion of a program in BASIC is:
- a. STOP.
 - b. END.
 - c. FINISH.
 - d. all of the above.
- 17) When a program is ready for execution, the appropriate BASIC instruction is:
- a. EXECUTE.
 - b. DO.
 - c. RUN.
 - d. INPUT.
- 18) Which computer component coordinates the work of all the other parts?
- a. BASIC.
 - b. CPU.
 - c. Logical Unit.
 - d. Arithmetic Unit.
- 19) The control unit of the CPU:
- a. controls the flow of electricity.
 - b. does the calculations.
 - c. transmits coordinating signals.
 - d. schedules programmers.
- 20) Here is a BASIC statement: $A = B + C$. Which is the operand?
- a. A.
 - b. =.
 - c. C.
 - d. +.
- 21) In BASIC every instruction begins with a
- a. number.
 - b. capital letter.
 - c. lower case letter.
 - d. special signal.
- 22) Which of the following cannot be used for output?
- a. video screens.
 - b. magnetic tape.
 - c. magnetic disk.
 - d. control unit.
- 23) Even though computers differ in cost, size and capabilities all computers have the following components.
- a. input/output devices.
 - b. memory.
 - c. CPU.
 - d. all of the above.
- 24) When names such as A, B, or C, are used in a BASIC program, programmers must know:
- a. their locations.
 - b. their addresses.
 - c. their CPU locations.
 - d. none of the above.

- 25) A disadvantage of magnetic devices is that:
- they are slower than printing on paper.
 - output must be printed to be understood.
 - data retrieval is slow.
 - they take up more space.
- 26) Programs and data are stored in :
- different locations.
 - the same location.
 - the control unit.
 - the terminal.
- 27) Which of the following is most similar to writing a computer program?
- Writing a mathematical formula.
 - Giving a set of instructions to manipulate data.
 - Recording on audio tape.
 - Wiring an electric light switch.
- 28) Which computer component manipulates the data?
- Memory.
 - Output device.
 - Input device.
 - CPU.
- 29) An "echo" print:
- repeats tape input.
 - displays what has been read in for checking.
 - repeats disk input.
 - does all of the above.
- 30) One computer memory cell can
- either be full or empty.
 - hold only one piece of information.
 - store only numbers.
 - store anything but pictures.
- 31) The memory of a computer:
- works much like a human memory.
 - consists of an ordered series of cells.
 - is the slowest part of the computer operation.
 - all of the above are true.

- 32) Which type of information can be represented by computer?
- Numbers.
 - Names.
 - Pictures.
 - All of the above.
- 33) Which of the following is not a valid name for a BASIC variable.
- A.
 - Al.
 - X3.
 - XY.
- 34) The most useful part of a computer is its ability to:
- handle different input channels.
 - print rapidly.
 - manipulate data.
 - solve mathematical problems.
- 35) If you are interested in finding the distance driven, a mathematical formula would be $\text{Distance} = \text{Time} \times \text{Miles per hour}$. In BASIC, this formula is best written as:
- $D = T * M.$
 - $D = T / M.$
 - $DIS = TIM * MIL.$
 - any of the above.
- 36) The general form of the assignment statement in BASIC is:
- RESULT = OPERAND1 ARITHMETIC-OPERATOR OPERAND2.
 - RESULT OPERAND1 ARITHMETIC-OPERATOR OPERAND2.
 - RESULT = OPERAND1 OPERAND2.
 - none of the above.
- 37) BASIC was developed at
- Dartmouth College.
 - Boston University.
 - Stanford University.
 - Boston College.
- 38) In BASIC, the instruction INPUT C, D will cause the computer system to:
- read two values, assign the first one to C, and the second one to D.
 - read two values, assign the first one to D, and the second one to C.
 - output two values, assign the first one to C, and the second one to D.
 - output two values, assign the first one to D, and the second one to C.

- 39) Which of the following is a BASIC assignment statement?
- a. A = B.
 - b. INPUT A, B.
 - c. PRINT A, B
 - d. None.
- 40) In machine language data can be processed:
- a. only if you know its address in memory.
 - b. without knowing where the data are stored.
 - c. only if variables consist of numbers.
 - d. in all of the above cases.
- 41) In conversations in languages such as French, English or Russian, words often have more than one meaning. In computer languages this practice is:
- a. also permissible.
 - b. not permissible.
 - c. permitted only in BASIC.
 - d. none of the above.
- 42) The statement PRINT A, B prints the
- a. current values of A and B.
 - b. former values of A and B.
 - c. sum of A and B.
 - d. product of A and B.
- 43) The rules of programming languages are:
- a. more precise than other languages.
 - b. less precise than other languages.
 - c. stated mathematically.
 - d. written in the form of electronic diagrams.

- 44) During execution, data may
- not be entered.
 - be entered.
 - not be displayed.
 - be read in as output.
- 45) In BASIC the = sign means
- assignment.
 - replacement.
 - equality.
 - the same thing as in arithmetic.
- 46) In the statement $A = B / C$ which is the mathematical operator?
- | | |
|-------|----------|
| a. B. | b. /. |
| c. =. | d. None. |
- 47) The program which translates BASIC into instructions usable by the computer is the:
- mathematical translator.
 - compiler.
 - transducer.
 - transferer.
- 48) Which of the following is not a legitimate computer operation?
- Input data sent directly to the CPU.
 - Information entered into memory.
 - Results are displayed.
 - Data are manipulated by the CPU.
- 49) A program will execute only if all
- the steps needed to solve the problem are identified.
 - of the problem solving steps are correctly identified.
 - programming rules are followed.
 - of the above are done.
- 50) What name is given to the following BASIC statement? $X = 20$.
- | | |
|----------------|------------|
| a. Echo check. | c. input. |
| b. assignment. | d. output. |

PAGE 1

A COMPUTER IS A TOOL FOR REPRESENTING AND MANIPULATING INFORMATION. THERE ARE MANY DIFFERENT TYPES OF COMPUTERS, RANGING IN SIZE FROM HAND-HELD CALCULATORS TO LARGE AND COMPLEX COMPUTING SYSTEMS FILLING SEVERAL ROOMS OR EVEN ENTIRE BUILDINGS. IN THE RECENT PAST, COMPUTERS WERE SO EXPENSIVE THAT THEY COULD BE USED ONLY FOR BUSINESS OR SCIENTIFIC COMPUTATIONS. AT PRESENT COSTS HAVE GONE DOWN CONSIDERABLY AND PERSONAL COMPUTERS AVAILABLE FOR USE IN THE HOME ARE IN THE SAME PRICE RANGE AS COLOR TELEVISION SETS.

THE SIZE AND COST OF A COMPUTER GENERALLY DEPENDS UPON THE AMOUNT OF WORK IT CAN TURN OUT IN A GIVEN TIME. LARGER, EXPENSIVE COMPUTERS HAVE THE CAPABILITY OF CARRYING OUT MANY OPERATIONS SIMULTANEOUSLY, THUS INCREASING THEIR WORK CAPACITY. THEY ALSO HAVE MANY ATTACHED DEVICES FOR PERFORMING SPECIAL FUNCTIONS, ALL OF WHICH INCREASE THEIR CAPABILITY AND COST.

PAGE 2

DESPITE THE LARGE VARIETY IN THE COST, SIZE AND CAPABILITIES OF MODERN COMPUTERS, THEY ARE REMARKABLY SIMILAR IN A NUMBER OF WAYS. BASICALLY, A COMPUTER SYSTEM CONSISTS OF FOUR COMPONENTS: 1) AN INPUT DEVICE, 2) A CENTRAL PROCESSOR, 3) MEMORY, AND 4) AN OUTPUT DEVICE.

ALL INFORMATION TO BE PROCESSED MUST FIRST BE ENTERED INTO THE COMPUTER MEMORY VIA AN INPUT DEVICE. INFORMATION IN MEMORY IS MANIPULATED BY THE CENTRAL PROCESSOR, AND THE RESULTS OF THIS MANIPULATION ARE, THEN, ALSO STORED IN THE MEMORY OF THE COMPUTER. INFORMATION IN MEMORY CAN BE DISPLAYED THROUGH THE USE OF APPROPRIATE OUTPUT DEVICES.

THE MEMORY OF A COMPUTER MAY BE PICTURED AS AN ORDERED SEQUENCE OF STORAGE LOCATIONS CALLED MEMORY CELLS. ASSOCIATED WITH EACH MEMORY CELL IS A DISTINCT ADDRESS, WHICH INDICATES ITS RELATIVE POSITION IN THE SEQUENCE. SOME LARGE-SCALE COMPUTERS HAVE MEMORIES CONSISTING OF MILLIONS OF CELLS.

PAGE 3

THE MEMORY CELLS OF A COMPUTER ARE USED TO REPRESENT INFORMATION. ALL TYPES OF INFORMATION - NUMBERS, NAMES, LISTS, AND EVEN PICTURES MAY BE REPRESENTED IN THE MEMORY OF A COMPUTER. THE INFORMATION IN A MEMORY CELL IS CALLED ITS CONTENT. EVERY MEMORY CELL CONTAINS SOME INFORMATION—NO CELL IS EVER EMPTY. FURTHERMORE, NO CELL CAN EVER CONTAIN MORE THAN ONE DATA ITEM. WHENEVER A DATA ITEM IS STORED IN A CELL, ANY INFORMATION ALREADY THERE IS DESTROYED, AND CANNOT BE RETRIEVED.

THE ABILITY OF THE COMPUTER TO REPRESENT INFORMATION WOULD BE OF LITTLE USE BY ITSELF. THE MANIPULATIVE CAPABILITY OF COMPUTERS ENABLES US TO STUDY PROBLEMS THAT WOULD OTHERWISE BE IMPOSSIBLE BECAUSE OF THEIR COMPUTATIONAL COMPLEXITY. WITH APPROPRIATE DIRECTIONS, MODERN COMPUTERS CAN GENERATE LARGE QUANTITIES OF NEW INFORMATION FROM OLD, SOLVE MANY OTHERWISE IMPOSSIBLE PROBLEMS, PROVIDE USEFUL INSIGHTS INTO OTHERS, AND DO THEIR WORK WITH INCREDIBLE SPEED.

PAGE 4

THE PART OF THE COMPUTER WHICH MANIPULATES INFORMATION IS THE CENTRAL PROCESSING UNIT (CPU). THE CPU CAN RETREIVE INFORMATION FROM THE MEMORY. THIS INFORMATION MAY CONSIST OF EITHER DATA OR INSTRUCTIONS FOR MANIPULATING DATA. THE CPU CAN ALSO STORE THE RESULTS OF MANIPULATIONS BACK INTO THE MEMORY UNIT FOR LATER REFERENCE.

THE CPU COORDINATES ALL ACTIVITIES OF THE VARIOUS COMPONENTS OF THE COMPUTER. IT DETERMINES WHICH OPERATIONS SHOULD BE CARRIED OUT AND IN WHAT ORDER. THE TRANSMISSION OF COORDINATING CONTROL SIGNALS AND COMMANDS IS THE FUNCTION OF THE CONTROL UNIT WITHIN THE CENTRAL PROCESSOR.

PAGE 5

AN ARITHMETIC-LOGIC UNIT IS PART OF THE CENTRAL PROCESSOR. THE ARITHMETIC PART OF THE UNIT CONSISTS OF ELECTRONIC CIRCUITRY WIRED TO PERFORM A VARIETY OF ARITHMETIC OPERATIONS, INCLUDING ADDITION, SUBTRACTION, MULTIPLICATION AND DIVISION. THE SPEED WITH WHICH THESE OPERATIONS CAN BE PERFORMED IS ON THE ORDER OF A MILLIONTH (1,000,000) OF A SECOND. THE LOGIC UNIT CONSISTS OF ELECTRONIC CIRCUITRY TO COMPARE INFORMATION AND TO MAKE DECISIONS BASED UPON THE RESULTS OF THE COMPARISON. THE LOGICAL UNIT AND THE MEMORY ARE TWO OF THE FEATURES, AMONG OTHERS, THAT DISTINGUISH THE COMPUTER FROM SIMPLE, HAND-HELD CALCULATORS. MOST CALCULATORS CAN BE USED ONLY TO PERFORM ARITHMETIC OPERATIONS ON NUMBERS; THEY CANNOT COMPARE THESE NUMBERS, MAKE DECISIONS, OR STORE LARGE GROUPS OF NUMBERS.

- PAGE 6

COMPUTER TERMINALS USUALLY CONSIST OF A TYPEWRITER-LIKE KEYBOARD ON WHICH INFORMATION REQUIRED BY THE COMPUTER IS TYPED. TERMINALS CAN BE USED BOTH AS INPUT AND OUTPUT DEVICES. THE RESULTS OF A COMPUTATION MAY BE PRINTED ON PAPER OR DISPLAYED ON A VIDEO SCREEN AS ALPHANUMERIC CHARACTERS (LETTERS AND NUMBERS). SOME TERMINALS ARE EQUIPPED WITH GRAPHICS CAPABILITY WHICH ENABLES THE DISPLAY OF TWO-DIMENSIONAL GRAPHS OR PICTURES AND NOT JUST ROWS OF LETTERS AND NUMBERS. WITH SOME GRAPHICS DEVICES, THE USER CAN COMMUNICATE WITH THE COMPUTER BY POINTING AT INFORMATION DISPLAYED ON THE SCREEN WITH AN ELECTRONIC POINTER CALLED A LIGHT PEN.

IN ADDITION TO DISPLAYING OUTPUT ON PAPER OR VIDEO SCREENS, SUCH INFORMATION CAN ALSO BE TRANSFERRED TO A MAGNETIC STORAGE MEDIUM SUCH AS MAGNETIC TAPE OR DISC. SUCH MAGNETIC DEVICES ARE OFTEN CALLED AUXILIARY STORAGE DEVICES. THE MAGNETIC TAPE USED BY COMPUTERS IS SIMILAR TO THE MAGNETIC TAPE USED IN RECORDERS, AND MAGNETIC DISCS ARE ANALOGOUS TO LONG PLAYING PHONOGRAPH RECORDS.

PAGE 7

THE USE OF MAGNETIC AUXILIARY STORAGE DEVICES FOR COMPUTER OUTPUT HAS AT LEAST THREE ADVANTAGES, AND A DISADVANTAGE. TO TURN TO THE ADVANTAGES FIRST: 1) SPACE. AN ENORMOUS AMOUNT OF MATERIAL CAN BE STORED ON MAGNETIC TAPE. TO GIVE YOU AN EXAMPLE, IF ALL THE DATA ON A ROLL OF MAGNETIC TAPE WAS PRINTED, IT WOULD REQUIRE AN AVERAGE SIZE ROOM FOR STORAGE. 2) SPEED. DATA CAN BE TRANSFERRED TO MAGNETIC DEVICES MANY TIMES MORE RAPIDLY THAN IT CAN BE PRINTED, OR FLASHED ONTO A VIDEO SCREEN. THIS IS TRUE DESPITE THE FACT THAT THE HIGH SPEED PRINTERS ATTACHED TO MANY COMPUTER SYSTEMS CAN PRINT UPWARDS OF 1100 LINES, CONTAINING 132 CHARACTERS, A MINUTE. DESPITE THIS SPEED, TRANSFERRING DATA TO MAGNETIC TAPES OR DISCS IS MUCH, MUCH FASTER. 3) RETRIEVAL OF INFORMATION. DATA ON TAPE OR DISC CAN MORE RAPIDLY BE READ BACK INTO THE COMPUTER FOR FURTHER ANALYSIS THAN PRINTED INFORMATION.

A DISADVANTAGE OF MAGNETIC DEVICES IS THAT UNLIKE PRINTED OUTPUT, MAGNETIC DEVICES CANNOT BE DIRECTLY READ OR UNDERSTOOD BY HUMAN BEINGS. A TAPE OR DISC WOULD HAVE TO BE PRINTED UNDER COMPUTER CONTROL BEFORE IT CAN BE UNDERSTOOD BY PEOPLE.

PAGE 8

A GROUP OF INSTRUCTIONS BY WHICH COMPUTERS ARE ORDERED TO MANIPULATE DATA ARE CALLED A PROGRAM. ONCE THE COMPUTER HAS BEEN PROVIDED WITH A PROGRAM IT CARRIES THE INSTRUCTIONS OUT, OR "EXECUTES" THE PROGRAM. A PROGRAM IS STORED IN THE COMPUTER MEMORY ALONG WITH THE DATA IN WHICH THE PROGRAM OPERATES. PROGRAM AND DATA ARE STORED IN DIFFERENT MEMORY LOCATIONS, OF COURSE, OTHERWISE ONE WOULD ERASE THE OTHER.

WRITING A COMPUTER PROGRAM, OR PROGRAMMING IS VERY SIMILAR TO GIVING DIRECTIONS TO A STUDENT WHO REQUIRES VERY DETAILED INSTRUCTIONS. THE STUDENT MUST BE FAMILIAR WITH ALL THE VOCABULARY AND CONVENTIONS OF THE LANGUAGE IN ORDER TO SOLVE THE TASK. USE OF UNFAMILIAR WORDS, OR BREAKING THE RULES OF THE LANGUAGE WILL LEAD TO ERROR—WHETHER IN INSTRUCTING A STUDENT OR WRITING A COMPUTER PROGRAM.

PAGE 9

LANGUAGES USED FOR COMMUNICATION BETWEEN PEOPLE AND COMPUTERS ARE CALLED PROGRAMMING LANGUAGES. IN ORDER TO WRITE A PROGRAM, INSTRUCTIONS MUST BE COMBINED ACCORDING TO THE RULES OF THE PROGRAMMING LANGUAGE. THERE IS, HOWEVER, ONE SIGNIFICANT DIFFERENCE BETWEEN A PROGRAMMING LANGUAGE AND A LANGUAGE SUCH AS FRENCH, ENGLISH OR RUSSIAN. THE RULES OF A PROGRAMMING LANGUAGE ARE VERY PRECISE AND HAVE NO EXCEPTIONS OR AMBIGUITIES.

COMPUTERS CANNOT THINK OR INFER THE MEANING OF A VAGUE OR INCORRECT EXPRESSION. MACHINES CAN ONLY FOLLOW INSTRUCTIONS PRECISELY AS GIVEN. A PERSON EXPLAINING HOW TO SOLVE A PROBLEM TO ANOTHER PERSON CAN USE DIFFERENT EXPRESSIONS MEANING THE SAME THING, GIVE EXAMPLES, AND WHEN ALL ELSE FAILS SAY "YOU KNOW WHAT I MEAN" AND TRY TO EXPLAIN SOMETHING DIFFICULT BY GESTURE, VOICE, SMILES ETC. NONE OF THESE CAN OCCUR WITH COMPUTERS, NOR CAN A COMPUTER UNDERSTAND THE EXPRESSION "YOU KNOW WHAT I MEAN." COMPUTERS DO NOT KNOW WHAT IS MEANT UNLESS IT IS SPECIFIED VERY PRECISELY.

PAGE 10

WRITING A PROGRAM REQUIRES THAT THE PROGRAMMER ANALYZE THE TASK TO BE SOLVED VERY PRECISELY. THEN, THE STEPS REQUIRED TO SOLVE THE TASK ARE FIRST IDENTIFIED AND THEN ORDERED INTO A SEQUENCE. THIS SEQUENCE IS, FINALLY, TRANSLATED INTO A SET OF INSTRUCTIONS AND WRITTEN IN A PROGRAMMING LANGUAGE "UNDERSTOOD" BY THE MACHINE. IF THE INSTRUCTIONS ARE CLEAR, SEQUENCED CORRECTLY, AND FOLLOW ALL THE RULES OF THE LANGUAGE--THE PROGRAM WILL EXECUTE AND SOLVE THE PROBLEM. IF, ON THE OTHER HAND, THERE ARE MISSING STEPS IN THE INSTRUCTIONS, ANY OF THE INSTRUCTIONS ARE AMBIGUOUS, OR SOME OF THE RULES HAVE BEEN BROKEN THE PROGRAM WILL NOT RUN, OR EXECUTE.

BASIC (BEGINNER'S ALL-PURPOSE SYMBOLIC INSTRUCTION CODE) IS A PROGRAMMING LANGUAGE THAT WAS DEVELOPED AT DARTMOUTH COLLEGE. BASIC WAS DESIGNED FOR USE BY STUDENTS AND OTHERS WHO REQUIRE A RELATIVELY SIMPLE LANGUAGE WITH WHICH TO BEGIN PROGRAMMING. MANY BASIC PROGRAMMING AND PROBLEM SOLVING CONCEPTS WILL BE APPLICABLE TO OTHER PROGRAMMING LANGUAGES. BASIC CONCEPTS WILL BE USED TO ILLUSTRATE THE WAY COMPUTERS WORK, RATHER THAN TO EXPECT YOU TO BE A PROFICIENT BASIC PROGRAMMER.

PAGE 11

MOST COMPUTERS CANNOT EXECUTE BASIC PROGRAMS DIRECTLY. THEY MUST FIRST BE TRANSLATED INTO THE LANGUAGE UNDERSTOOD BY THE COMPUTER CALLED MACHINE LANGUAGE. THE TRANSLATION IS PERFORMED BY A PROGRAM CALLED A COMPILER. IF THE TRANSLATION IS SUCCESSFUL, THE MACHINE LANGUAGE VERSION OF THE PROGRAM IS STORED IN MEMORY READY TO BE CARRIED OUT, OR EXECUTED.

THERE ARE TWO MAJOR ADVANTAGES TO PROGRAMMING IN A LANGUAGE LIKE BASIC. FIRST, BASIC, IS MUCH CLOSER TO OUR OWN LANGUAGE THAN IS MACHINE LANGUAGE; HENCE IT IS MUCH EASIER TO WRITE BASIC PROGRAMS. SECOND, BASIC PROGRAMS ARE HIGHLY TRANSFERABLE; A BASIC PROGRAM WRITTEN FOR ONE COMPUTER CAN OFTEN BE EXECUTED ON A VARIETY OF OTHER MACHINES. ON THE OTHER HAND, A MACHINE LANGUAGE PROGRAM WRITTEN FOR ONE COMPUTER WILL NOT NORMALLY EXECUTE ON A DIFFERENT TYPE OF COMPUTER.

IN ORDER TO EXECUTE A PROGRAM, THE COMPUTER CONTROL UNIT EXAMINES EACH PROGRAM STEP IN MEMORY, STARTING WITH THE FIRST, AND SENDS OUT THE COMMAND SIGNALS APPROPRIATE FOR CARRYING OUT THE INSTRUCTION. NORMALLY, THE INSTRUCTIONS ARE EXECUTED IN SEQUENCE; HOWEVER, IT IS POSSIBLE TO HAVE THE CONTROL UNIT SKIP OVER SOME INSTRUCTIONS OR EXECUTE SOME INSTRUCTIONS MORE THAN ONCE.

PAGE 12

DURING EXECUTION, DATA TO BE PROCESSED MAY BE ENTERED INTO MEMORY OF THE COMPUTER, AND THE RESULTS OF THE MANIPULATION PERFORMED ON THIS DATA MAY BE DISPLAYED. OF COURSE, THESE THINGS WILL HAPPEN ONLY IF THE PROGRAM CONTAINS INSTRUCTIONS TELLING THE COMPUTER TO ENTER OR DISPLAY THE APPROPRIATE LANGUAGE.

ONE OF THE MOST IMPORTANT FEATURES OF BASIC IS THAT IT PERMITS US TO REFER TO DATA THAT ARE STORED IN MEMORY WITHOUT HAVING TO SPECIFY THE ADDRESS IN WHICH THE DATA ARE CONTAINED. FOR EXAMPLE, IN MACHINE LANGUAGE WHEN AN ADDITION IS PERFORMED ONE MIGHT INSTRUCT THE MACHINE TO STORE A VALUE IN MEMORY CELL #101, AND A SECOND VALUE IN MEMORY CELL #102. IF THE TWO NUMBERS ARE TO BE ADDED, THE CONTENTS OF CELL 101 AND CELL 102 WILL BE TRANSFERRED TO THE ARITHMETIC UNIT OF THE CPU WHERE THE ADDITION OF THE CELLS IS PERFORMED. THE PROGRAMMER WOULD ALSO SPECIFY THAT THE RESULTS OF THAT OPERATION SHOULD BE STORED IN LOCATION #103, FOR EXAMPLE. FINALLY, ANOTHER INSTRUCTION IS NEEDED TO PRINT THE CONTENTS OF CELL #103.

PAGE 13

WHEN VERY LARGE GROUPS OF NUMBERS, OR OTHER DATA, ARE TO BE MANIPULATED, KEEPING TRACK OF THE ADDRESSES IN WHICH THESE NUMBERS ARE STORED IN THE MACHINE BECOMES VERY LABORIOUS, AND SUBJECT TO A GOOD DEAL OF ERROR. PROGRAMMING IN A LANGUAGE LIKE BASIC MAKES IT UNNECESSARY TO KEEP TRACK OF THE STORAGE LOCATIONS. IN BASIC FOR EXAMPLE, DATA ARE REFERRED TO BY NAMES RATHER THAN ADDRESSES. THE COMPUTER ASSIGNS MEMORY CELLS TO EACH NAME USED IN A PROGRAM, AND KEEPS TRACK OF THE LOCATION OF THE CELLS. TO REPEAT THE EXAMPLE DESCRIBED ON PAGE 12, THE BASIC PROGRAM TO PERFORM THE ADDITION DESCRIBED ABOVE WOULD BE:

LET C = A + B.

THE BASIC COMPILER GENERATES THE INSTRUCTIONS TO KEEP TRACK OF WHERE A, B, AND C ARE STORED, FREEING THE PROGRAMMER OF THIS BOTHERSOME CHORE. A, B, + C ARE CALLED VARIABLE NAMES IN BASIC.

PAGE 14

IN BASIC VARIABLE NAMES CONSIST OF A SINGLE LETTER OR A LETTER FOLLOWED BY A DIGIT (0-9). EXAMPLES OF VALID VARIABLES NAMES WOULD BE: A, C, C5, D9. INVALID VARIABLE NAMES WOULD BE: 5C, A+, B36, TAX, 25.

IT IS A GOOD IDEA TO CHOOSE THE FIRST LETTER OF A WORD AS THAT BASIC NAME FOR THE VARIABLE. FOR A PAYROLL PROGRAM, WE MIGHT USE THE VARIABLES H FOR HOURS WORKED, R FOR RATE OF PAY, T FOR TAX AMOUNT, G FOR GROSS SALARY AND N FOR NET PAY.

THERE ARE MANY DIFFERENT TYPES OF COMPUTERS AVAILABLE AND EACH IS CAPABLE OF OPERATIONS THAT ARE COMMON TO MOST COMPUTERS. THESE TYPES OF OPERATIONS MAY BE DIVIDED INTO THREE DIFFERENT CLASSES: 1) INPUT/OUTPUT OPERATIONS WHICH READ AND PRINT DATA, 2) DATA MANIPULATION AND COMPARISON (ADD, SUBTRACT, MULTIPLY, DIVIDE, COPY, COMPARE), AND 3) CONTROL OPERATIONS (TRANSFER, CONDITIONAL EXECUTION, STOP).

PAGE 15

IN ORDER TO DESCRIBE HOW SOME OF THESE OPERATIONS ARE PERFORMED, THEY WILL BE DEMONSTRATED IN BASIC. BEFORE WE GO ON, HOWEVER, IT IS IMPORTANT TO DESCRIBE SOME OF THE SYMBOLS USED FOR THE MOST COMMON MATHEMATICAL OPERATIONS. IN BASIC THESE ARE REFERRED TO AS OPERATORS. THE FOUR MOST COMMONLY USED OPERATORS ARE DESCRIBED BELOW:

- + ADDITION
- SUBTRACTION
- * MULTIPLICATION
- / DIVISION

WE WILL USE THESE FOUR ARITHMETIC OPERATORS IN A NUMBER OF EXAMPLES OF A PAYROLL PROGRAM TO GIVE YOU AN IDEA OF WHAT IT IS LIKE TO PROGRAM IN BASIC.

THE PROBLEM IS AS FOLLOWS: COMPUTE THE GROSS SALARY AND NET PAY FOR AN EMPLOYEE, GIVEN THE EMPLOYEE'S HOURLY RATE, THE NUMBER OF HOURS WORKED, AND THE AMOUNT OF TAX DEDUCTED.

PAGE 16

AS INDICATED ABOVE IT IS A GOOD IDEA TO USE THE FIRST LETTER OF A WORD AS THE BASIC NAME FOR THE VARIABLE. H WILL REPRESENT THE NUMBER OF HOURS WORKED AND R THE RATE OF PAY PER HOUR. THE VARIABLES G AND N WILL BE USED TO REPRESENT THE GROSS AND NET SALARY, RESPECTIVELY. THE VARIABLE T WILL REPRESENT THE AMOUNT OF TAX TO BE WITHHELD FROM THE PAYCHECK. FOR SIMPLICITY, WE WILL ASSUME THE WITHHOLDING AMOUNT TO BE 25% REGARDLESS OF AN EMPLOYEE'S GROSS SALARY. (A MORE REALISTIC TAX SCHEDULE WOULD CALCULATE THE AMOUNT OF TAX WITHHELD BY USING A TABLE OF VARYING PERCENTAGES BASED ON THE EMPLOYEE'S GROSS SALARY.)

OUR FIRST PROBLEM IS TO FIND THE NET PAY (N) BY DEDUCTING THE TAX (T) FROM THE GROSS SALARY (G). THE BASIC STATEMENT TO ACCOMPLISH THIS WOULD READ:

$$\text{LET } N = G - T.$$

A SECOND STATEMENT WOULD BE NEEDED TO COMPUTE THE GROSS SALARY (G) GIVEN THE NUMBER OF HOURS (H) WORKED AND THE RATE OF PAY PER HOUR (R). THE BASIC STATEMENT FOR THIS MANIPULATION WOULD BE:

$$\text{LET } G = H * R.$$

PAGE 17

THESE TWO DATA MANIPULATION INSTRUCTIONS ARE CALLED ASSIGNMENT STATEMENTS BECAUSE THEY SPECIFY AN ASSIGNMENT OF VALUE TO A GIVEN VARIABLE. FOR EXAMPLE, THE STATEMENT:

$$\text{LET } G = H * R$$

SPECIFIES THAT THE VARIABLE G WILL BE ASSIGNED TO THE RESULT OF THE MULTIPLICATION (*) OF THE VARIABLES H AND R .

THE $=$ SIGN IS A POSSIBLE SOURCE OF CONFUSION BECAUSE IT HAS DIFFERENT MEANINGS IN MATHEMATICS AND IN BASIC. IN MATHEMATICS, OF COURSE $=$ MEANS THAT WHATEVER IS ON ONE SIDE OF THE EQUATION IS EQUAL TO THE OTHER SIDE. THIS IS NOT THE WAY THIS SIGN IS USED IN BASIC. INSTEAD THE $=$ SIGN REPRESENTS IN REPLACEMENT IN BASIC. FOR EXAMPLE THE STATEMENT:

$$\text{LET } G = H * R$$

MEANS LET THE VALUE OF THE VARIABLE G BE REPLACED BY THE PRODUCT OF THE VARIABLES H AND R . SIMILARLY, THE STATEMENT:

$$\text{LET } N = G - T$$

WOULD BE TRANSLATED TO SAY THAT N SHOULD BE REPLACED BY THE VALUE T SUBTRACTED FROM G .

PAGE 18

THE GENERAL FORM OF THE ASSIGNMENT STATEMENT IS SHOWN BELOW:

LET RESULT = OPERAND 1 ARITHMETIC-OPERATOR OPERAND 2.

OPERAND 1 AND OPERAND 2 REPRESENT THE QUANTITIES OR VARIABLES BEING MANIPULATED; ARITHMETIC-OPERATOR INDICATES THE MANIPULATION TO BE PERFORMED (+, -, * OR /). THE OPERANDS MAY BE EITHER VARIABLES NAMES SUCH AS N, G, T, OR NUMBERS. THE ARITHMETIC-OPERATOR MAY BE ANY OF THE FOLLOWING FOUR SYMBOLS DESCRIBED ABOVE.

ASSIGNMENT STATEMENTS CAN ALSO BE WRITTEN WITH A SINGLE OPERAND.

THE STATEMENT:

LET A = B

INSTRUCTS THE COMPUTER TO REPLACE, OR COPY THE VALUE OF THE VARIABLE B INTO A.

INFORMATION CANNOT BE MANIPULATED BY THE COMPUTER UNLESS IT IS FIRST STORED IN MEMORY. THERE ARE TWO WAY OF INITIALLY PLACING DATA TO BE MANIPULATED INTO COMPUTER MEMORY: 1. BY USE OF A "COPY" ASSIGNMENT STATEMENT, OR 2. BY READING THE DATA INTO MEMORY DURING THE EXECUTION OF THE PROGRAM. NORMALLY, THE FIRST APPROACH IS TAKEN FOR A DATA ITEM THAT IS A "PROGRAM CONSTANT" AND DOES NOT CHANGE FROM ONE USE OF THE PROGRAM TO THE NEXT. THE SECOND APPROACH IS TAKEN FOR DATA THAT ARE LIKELY TO VARY.

PAGE 19

TO RETURN TO OUR PAYROLL EXAMPLE, IF THE TAX WITHHOLDING RATE IS 25% REGARDLESS OF THE EMPLOYEE'S NET PAY THIS VALUE CAN BE COPIED INTO THE VARIABLE T BY THE USE OF THE FOLLOWING ASSIGNMENT STATEMENT:

LET T = .25

THIS STATEMENT DEFINES THE VALUE OF T AS A CONSTANT 25%. UNLESS OTHERWISE CHANGED, T WILL STAND FOR 25% WHENEVER IT IS EXECUTED LATER IN THE PROGRAM.

ANOTHER WAY OF ASSIGNING A VALUE TO A VARIABLE IN THE PROGRAM IS TO PROVIDE IT THROUGH THE INPUT CHANNEL. FOR EXAMPLE, THE FOLLOWING STATEMENT:

INPUT H, R

CAUSES THE COMPUTER TO EXPECT TO READ TWO VALUES ON THE INPUT CHANNEL. THE FIRST VALUE WILL BE ASSIGNED TO THE VARIABLE H AND THE SECOND VALUE ASSIGNED TO THE VARIABLE R.

PAGE 20

COMPUTERS ALMOST NEVER MAKE MISTAKES. WHEN A COMPUTER MANIPULATION DOES RESULT IN ERROR, IT IS GENERALLY BECAUSE INCORRECT DATA, OR INPUT WERE PROVIDED. FOR THIS REASON IT IS ADVISABLE TO DISPLAY WHATEVER DATA WERE READ IN SO THAT ONE CAN BE SURE THAT THE CORRECT VALUES ARE MANIPULATED. SUCH AN OPERATION IS CALLED AN "ECHO PRINT" BECAUSE ONE IS SIMPLY DISPLAYING ALL THE VARIABLES WHICH HAVE BEEN READ INTO THE PROGRAM. THE BASIC STATEMENT:

```
PRINT H,R
```

WILL CAUSE THE VALUES OF THE VARIABLES H AND R TO BE PRINTED OUT OR DISPLAYED AS PROGRAM OUTPUT. THE VALUES OF H AND R ARE NOT CHANGED BY THIS OPERATION. IN THIS WAY THE PROGRAMMER CAN IMMEDIATELY CHECK WHETHER THE PROGRAM IS USING THE CORRECT VALUES.

THE PRINT STATEMENT IS ALSO USED TO DISPLAY THE RESULTS OF ANY PROGRAM. FOR EXAMPLE, THE STATEMENT:

```
PRINT G,N
```

WOULD CAUSE THE VALUES G AND N TO BE DISPLAYED AS OUTPUT.

PAGE 21

TO REVIEW THE THREE DIFFERENT TYPES OF STATEMENTS WE HAVE USED:
THE INPUT, PRINT AND ASSIGNMENT STATEMENT IN A LITTLE PROGRAM.

```
INPUT H,R  
PRINT H,R  
LET G = H * R  
LET T = .25  
LET N = G - T  
PRINT G,N  
END
```

TO REVIEW THE LOGIC OF THIS LITTLE PROGRAM. FIRST WE PROVIDE THE PROGRAM WITH THE INPUT OF THE NUMBER OF HOURS WORKED, AND THE RATE OF PAY. AN "ECHO CHECK" IS RUN TO MAKE SURE THAT THE CORRECT VALUES WERE SUPPLIED. WE THEN COMPUTE THE GROSS RATE OF PAY, PROVIDE THE AMOUNT OF TAX TO BE WITHHELD, AND COMPUTE THE NET RATE OF PAY. FINALLY, WE PRINT THE RESULTS OF THE CALCULATION. YOU WILL NOTICE ONE FINAL STATEMENT, THE END. OBVIOUSLY THAT SIGNIFIES THAT THE PROGRAM HAS COME TO A COMPLETION.

PAGE 22

FOR PURPOSES OF CLARITY WE HAVE OMITTED ONE REQUIREMENT: THAT EACH LINE IN A BASIC PROGRAM HAS TO BE NUMBERED. FOR EXAMPLE, THE FIRST TWO LINES OF A PROGRAM ARE REPRODUCED BELOW WITH NUMBERS.

```
10 INPUT H,R  
20 PRINT H,R
```

THE NUMBERS INDICATE THE ORDER IN WHICH A PROGRAM IS EXECUTED. TYPICALLY, A PROGRAM BEGINS EXECUTION WITH THE SMALLEST NUMBER AND PROCEEDS TO THE HIGHEST OR LAST NUMBER. THIS SEQUENCE IS FOLLOWED UNLESS THE PROGRAMMER GIVES ALTERNATE INSTRUCTIONS WHICH WE WILL NOT GO INTO HERE.

WHEN PROGRAMMERS COMPLETE WRITING THE PROGRAM AND WANT THE PROGRAM TO EXECUTE, THEY INFORM THE MACHINE THAT THE PROGRAM IS READY FOR EXECUTION. IN BASIC THIS INSTRUCTION IS CALLED RUN. WHEN THE WORD RUN APPEARS AFTER THE END STATEMENT, THE MACHINE AUTOMATICALLY PROCEEDS TO EXECUTE THE PROGRAM.

YOU HAVE NOW LEARNED SOME OF THE BASIC CONCEPTIONS DEALING WITH COMPUTERS, ILLUSTRATED BY EXAMPLES FROM THE BASIC LANGUAGE. IF YOU WOULD LIKE FURTHER INFORMATION REGISTER FOR A COURSE IN BASIC, OR BUY A BASIC MANUAL. HAPPY COMPUTING !!!!!!!!!

APPENDIX G

Adjunct Postquestions

1. The greater the number of operations the computer can carry out at the same time the higher its_____.
2. Here are three computer operations: (1) data manipulated by the central processor; (2) information entered into memory; (3) results are displayed. Which of the above computer operations occurs first_____ and last_____?
3. List two types of information that can be represented by computer: (1)_____ (2)_____.
4. Which part of the computer coordinates the work of all the other components_____?
5. Which part of the CPU performs multiplication and division_____?
6. In addition to video screens, name two units which can be used for output (1)_____ (2)_____.
7. In addition to the fact that data may be retrieved more rapidly with magnetic storage devices, such storage has two further advantages. With magnetic storage: (a) the amount of data that can be stored is_____; (b) the speed of the transferring is_____.
8. A group of instructions by which computers manipulate information is called a_____.
9. A student wants an instruction in a computer program to have more than one meaning. Such a program will probably_____.
10. If all the steps needed to solve a problem are identified, ordered correctly, and follow all programming rules, the program will_____?
11. Which one of the computer languages described so far is transferable from one machine to another_____?
12. In order to manipulate data in machine language programming, the programmer must specify the _____ in which the data are stored.

13. Programming in BASIC is easier because data are referred to by _____ rather than by addresses.
14. An example of a valid variable name in BASIC might be _____.
15. In BASIC the operator * stands for _____.
16. The most convenient BASIC name for a variable representing price would be _____.
17. The BASIC operator = means _____.
18. In the statement $N=G-T$, which is an operand _____?
19. If you want to read two values, A and B into the machine, the correct instruction is _____.
20. When data that have been read into the computer are displayed for checking, this is called _____?
21. The BASIC statement signifying that a program is finished is _____.
22. Every BASIC statement begins with a _____.

APPENDIX H

Posttest

1. The amount of work a computer can do in a specific period of time determines its _____.
2. Today the cost of a personal computer is roughly the same as the price of a _____.
3. Give two examples of alphanumeric characters:
_____.
4. In BASIC the symbol = means _____.
5. When large groups of numbers are to be manipulated, programming in machine language becomes _____.
6. A group of instructions by which computers manipulate information is called a _____.
7. When a machine language programmer wishes to manipulate data, the _____ in which the data are stored must be specified.
8. Two important differences between "hand-held" calculators and computers is that calculators can not perform the following operations:
 - 1) _____
 - 2) _____

9. Computer memory may be conceptualized as an ordered series of _____.
10. In BASIC, data are always referred to by their _____.
11. Compared to languages like English, Spanish, or French, programming languages are much more _____.
12. Name two types of information that can be represented by computer
1) _____ 2) _____.
13. Name at least three units which can be used for output.

14. An example of a valid variable name in BASIC would be _____.
15. The program which translates BASIC into instructions usable by the computer is called the _____.
16. When an instruction has more than one meaning the program will probably _____.

17. When a program is ready for execution the appropriate BASIC instruction is _____.
18. If you want to read two values, A and B, into the computer, the correct BASIC instruction is _____.
19. Write the BASIC instruction to display the variables X and Y
_____.
20. In BASIC every instruction begins with a _____.
21. Write the BASIC instruction which signals the conclusion of a program _____.
22. The computer component responsible for coordinating the work of all the other components is called the _____.
23. In BASIC the symbol * stands for _____.
24. Although computers differ widely in cost, size, and capabilities all computers have the following components: input and output devices and _____ and _____.
25. In BASIC it would be most convenient to assign what name to a variable representing "cost"? _____.

26. Answer true or false. Data may be entered into the computer during execution? _____.

27. Which component of the CPU transmits control signals and commands? _____.

28. Please list the order (1-3) in which the computer operations below occur:

- A. displaying results
- B. data entered into computer
- C. data manipulation by the CPU:

1) _____ 2) _____ 3) _____.

29. All computers are capable of the following operations (A) data manipulation (+, -) (B) control operations (transfer, stop) and (C) _____.

30. How many data items can be stored in one bit of computer memory at one time? _____.

31. Two advantages of using magnetic tape storage are _____

32. The component of the CPU that performs multiplication and division is called the _____ unit.

33. The BASIC instruction which displays data read into the computer is called a (an) _____.

34. A disadvantage of storing data on magnetic tape or disk is
_____.

35. In the BASIC statement $X=I-I$ which symbol is an operand?
_____.

36. Write a BASIC assignment statement.
_____.

37. Write a BASIC statement defining a constant value for X.
_____.

38. Where was the BASIC programming language developed?
_____.

39. List two advantages of programming in BASIC compared to machine language.

(1) _____.

(2) _____.

40. If all the steps needed to solve a problem are identified, ordered correctly, and follow all programming rules, the program will
_____.

41. In BASIC the symbol / stands for _____.
42. Both programs and data are stored in the computer's _____.
43. Please complete the general form of the assignment statement in BASIC: RESULT = OPERAND1... _____.
44. Which unit of the CPU compares information and makes decisions?
_____.

APPENDIX I

INSTRUCTIONS

These instructions will describe the use of the computer for this project. As you know, you will be reading text and you will be taking a detailed fill-in test when you have finished. The material will appear one sentence at a time, and each sentence is numbered. When the next sentence appears, the previous one will disappear. You can, if you wish, review at any time. The instructions will describe how that is done.

We have designed a number of features to make it easy for you to understand the material completely. Further description will appear on the machine, and on a summary sheet which you should keep in front of you while working on the computer.

<u>KEY</u>	<u>FUNCTION</u>
<u>SPACE BAR</u>	The SPACE BAR can be found at the bottom of the key board. Hit the SPACE BAR when you have finished reading one sentence and are ready for the next one.
<u>RETURN</u>	The RETURN key is found at the upper right of the key board. Whenever you use one of the features listed below, the RETURN key brings you back to the point at which you were working.
<u>A</u>	<p>Alternate text. We have prepared a clearer description of every paragraph. When A is pressed it will bring the alternate text into view. The Alternate text may be called <u>only</u> at the end of a paragraph which will be shown by an arrow.</p> <p>Alternate text may be reviewed, but it cannot be previewed. Press RETURN to return to the main text from the Alternate. To go from one sentence of the Alternate to another, press the SPACE BAR.</p>
<u>H</u>	<p>Headings. We have prepared a table of all the headings used in the text. When H is pressed all of the headings will appear on the screen, including the sentence numbers contained in each heading. The screen will also display the sentence you are presently working on so that you can call where the present spot fits into the overall text.</p> <p>Press RETURN to return to the spot you were working on in the main text.</p>

<u>KEY</u>	<u>FUNCTION</u>
<u>N</u>	<p>Notes. It will possible for you to take notes on the screen so that you can remember those things you consider important. When you are taking notes you may use the SHIFT key to capitalize any letter or word. The RETURN key may be pressed to start a new line, otherwise the computer will change lines automatically.</p> <p>Press RETURN <u>after a blank line</u> to return to the main text.</p>
<u>?</u>	<p>Preview. You may preview any sentence(s). Once you press ? the computer will ask you From: in that spot indicate the sentence number you wish to begin previewing. The computer will then ask you To: here supply the line where you wish to end previewing. For example, ? From: 12 To: 16 means preview sentences 12 To 16. ? From: 12 To: 12 means preview only sentence number 12. When you are previewing the SPACE BAR will permit you to go from one sentence to the other. Press RETURN to return to the spot in the main text on which you were working.</p>
<u>R</u>	<p>Review. Once you hit R the computer will ask you if you wish to review text (T), Alternate text (A), or notes (N). You can review any of these as often as possible. Here is how you go about doing it.</p> <p>Review sentences. When you wish to review sentences the computer will ask you From: you press the sentence number at which you wish to begin the review. The computer will then ask you To: supply the sentence number at which you wish to stop reviewing. For example, R From: 12 To: 16 means review sentences 12 - 16. R From: 29 To: 29 means review sentence 29. While you are reviewing sentences, the computer will remind you to hit the SPACE BAR to continue reviewing.</p> <p>Press RETURN to return to the main text.</p> <p>Once you select a Review of the Alternate text, the procedure is exactly the same as that above.</p> <p>Review Notes. When you review notes all your prior notes will be displayed. When you have finished press RETURN to go back to the main text.</p>

This is less complicated than it sounds. We have material in the computer, and the ? feature to help you. Also, keep the summary in front of you to clear up any confusion. HAVE FUN!!!

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