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City University of New York PH.D. 1985

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EVALUATIVE AND MATHEMATICS ANXIETY AND THE EFFECTS OF METACOGNITIVE STRATEGY TRAINING

Elenor Rubin Denker

A dissertation submitted to the Graduate Faculty in Educational Psychology in partial fulfillment of the requirements for the degree of Doctor of Philosophy, The City University of New York.

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Abstract

EVALUATIVE AND MATHEMATICS ANXIETY AND THE EFFECTS OF METACOGNITIVE STRATEGY TRAINING

by

Elenor Rubin Denker

Advisor: Dr. Sigmund Tobias

The purpose of this research was to examine the interactional effect of anxiety on learning, and to investigate the use of a metacognitive checking strategy in the possible reduction of the negative effects of debilitative anxiety. It was hypothesized that being taught a metacognitive checking strategy would reduce the interfering effects of high evaluative anxiety by allowing the subject to direct more attention to the work at hand.

One hundred and fifty-three subjects responded to an evaluative anxiety instrument (the Test Anxiety Scale), a mathematics anxiety instrument (the Mathematics Anxiety Rating Scale), three administrations of a state anxiety measure (the Worry-Emotionality Scale), an algebra lesson, and an algebra test (pre and post). Subjects were randomly assigned in a 2 x 2 experimental design with anxiety considered a continuous variable. One experimental treatment consisted of a self-instructional algebra module including items teaching students to check their own work;

the control module did not contain the checking instruction. There were also two conditions varying the administration of the post-test: an experimental format that encouraged checking and a standard test format.

Two specific hypotheses were tested: high anxious students taught to check their work were expected to perform better on a post-test than high anxious students who were not taught to check; and high anxious students encouraged to check by test format would perform better on a post-test than high anxious students not encouraged to check. Multiple linear regression analyses indicated no support for the first hypothesis. Some evidence that test format can influence the performance of high state-anxious students was found, but not in the expected direction. An additional tendency was observed that for high trait-anxious students, a checking format on the posttest is facilitative.

Results are discussed in terms of theoretical problems of error and anxiety, and procedural considerations such as the ceiling effect, difficulty level of the material, the non-stressful environment, and the one week delay after a one hour treatment. Suggestions for further research include the incorporation of a modeling component in the design, and the addition of guided checking on the posttest.

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Appreciation is also due to Lawrence Erlbaum Associates which permitted the reproduction of the Model of anxiety-treatment interactions (Tobias, 1977c).

TABLE OF CONTENTS

List of Tables

List of Figures

INTRODUCTION

The purpose of this study was to clarify the relationship between anxiety and learning and to investigate how the negative effects of anxiety can be ameliorated. The general hypothesis was of an interaction between anxiety and instructional strategy such that the achievement of high test anxious learners would increase with training in a metacognitive checking strategy, whereas the achievement of low anxious students would be unaffected. This hypothesis was based on the theories of Wine, Sarason, and Tobias. Wine (1980) and Sarason (1972) proposed an explanation of test anxiety which focused on the direction of attention. Learning and performing a task require that attention be devoted to the task. Anxiety diverts the attention of the person to negative self-concern, thus reducing the amount of attention devoted to the task. It was therefore postulated that high anxiety students who are taught a strategy which helps focus attention would perform better on a task. Tobias (1977c, 1982) has suggested that checking one's work is a metacognitive strategy which should improve performance at the pre-processing and processing stages of learning. This study tested that hypothesis by teaching checking skills in a mathematics context.

REVIEW OF THE LITERATURE

Evaluative Anxiety

The twelve or sixteen years that most Americans spend attending school tend to be filled with "evaluation" situations. In the academic sphere alone there are course placement test, quizzes, mid-terms, finals, regents, assignments, reports, and college placement tests. It is also a period when self-concept and self-esteem are developing, and social 'testing' situations are evident. People react to being evaluated in varied ways, some of which are productive and others counterproductive.

Hill (1984) reported that "by the end of the elementary school years, the 10 percent most anxious students are over two years behind the 10% least anxious students in reading and arithmetic test performance" (p. 3).

If the educational process is to improve, the anxiety engendered by evaluations must be better understood. When is it useful? When does it impede learning or performance? What causes it and how can it be moderated?

History

Mandler and Sarason's 1952 article on anxiety and learning is generally accepted as the origin of the concept of test anxiety. Specifically, they focused their investigation on the role of drive states in a testing situation. Their concept of drive states was

based on Miller and Dollard (1941) and Hull (1943). Thirty-three subjects were involved in this initial study. A questionnaire with items about anxiety was administered and these scores compared to intelligence test scores. In addition, subjects were randomly informed that they had done well, done poorly, or received no feedback in regard to the intelligence test scores. Results indicated that the variability of intelligence test scores of the high anxious subjects was significantly larger than for the low anxiety subjects. Feedback regarding success or failure tended to improve the performance on intelligence tests of low anxious subjects while depressing the scores of the high anxious subjects.

The next major stage in the development of the test anxiety construct came in 1960 when S.B. Sarason and his associates published a book on Anxiety in Elementary School Children. They characterized the test anxious child as having self-deprecatory attitudes and as anticipating not meeting certain standards on tests. Anxious children become more aware of their internal reactions and the perception of the external field narrows, resulting in an impairment of problem solving (p.20). Additionally, the authors hypothesized that teachers are generally unable to recognize test anxiety since it is a covert response. "The passage of time tends not to be therapeutic and the problem may remain at a particular level or become worse. In addition, since the test anxious response essentially prevents the child from an objective assessment either of himself or the external situation, and tends to result in self-defeating behavior, repeated test experiences would not be expected

in themselves to result in a reduction of test anxiety" (S.B.Sarason et al., 1960, p.22).

State and Trait Anxiety

During the 1960's, considerable research was generated concerning the school experience for test anxious students. In 1972, Spielberger edited a book on Anxiety: Current Trends in Theory and Research (I), which included a chapter by him on the distinction between anxiety as a transitory state and as a relatively stable personality trait. According to Spielberger:

> state anxiety (A-State) may be conceptualized 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 intensity should be low in non-stressful situations, or in circumstances in which an existing danger is not perceived as threatening.
>
> Trait anxiety (A-Trait) refers to relatively stable individual 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. A-Trait may also be regarded as reflecting individual differences in the frequency and the intensity with which A-States have been manifested in the past, and in the probability that such states will be experienced in the future. (Spielberger, 1972, p.39)

In addition to the state-trait distinction, another issue currently being investigated in the area of evaluative anxiety is the distinction between cognitive and physiological reactions (worry and emotionality) The effects of evaluative anxiety on attention to task and performance has also been investigated. These are discussed next.

Worry - Emotionality

A distinction is currently made in the literature between two components of anxiety: worry and emotionality. As originally suggested by Liebert and Morris (1967), worry refers to the cognitive area of focusing on concerns about performance, concerns about failure, and concerns about self in relation to others. Emotionality refers to the awareness of physiological reactions such as an upset stomach, increased heartbeat, or sweating. A ten-item scale (5 worry items and 5 emotionality items) was developed, based on the Test Anxiety Questionnaire. Subjects respond to each item on a five point Likert-type scale. Several studies of the relationship of worry and emotionality to test performance under varied conditions indicated that worry is more negatively related to intellectual performance than emotionality (Morris & Liebert, 1969, 1970, 1973).

According to Deffenbacher's review (1980), worry and emotionality tend to correlate with each other (r's range from .55 to .76) during evaluative stress. Although worry has been found to correlate negatively with performance fairly consistently, the data on emotionality are less consistent. The cues that elicit worry and emotionality are different: emotionality, for example, occurs at the beginning of an exam; worry appears to be related to cues signaling probable success or failure (Deffenbacher, 1980, p. 120).

Wine (1971) suggested that the worry component is closely related to an attentional interpretation of test anxiety: cognitive concerns about the adequacy of one's performance divert one's attention from the task, whereas sweating or increased pulse rate

may not necessarily involve cognition, unless one is worried about these reactions. "An attentional interpretation states simply that the reason 'worry ' debilitates task performance is that it is attentionally demanding and distracts attention from the task" (Wine, 1971, p.100). Wine's theory is discussed next.

Direction of Attention

In 1971 Wine published her seminal paper suggesting that the adverse effects which test anxiety has on performance should be viewed from the perspective of the direction of attention. (The attentional interpretation was also developed independently by I. Sarason in 1972). According to Wine "the high test anxious individual focuses on selfevaluative, self-deprecatory thinking, and perception of ... autonomic responses" while the low test anxious individual is focusing on task-relevant matters (p.92). The high test anxious individual is therefore unable to attend fully to difficult tasks in evaluative settings and performance declines. In support of Wine's hypothesis, Doris and S. Sarason (1955) found that high-anxious subjects blamed themselves for their failures significantly more than did low anxious subjects, although the performance of both groups was not different.

Meunier and Rule (1967) had similar results: high test anxious subjects rated their confidence level during a negative-feedback condition the same way they rated their confidence level during a no feedback condition, whereas the low test anxious subjects were equally confident during no feedback as they were during the

positive feedback condition.

Wine also discussed studies which indicated that high test anxious individuals are generally self-deprecating and self-preoccupied, and that these characteristics are particularly evident in testing situations. Four studies found that high test anxious individuals reported thinking about how well or badly they were doing during testing more often than did low test anxious subjects (Mandler & Watson, 1966; Neale & Katahn, 1968, Marlett & Watson, 1968; Stanford, Dember, & Stanford, 1963). Similarly Ganzer (1968) found that high test anxious females uttered more task irrelevant comments during a task, primarily selfevaluative or apologetic thoughts, than did low test anxious females; this was particularly true of the group that was observed during the task. Sarason (1980) developed a Cognitive Interference Questionnaire (CIQ) to examine the effects of non-task relevant thoughts during an evaluation. With this instrument, Paulman and Kennelly (1984) found significant negative correlations between scores on the CIQ and three problem solving measures. The three correlations ranged from -.38 to -.43. The authors concluded that there was a negative impact on achievement from self- rumination by high test anxious students.

According to Wine there is considerable evidence (13 sources cited) that the relationship between performance and test anxiety is interactive when evaluative emphasis is varied: high test anxious individuals perform better when non-stressful instructions are used than when the task is presented as a highly evaluative one; the

reverse is true for low-test anxious subjects. When highly evaluative instructions are given, high test anxious subjects do not perform as well as low test anxious subjects; with non-evaluative instructions, high test anxious subjects perform better than low test anxious subjects.

I. Sarason (1958) found that high test anxious students performed better with special (reassurance) instructions than with regular instructions. The "reassurance" instructions prepared them that progress might be slow and that they should concentrate on the task, not on how they were doing. According to Wine (1971, p.96) "Sarason's study suggests that it may not be necessary to resort to removing the evaluative emphasis from the highly anxious subject's performance in order to improve it. The results indicate that it may be sufficient to substitute task-relevant responses for the self-orienting ones by means of rather straightforward attention directing instructions." Subsequently Sarason (1984) compared reassurance instructions to attention directing instructions. He found that reassurance tended to be helpful to students reporting a high amount of "worry" and detrimental to others. In contrast, he found that attention direction instructions facilitated performance for high worriers with no negative effects for other groups.

These studies suggest that high anxiety diverts attention from the task and results in lowered achievement.

In addition to the effects of evaluative anxiety on the direction of attention, other effects on performance have also been noted. These are presented next.

Effects on Performance

Within the last ten years a number of books have been published on evaluative anxiety (Sieber, O'Neil, and Tobias, 1977; Sarason, 1980; Krohne and Laux, 1982; Schwarzer, van der Ploeg and Spielberger, 1982; and R. Schwarzer, in press). According to these books, during the time that an individual is experiencing evaluative anxiety, cue utilization is affected as are reactions to manipulated success and failure, the encoding of information and information processing; some of these findings are cited below.

Geen (1980) cited evidence that during high evaluative anxiety the drive state is increased which results in a reduction in the range of cue use. If the peripheral cues are relevant to the task, this will inhibit performance; if the peripheral cues are irrelevant this may facilitate performance. However, there is evidence of a curvilinear effect of anxiety on cue utilization: the use of cues is reduced under conditions of moderate anxiety; as anxiety increases beyond the "moderate" point, subjects begin to broaden their scope (Geen, p. 47-48).

Another effect of high anxiety is on reactions to manipulated success and failure. An interactive effect has been found between level of evaluative anxiety and success/failure (Weiner, 1966). When the feedback is positive (success condition) high test anxious students perform better than low test anxious students even when the task is difficult. When the feedback is negative (failure condition), high test anxious students perform worse than low test anxious students even when the task is easy (Weiner, 1966).

According to Mueller (1980), encoding (the storage of information in short term memory) is affected by high evaluative anxiety. For example, high anxious subjects recall fewer digits than low anxious subjects. Preliminary evidence suggests that high anxious subjects may use more limited strategies than their less anxious counterparts during the encoding process. Mueller also speculated that the retrieval process differs for the high test anxious student although little examination of this area has been performed.

Evaluative Anxiety as a Dependent Variable

Almost ten years after Wine's paper, Tryon (1980) published a review of test anxiety research, particularly concerning the treatment of test anxiety, for which she examined 85 studies. She categorized the treatments into five basic sections:

Systematic desensitization and implosion
Self-controlled relaxation and desensitization
Cognitive procedures
Observational learning
Study skills

Denny (1980) reviewed self-control approaches to test anxiety treatment and identified three primary types of treatments: applied relaxation, self-controlled training, and cognitive coping techniques. These are generally equivalent to Tryon's first three categories.

Each of Tryon's sections will be briefly reviewed. For the sake of consistency these same categories will be used in this paper. In all cases, the primary sources were reviewed.

Denny (1980) categorized systematic desensitization as an applied relaxation technique. These applied relaxation techniques have three primary characteristics (according to Denny, p. 211) which are a self-control rationale, training in the induction of relaxation, and application training.

Generally the systematic desensitization procedure involves testing a large group of students with a self-report measure of test anxiety, selecting those students with high scores, and treating a portion of these high scorers in a group treatment situation. The duration of the treatment can be one hour sessions over many weeks (eg. Kipper & Giladi, 1978; Osterhouse, 1972; Mitchell & Ng, 1972; Kostka & Galassi, 1974), or a more intensive accelerated massed desensitization, where the treatment is completed within a few days. Implosion, a third treatment alternative, exposes individuals to only the most feared hierarchy items but subjects are not relaxed during treatment (eg. Richardson & Suinn, 1974; Suinn, Edie, & Spinelli, 1970). Richardson and Suinn (1974) found systematic desensitization and implosion to be equally successful and able to significantly reduce self reported anxiety.

Zemore (1975) found that systematic desensitization treatment in one anxiety area not only lowered anxiety in the treated area but also significantly lowered the anxiety in another area: the two areas compared were fear of public speaking and test anxiety. Zemore suggested that one possible reason for this carry-over was the fact that both are evaluative fears and that future research should investigate the effects on more discrepant fears such as test

anxiety and snake phobia.

In a review of 98 studies in systematic desensitization published between 1961 and 1974, Kazdin and Wilcoxon (1976) found that most studies had significant results indicating the usefulness of systematic desensitization. However, a careful examination of these studies revealed that the control conditions were less credible than the desensitization conditions and therefore an equally likely explanation for the results was that subjects expected the treatment to be effective. They noted that desensitization has not been found superior to those control groups "that unambiguously rule out as a rival hypothesis differential expectancies across treatment and control conditions" (p.729).

There is a general finding that systematic desensitization and implosion reduce self-reported anxiety but has had little apparent effect on academic performance (Tryon, 1980). This may indicate that the treatments are influencing the emotional component of test anxiety, rather than the worry component. Wine (1980) has also commented on this aspect and has encouraged research on the worry component.

A second anxiety treatment technique is self-controlled relaxation. According to Denny (1980), self-controlled relaxation is distinguished from applied relaxation by a guided rehearsal component. Treatments which emphasize relaxation as a general skill for coping have been found to be effective in reducing self-reported test anxiety (Tryon, 1980). Lent and Russell (1978), for example, compared study skills training and cue-controlled desensitization as

treatments for test anxiety. The study-skills training focused on test-preparation, and test-taking behaviors. The subjects who also had systematic desensitization were exposed to a 16 or 17 item hierarchy during relaxation and these subjects were instructed to practice relaxation daily. The cue-controlled desensitization treatment instructed students in pairing muscle relaxation with the word "calm" and then desensitization training with a hierarchy of test anxiety fears was conducted. Neither the control group nor the study-skills training group reduced their test anxiety scores, although the other two treatments did yield significant differences between pre-and post-testing. The performance measures were not affected by the treatments.

Other studies which also measured change in course grades as a result of self-controlled relaxation training found significant improvement (Deffenbacher, Mathis, & Michaels, 1979; Delprato & Dekraker, 1976; Denny & Rupert, 1977; and Russell & Sippich, 1974). Denny (1980) reported on eight studies in the self-control training category, 50% of which resulted in improved performance.

The multimodal or treatment package approach has been found to be more effective than systematic desensitization alone (Tryon, 1980). However, Wine's criticism that the studies focus on emotionality and neglect the more important variable of worry is true for this research.

Studies which have cognitive procedures as the main focus include helping the student to focus attention or to learn self-reinforcement techniques. Cognitive coping techniques generally

include the components of a self-control rationale, training in relaxation induction, and application training (as do applied relaxation techniques), and guided rehearsal (as with self-control training techniques), but the addition of a cognitive element characterizes these treatments (Denny, 1980). The cognitive aspect emphasizes that the beliefs held influence emotional reactions, and that negative self- beliefs can be replaced with more positive ones (Denny, 1980, p.214).

McCordick, Kaplan, Finn, and Smith (1979) investigated the effectiveness of cognitive behavior modification. McCordick et al. exposed 48 students to ten hours of treatment under one of three experimental or two control conditions: a) training in task-oriented self-instruction rather than negative self-statements plus modified systematic desensitization combined with study skills training (core treatment); b) core treatment plus video-taped modeling; c) core treatment plus rehearsed modeling; d) study skills control; e) wait list. On self-report measures (Liebert-Morris Worry Scale, and Achievement Anxiety Test) treated groups improved more than controls. None of the treatments led to a significant improvement in academic performance, "a finding which is consistent with the majority of test anxiety studies which have used grades as a dependent variable. ...Spielberger et al. suggested that interventions would be effective if they combine a treatment for debilitating anxiety with a treatment for poor study skills. Our results disconfirm this prediction." (McCordick et al., 1979, p.420).

Significant reductions in self-reported test anxiety are

evident in cognitive studies, a finding similar to that with systematic desensitization and self-relaxation (Tryon, 1980). In addition, two of the four studies that assessed changes in academic performance indicated improvement for the cognitive therapy treatment versus the no-treatment controls (Holroyd, 1976; Meichenbaum, 1972). In Denny's review (1980), he reported that 71% of the research he reviewed in the area of cognitive coping training indicated performance improvements. These studies support Wine's contention that in order to see change in performance, considerable attention must be given to the worry component through cognitive training.

Observational learning has also been used as a treatment for test anxiety (Denny, 1974; Horne & Matson, 1977; Jaffe & Carlson, 1972; McCordick et al; 1979). These studies are based on the findings that high test-anxious individuals are more sensitive to modeling cues than the low-test anxious (Sarason, et al., 1968). By providing the subject an opportunity to view a model of appropriate test-taking behavior, or to view the process of desensitization on someone else, self-reported test anxiety has generally been reduced. Some studies which assessed achievement changes noted an improvement in this area (Denny, 1974; Horne and Matson, 1977; Jaffe and Carlson, 1972). Again, the majority of these studies focus on the emotionality dimension of test anxiety.

Researchers have examined study skills training and its effect on test anxiety. Some researchers have compared treatments, while others examined treatment combinations. Horne and Matson(1977), for

example, found both modeling and desensitization to be effective in reducing self-reported test anxiety, whereas study skills training seemed to be significantly more effective in increasing final grades. Osterhouse (1972) compared systematic desensitization with study skills training. It was hypothesized that students who reported high levels of emotional arousal under evaluative situations would benefit more from the desensitization treatment, whereas those students who scored higher on the worry component would benefit more from improved study skills. Although this hypothesis was not supported, the desensitization subjects did report significantly less anxiety during a final exam than did the no-contact control group.

An investigation of combination treatments was performed by Mitchell and Ng (1972) who assigned high test anxious students who were low on study-skill competence to a desensitization treatment, a studyskills counseling treatment, a combination treatment, or a no-treatment control. Although the desensitization treatment was effective in reducing self-reported anxiety, the counseling treatment did not result in lower anxiety scores. The multi-modal treatment improved study skills, reduced self-reported test anxiety, and increased course grades and achievement test scores. McManus (1971) also found that study skills counseling in combination with desensitization training resulted in significant improvement in grades compared to a no-treatment control. Lent and Russell (1978), as previously noted, found a reduction in self-reported anxiety for the desensitization treatment combined with study skills training,

and the cue-controlled relaxation combined with study skills training, but found no improvement in self-reported anxiety for the group that received only study skills training.

Allen's (1971) results support the conclusion that combination treatments are more effective than single mode treatments. With a total sample of 75, Allen found that desensitization and study skills training significantly reduced physiological measures of test anxiety and resulted in improved course grades and grade point averages. Whereas, neither desensitization nor study counseling employed alone was reliably more effective than the placebo in improving academic performance. In 1972, Allen reviewed over 30 studies and also concluded that combination treatments are more effective in alleviating anxiety and improving academic performance. He noted, however, that all studies were based on samples of highly motivated volunteers, and the generality of the findings is therefore limited.

A follow-up study by Allen and Desaulniers (1974) found that students maintained positive attitudes toward treatments, and that there were significant improvements for treatment groups after the first semester, but that these treatment effects were obscured after two years. In contrast, Mitchell, Hall, and Piatkowska (1975) found that 73% of their failing students were succeeding after two years. The treatment in this study, however, was extensive and involved structured therapy in the areas of academic and vocational goal setting, desensitization, relaxation training, and study skills training.

Denny (1980) suggested that each aspect of test anxiety might be best treated with different approaches. His analysis indicated that relaxation might be effective for emotionality, and cognitive restructuring the best treatment for worry. A study by Finger and Galassi (1977) supported Denny's hypotheses.

Allen, Elias, & Zlotlow (1980) reviewed the current therapeutic treatments of test anxiety from a methodological standpoint. A number of methodological problems were observed including inadequate randomization, deficiencies in non-treated control groups, mono-method evaluations, and weak statistical analyses. The two most critical problems, however, according to the authors (p. 179), were the lack of analysis of therapist characteristics and the lack of adequate placebo conditions. In addition, although many of the studies resulted in reduced self-reported test anxiety, for those that assessed performance, only 50% demonstrated improvement.

Summary of evaluative anxiety

Evaluative anxiety can be a major influence on the lives of people and the construct has prompted examination by theorists, researchers, and therapists for over 30 years. Current theory generally posits a distinction between state anxiety (a transitory condition) and trait anxiety (a stable tendency); a distinction between worry (cognitive reactions) and emotionality (physiological reactions) are also accepted as the two main components of evaluative anxiety. According to Wine (1971) evaluative anxiety is debilitating; it generally distracts the individual from the main

task, reduces the range of cue use, alters reactions to manipulated success and failure, and limits encoding.

Numerous studies have been performed to determine the effectiveness of various treatments of test anxiety. These treatments varied from watching someone take a test calmly to extensive desensitization procedures. Many of the studies found that self reported test anxiety declined after the treatment; in fact, more than one treatment (the multi-method approach) seemed to be more successful in reducing self-reported test anxiety than single treatments. However, the carryover to academic performance, generally hypothesized to improve, has been inconsistent. Many studies did not assess performance; for those that did, increase in achievement was indicated in some studies (Horne & Matson,1977; Mitchell & Ng, 1972; McManus, 1971; Allen, 1971; Holroyd, 1976; Zitzow, 1983; Meichenbaum, 1972) while no academic improvement was evident in others (Melnick & Russell, 1976; Romano & Cabianca, 1978; Lent & Russell, 1970; Jackson & Van Zoost, 1972). However, as Morris et al. (1981) have pointed out, "although test anxiety variables ... are consistently negatively related to performance, they typically account for less than 10% of the variance in performance measures" (p. 546). Therefore reducing anxiety would not necessarily be demonstrated in measured performance.

The Theoretical Model

Tobias (1977c) has proposed a research model for investigating the effect of anxiety on learning. Tobias' model is described in the next section, which is followed by a review of current research in this area.

It is evident from the preceeding section that there are numerous effective treatments for reducing anxiety. However, the expected improvement in performance is not conclusive. Another approach to improving the performance of anxious students is to treat anxiety as an independent variable and modify instruction to reduce the debilitating effects of anxiety. In 1977, Tobias outlined a model for research on the effects of anxiety on performance in an instructional setting. The basis of the model is depicted in Figure 1 (Tobias, 1977c, p. 226) which is an information processing system, with three primary components:

Input - The material to be learned which may be in the form of lecture, workbook or laboratory experiment.

Processing - The actions taken by the learner such as coding, attending, deducing, or describing.

Output - The 'product' such as a correct answer, a completed problem or a project.

Anxiety can only affect learning indirectly by impacting on the cognitive processes which can alter the output. The learning process may be affected by anxiety at three different points in this model: prior to processing (before acquisition), during processing

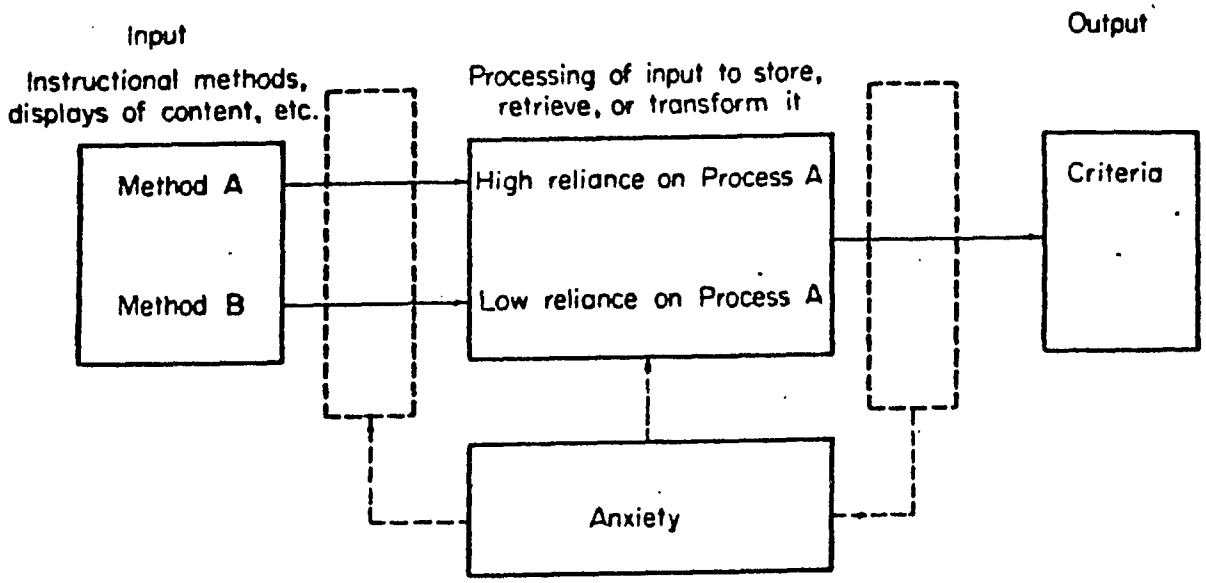


Figure 1. Model of anxiety-treatment interactions (Tobias, 1977). Reproduced by permission.

(during acquisition), and after processing but prior to output. Output, therefore is affected because the information may not have been properly received, properly processed, or properly reformulated. In fact, anxiety in some individuals may affect all three stages of information processing and may even be cumulative. For example, students who get bewildered during a lecture may not encode information effectively, may process it poorly, and may have trouble retrieving it during a test.

The specification of this model allows the researcher to investigate the point in the learning process there has been interference from anxiety. Conceptually anxiety at the pre-processing stage will yield a different cognitive product than anxiety after processing. For example, if a student experiences anxiety during processing then the product will probably be flawed; however if this student has been free of the effects of anxiety in the pre-processing stage (during input), she/he should be able to accurately identify the input elements. In contrast, the student whose anxiety interfered at the outset (during pre-processing) will probably be unable to identify or recognize the input elements accurately. Therefore, one major benefit of this model is that it allows researchers to differentiate between the effects of anxiety at different stages of the learning process.

What predictions can be made about the pre-processing stage? According to Tobias (1977c, p.231), one would expect that the student who is affected by high anxiety levels at the pre-processing

stage and becomes easily distracted would benefit from metacognitive skills training such as the checking of input materials, and the review of the input that is implied by checking. It was reasoned that the attention of anxious students may have been diverted when instruction was presented, reducing the amount of material encoded. Therefore, the review of input required by checking would have a differential effect on high anxious and low anxious students; the low anxious student may not need checking, and the review it implies, to the same degree and therefore would not improve in performance after reviewing the materials. High anxious students, on the other hand, would need to review because portions of the input were not attended to; this review would be expected to lead to performance improvement.

Predictions about the effects of anxiety during processing can involve factors such as the difficulty of the content, the organization of the task, and the degree to which the task relies on memory (Tobias, 1977c, p. 234). On the basis of prior research, it can be predicted that the more difficult the content, the less organized the task, or the more dependent the task is on memory skills, the more susceptible the high-anxious student's processing is to interference.

At the post-processing stage, anxiety interferes with the recall of correct responses of previously learned material. When a student freezes on an examination, the question is whether the student knew the material and couldn't produce it under an

examination setting, or whether the student hasn't learned the material. In this case the student's behavior prior to the examination can be assessed; correct homework problems, accurate class participation and peer assessment may suggest that the material was mastered at acquisition, but that there was interference in retrieving it during the test.

Research Related to Model

Some researchers have treated anxiety as a dependent variable and have investigated the effects of modifying instructional treatment on the anxiety levels of students. Other investigators have viewed anxiety as an independent variable and have focussed on the differential effects for high and low anxious students of instructional modifications. As noted by Tobias (1977a), the effects of anxiety in educational settings have not been extensively studied and they deserve considerable scrutiny. The following review is based to a large extent on Tobias' (1980) work and on his research model (1977c, 1979) on the effects of anxiety on learning from instruction.

Pre-processing interference. In the pre-processing stage, high anxiety may interfere with registering and internally representing the instructional material presented. Pre-performance factors such as opportunity to review the input, stress or relaxation instructions, opportunity to view a model, or sensitivity to environmental cues are affected by and affect anxiety levels.

Deutsch and Tobias (1980) investigated the effect of the

opportunity to rewind instructional tapes on performance. Those students who saw the tapes in a group, did not have the opportunity to rewind the tapes; the 'rewinders' saw the tapes individually. Significant main effects and interactions were found. Those who viewed the modules individually and had the opportunity to rewind, performed significantly better than those who saw the tapes in a group. There was an interaction between anxiety and treatment in that anxiety had less of a negative influence on post-test scores for 're-winders' than for those students who were not able to rewind the tape. These results indicated that when students have the opportunity to test their learning against a standard (i.e. re-view the tape) they can correct misunderstanding during the learning process and thereby increase their competence; this is particularly useful for high anxious students. Similar results were reported by Oosthoek and Ackers (1973) who also found that high anxious students were more apt to use the rewind option than were low-anxious students.

On tasks involving memory, Hashemian (1978) found that instructions designed to impose stress had an interactive effect on performance depending on state anxiety: with low stress (relaxation) instructions, there was a positive relationship between state anxiety and performance, while with high stress instructions, the relationship between state anxiety and performance was negative. Similarly, Straughan and Dupert (1969) found that relaxation instructions prior to a paired associate learning task resulted in performance improvement for high anxious students. These studies indicate

that pre-processing interference can be reduced by presentation of relaxation instructions.

Processing Interference. During processing, anxiety is hypothesized to interfere directly with cognitive tasks. The following variables have been investigated: difficulty level of the material, the degree to which the task relies on memory, and the availability of learner supports (such as control of pacing and sequence, objectives and feedback). These are discussed in some detail on the following pages.

There are a number of studies in which the difficulty level of material has been varied. Crawford (1976), for example, found no significant interactions between level of difficulty and test anxiety, nor were significant interactions found between level of difficulty and need for achievement. However, a three-way interaction was significant: high test anxious students who were low in need for achievement obtained the highest post-test scores when the level of difficulty was low; low test anxious students who were high in need for achievement obtained the highest post-test scores when the material was difficult.

Griffiths et al. (1979) reported a negative relationship ($r = -.46$) between state anxiety and performance during scuba diving instruction on the most complex tasks but no relationships between anxiety and performance were evident on the easier tasks. Investigations of computer assisted learning have also found evidence that high state-anxious learners make more errors on difficult problems than do low state anxious learners (O'Neil, Spielberger & Hansen,

1969; O'Neil, Hansen & Spielberger, 1969).

James and O'Neil (1971) found that males who had high state anxiety scores made significantly more errors on difficult problems than those with low state anxiety scores. Females with high state anxiety however, performed significantly more poorly on the less difficult problems than did low state anxiety females; there were no performance differences on the most difficult problems between females who were high and low in state anxiety (cited in O'Neil, Judd & Hedl, 1977, p.206).

The task demands of memorization are hypothesized to be related differentially to performance for high anxious and low anxious students. When memory aids are provided, they facilitate the performance of high state anxious students who then perform at level equal to the middle or low anxious learners (Gross & Mastenbrook, 1980; Leherissey, O'Neil & Hansen, 1971; Sieber, Kameya, & Paulson, 1970).

In the Sieber et al. study (1970), two experiments were conducted with fifth and sixth grade students, with high or low test anxiety, who were assigned to cognitive tasks with conditions of memory support or no memory support. In the first experiment the task involved moving marbles along a board under certain rules. The memory support condition provided three sets of marbles and boards so that incorrect strategies could be visible; in the other condition only one board was available and students needed to rely on their memories to recollect incorrect strategies. In the second experiment, the task involved identifying the characteristics of

objects on cards that made them similar (size, shape, color, etc.). In the memory support condition, the prior cards continued to be visible until the correct characteristic was identified; in the other condition, the cards were not available for review. Analyses of variance on the data for both studies indicated that main effects were significant: low anxious students (as measured by the Test Anxiety Scale for Children; Sarason, Davidson, Lighthall, & Waite, 1958) committed fewer errors than high anxious students, and memory support facilitated performance for all children. In the second experiment the interaction was also significant: high anxious students without memory supports made more errors than any of the other three groups of students.

The organizational structure of the instructional material affects performance and anxiety. Dowaliby and Schumer (1973) found that a teacher-centered approach (vs a student-centered approach) was preferable for high anxious students; the reverse was true for low anxious students. These results were attributed to the effect of structure, although Peterson (1976) suggested that the amount of student participation also varied considerably in the two settings.

Harmon (1978) varied the structure of science lessons on the amount of teacher or student control within a task. One hundred sixty eight fifth and sixth grade students were assigned to one of six treatment groups which ranged from highly structured teaching (high teacher control) to little teaching structure (high student control). High anxiety subjects gained more knowledge when the tasks were teacher controlled than when the tasks were student

controlled. The opposite was true for low anxious students.

Okamoto's results (1977) indicated that logically ordered of materials were more important to high anxious male junior high school students (Japanese) than to those low in anxiety. Programmed materials were presented in a logical or a random order. The random order induced high state anxiety and stress in high trait anxious subjects compared to low trait anxious subjects, which resulted in decreased performance.

When the learner is in control of aspects of the material, high anxious students are positively affected. Mayer (1977) for example, found that high anxious students performed better when they worked at their own pace than when the experimenter determined the pace. Scott and Nelson (1979) also found that time pressure negatively affected the performance of high anxious students. Collier et al. (1973) found that high anxious students performed at higher levels when they had control over the availability of memory supports (cited in Hedl & O'Neil, 1977, p. 159).

In 1968, Campeau investigated the effects of feedback on performance. A significant interaction was found for girls between anxiety and feedback: the performance of high anxious girls was facilitated with feedback. In the no feedback condition, low anxious students performed better than high anxious students. J. Hansen (1974) found no effect on performance, but did find that state anxiety decreased in a feedback condition.

Post-processing Interference: During post-processing, anxiety is hypothesized to affect the retrieval of material previously

learned. For example, if high and low test anxious students perform equally well on one test format whereas, another format yields a differential result, and if there is independent evidence that the material was acquired equally, one could assume that post-processing interference was evident.

The recent examination of two different models of anxiety, interference or deficit, is particularly relevant to post-processing interference. Based on a correlational study of self-report measures and academic performance, Kirkland and Hollandsworth (1979) questioned the traditional interference model of anxiety. They suggested that the lack of effective study skills might result in test anxiety. Mitchell and Ng (1972) had raised the same question several years earlier. Their study of multimodal procedures on the academic performance of 30 high test anxious students led to the speculation that inadequate study habits might develop independently of test anxiety and that test anxiety might develop as a result of repeated academic failure due to poor study habits. As therapists they concluded the distinction was irrelevant, but the theoretical issue remained.

The research on test taking skills (Bruch, 1981; Bruch, Juster and Kaflowitz, 1983) suppports the position that high test anxious individuals have poor test taking skills as do the findings by Wittmaier (1972) and Culler and Holahan (1980). Culler and Holahan found a significant positive correlation between test anxiety (TAS) and scores on a study habits scale. There was also a significant positive correlation between GPA and study habits scores. "The

findings suggest that at least part of the academic performance decrement may be due to less knowledge of the relevant material as a function of differential study skills" (Culler & Holohan, 1980, p.18). This lack of knowledge would result in increased test anxiety because students with poor study skills may know they are poorly prepared.

In an extensive discussion of this issue, Tobias (1984b) suggested that the two models are compatible. In an update of his original model (1977c, 1979), Tobias proposed a cognitive capacity analysis to account for both interference and deficit findings. In this explanation the cognitive demands of a task are considered in two respects. Firstly, interference from anxiety reduces the cognitive capacity available for a task. Secondly, good study skills or test taking skills reduce the cognitive demands of a task.

A study by Paulman and Kennelly (1984) supported this explanation. They categorized subjects according to level of test anxiety (high or low) and according to exam-taking skills (good or poor). Students were administered a primary task (Raven Matrices) and a secondary task (6 digit backward digit span). Information processing theory led to the hypothesis that level of test anxiety would influence the secondary task, not the primary task; high anxious individuals would concentrate on the primary task and would compensate for the demands of anxiety by exerting extra effort, but this effort would leave less cognitive capacity and therefore performance on the the secondary task would suffer. This hypothesis was supported. The authors concluded that the constructs of exam-taking and

test anxiety are independent, partially related, and that both constructs influence performance.

A study by Weinstein, Cubberly and Richardson (1982) is relevant to the cognitive capacity interpretation. In a study of 90 college students who learned a paired associates word list, they found that high anxiety levels negatively affected learning when it was based on a deep processing strategy, but not when a superficial processing strategy was required; deep processing requires greater cognitive capacity than does superficial processing. This finding also supports the hypothesis that anxiety demands cognitive attention, which reduces the available cognitive capacity for tasks which require considerable effort.

Post-processing interference then may be influenced by cognitive deficits as well as test anxiety interference. A cognitive capacity analysis accepts these two formulations as compatible.

Summary of the theoretical model

Evidence suggests that high anxiety does interfere with performance at the pre-processing, processing and post-processing stages. During processing, task factors such as difficulty level, degree of memorization, organization of the task and availability of learner supports affect high and low test anxious students differentially; high anxious students tend to equal low anxious students in performance scores when the material is easy, not reliant on memory, clearly organized, or when learner supports (such

as control of pacing and sequence, objectives, and feedback) are available; otherwise high anxious students tend to perform at a lower level. During post-processing, test anxiety as well as deficits in study skills or test taking skills, appear to interfere with the retrieval of prior learning; this is currently being investigated.

Mathematics is a particularly interesting area to observe the effects of anxiety. Tobias (1981, personal communication) has suggested that mathematics anxiety is particularly susceptible to feelings of evaluation anxiety because the judgments of right and wrong are more absolute in math than in comparable materials and therefore more likely to invoke anxiety. Research on math anxiety is presented next.

Mathematics Anxiety

Mathematics competence is becoming increasingly important in our society. All adults are faced with such tasks as paying bills, computing taxes and measuring sizes. Engineers, accountants, scientists, dressmakers, bookkeepers, waitresses, bank tellers, computer programmers and office managers are just a few of the workers who need to use math daily for their jobs. Mathematics literacy is essential for every individual, and yet a high proportion of adults express discomfort, tension and/or panic when faced with a numerical chore. This reaction has been defined as math anxiety, "feelings of tension and anxiety that interfere with the manipulation of numbers and the solving of mathematical problems in a wide variety of ordinary life and academic situations" (Richardson and Suinn, 1972).

Sheila Tobias and Carol Weissbrod (1980) discussed the history of the concept of math anxiety and its current status. According to the authors, math avoidance was first noticed in 1973 by Lucy Sells, a sociologist at the University of California at Berkeley. The Sells report indicated significantly less math preparation by entering college females than males. This finding prompted considerable research on math anxiety and sex differences in math achievement.

Recently books have been published which attempt to assist the math anxious individual (Sheila Tobias, 1980; Kogelman & Warren, 1979; Brush, 1980), bibiliographies are available (Brush, 1976), and articles in popular magazines offer advice on how to overcome

the negative effects of math anxiety (Henig, 1983; Louie, 1982). In addition, many colleges now offer math anxiety reduction courses (Kogelman, et al., 1982; Chapline, et al., 1982; & Salholz, 1982)

The prevalence of math anxiety has been difficult to assess. Betz (1977) administered the Fennema/Sherman Math Anxiety Scales (Fennema & Sherman, 1976a) to a college student sample and concluded that math anxiety occurs frequently and is more apt to be found among women than men. Norman (1977) sampled almost 2000 students from second grade to college and found a consistent decline in positive attitudes towards mathematics.

Math anxiety has been examined from numerous perspectives and within various contexts; these include the measurement of math attitudes, the apparent sex differences in math achievement and math anxiety, and the possible treatments for math anxiety. A short review of each of these areas follows.

Measuring Math Attitudes

One of the most popular measures of math anxiety is Richardson and Suinn's (1972) Mathematics Anxiety Rating Scale (MARS). The MARS is a 98 item instrument which requests individuals to rate themselves on a five point scale as to how "frightened they are nowadays" by the situations presented. The situations range from watching someone use a slide rule, to taking a math course, to checking the bill after lunch. Brush (1978) performed a validation study of the MARS on two groups of undergraduate students (n's =109 and 80). MARS scores were found to correlate in the expected

direction with dislike of mathematics, a self report of anxiety about mathematics, and length of time anxiety has persisted. Humanities majors were found to receive the highest anxiety scores, then social science majors, and then physical science majors.

Morris, Kellaway, and Smith (1978) also examined the MARS and compared 52 psychology undergraduates to 54 mathematics majors. MARS scores were higher for the psychology majors. Clute (1984) found that high math anxious students, as measured by the MARS, had significantly lower achievement than low math anxious students.

Studies of the MARS by Richardson and Suinn (1972) include testretest data, internal consistency measures, and a factor analysis. On a sample of 119, the test-retest correlation was .78 after two weeks, and after seven weeks a sample of 35 yielded a correlation of .85. Internal consistency examinations (alpha coefficient) yielded a reliability estimate of .97 (N=397). On a factor analysis by Rounds and Hendel (1980), two main factors emerged: mathematics test anxiety and numerical anxiety. The same factors were evident with both oblique and orthogonal solutions. Factor derived scales were developed and correlated with six other measures of anxiety and arithmetic achievement. The results supported the factor interpretations.

In 1982 Suinn and Edwards published a revised version of the MARS for adolescents. The same factors of math test anxiety and numerical anxiety were found.

Other attitude scales have also been developed. Fennema and Sherman (1976a) developed a series of scales to measure attitudes

toward mathematics. One of these is a confidence scale, and a second is a mathematics anxiety scale. Chapline, Denker, and Newman (1979) found a positive correlation between MARS scores and scores on the Fennema/ Sherman Confidence Scale. Their sample was comprised of 50 females, prospective elementary school teachers, who were self-selected as highly math anxious.

Aiken (1974) developed the Mathematics Attitude Scales, a questionnaire consisting of 40 items, which pertains to the enjoyment of math and the value of math. Internal reliability coefficients are .95 for the enjoyment scale and .85 on the value scale (N=190).

Bowling (1976) developed a mathematics attitude instrument with three subscales. The Enjoyment scale (E Scale) and Value Scale (V Scale) developed by Aiken (1974) were combined with a Nature Scale (N Scale) designed to measure attitude toward the nature of mathematics, specifically those aspects of the study of mathematics which make it unique as a discipline. Internal reliabilities for the E and V scales were lower than those reported by Aiken. N Scale coefficient alphas ranged from .70 to .85. Scale separation was supported by a factor analysis.

Of these four instruments (MARS, Fennema/Sherman Scales, Aiken's Mathematics Attitude Scales, and Bowling's version), the MARS has generated the most research. A primary disadvantage of the MARS is the 30-40 minute time period necessary for administration. However Plake and Parker(1982) developed a revised MARS of 24 items. Coefficient alpha reliability was estimated at .98 and the correla-

tion with the full scale MARS was .97 (n=170). The relationships of the short form with state, trait, and test anxiety, as well as with math achievement parallel the long form.

Sex Differences in Math Anxiety and Math Achievement

A number of researchers have investigated the relationship between years of math study, math achievement and math anxiety for females and males. Brush (1978) found that number of years of high school math and number of terms of calculus correlated negatively with scores on the Mathematics Anxiety Rating Scale (MARS) for a sample of 189 college undergraduates.

In a sample of 655 college students, math anxiety occurred frequently and was more prevalent among women than men (Betz, 1977). High math anxiety was related to low scores on math achievement tests. Dew and Galassi (1983) also found sex differences in math anxiety (MARS), but the differences were only about 1/5 of a standard deviation of the total sample. They also found that math anxiety was equally related to the emotionality and worry components of test anxiety.

According to Sells (1973), females discontinue math study before males do. Only 8% of entering freshman females at Berkeley had the requisite mathematics courses to major in the physical sciences, or economics; whereas 57% of the males had taken the important high school mathematics courses. Female participation in math courses declined steadily after eighth grade (Burton, 1979). By the third semester of college there was one female in math

courses for every six males.

Hendel (1977) also concluded that math avoidance was more prevalent in women than men and in 1979 he found, in a sample of 69 highly anxious women, that math anxiety and semesters of high school math were the most important predictors of arithmetic achievement. In the same sample self-estimated math ability had a -.68 correlation with math anxiety. Resnick et al. (1982) tested over 1000 college freshmen and found low levels of math anxiety and no large sex differences.

Females had significantly higher MARS scores than males in a sample of 109 undergraduates; however, these sex differences did not replicate with a second sample of 80 similar students (Brush, 1978).

In a study of the mathematics performance of male and female 7th and 8th grade students, McAfee (1978) controlled for IQ (Otis-Lennon Mental Ability Test). Results indicated no sex differences in mathematical reasoning and there were no significant sex differences in mathematical computation for 7th graders or for 8th graders, although a pooled comparison yielded sex differences. Freed (1983) similarly concluded that boys and girls were approaching equivalent mathematical ability.

In 1974, Fennema reviewed 36 studies of mathematics achievement and concluded that there was no evidence for the widespread belief that boys were better than girls in mathematics in elementary school, and very little evidence for sex differences in math in high school if number of years of mathematics study was controlled.

According to Fennema (1976), the major research projects such as Project Talent (1964), National Assessment of Educational Progress (1972-1973) and the National Longitudinal Study of Mathematics Abilities (1962-1967) did not consider number of math courses taken when assessing achievement. When prior math learning is controlled, Fennema and Sherman (1976b) found no sex differences in mathematics achievement in two of the high schools they studied, and a difference of only two test items at the other two schools, with boys scoring higher. A major difference was the high number of females who elected to discontinue their mathematics studies:

> One important factor that appears to be affecting females' studying of math is the societal stereotyping of the learning and usage of math as masculine ... because math is perceived as a male domain, females sometimes do not achieve as well, and tend not to elect to study to the same degree as they would if it were seen as a neuter domain. ... During adolescence, when the gap in boys' and girls' mathematical performance becomes increasingly evident, the most salient developmental task is establishing an appropriate sexual identity.
> (Fennema and Sherman, 1977, p.370.)

Most of these studies suggest that women report greater mathematics anxiety than men do, and that the number of years of mathematics study is a critical variable in the assessment of mathematics achievement and math anxiety; since females do not study math for as long a time as males do, achievement test scores cannot be compared unless the number of years of math study is controlled. Math anxiety has been found to be negatively correlated with math experience: either math anxious students discontinue math study, or math experience attenuates math anxiety (or both).

One theory of math anxiety is that females are expected to dislike and fear math and do poorly in math courses. "Nice Girls

Don't Study Mathematics" is the title of a paper by Boswell (1979). Based on a sample of 562 elementary school children between the ages of 10 and 12, findings were that initially (3rd grade) girls think girls are better than boys in math, and boys think boys are better than girls in math. With age, girls begin to shift toward favoring the boys as more able. Similar trends were found for how much boys and girls like math and for how much girls perceive that their friends and mothers like mathematics.

According to Burton (1979), females are taught to "be popular rather than to excel academically." Fox's (1976) findings were similar. "One thing very few girls seem to want to be is mathematically talented" (p.1). In fact, Fox found that many women who are talented in science and math do not choose to study these disciplines.

Boys seemed to value math more than girls according to Purdy (1976) who studied 504 sixth and eighth grade students; girls, it was found, enjoyed math more than boys. Expected career plans were used to explain these results whereby the boys see math as career related and are therefore unable to relax and enjoy it, although the value is evident to them.

Casserly (1983) studied schools where the sex differences in math achievement were minimal. She found many factors influencing the students including teachers who encourage girls to study math and who believe that math is an extremely important area to study. In a longitudinal study of high school girls and their attitudes to mathematics, Sherman (1982) found a relationship between lack of

self-confidence as a math student and discontinuation of math study. Sherman stressed the need for a supportive learning atmosphere. Paulsen and Johnson (1983) found in fact, that in a high SES area where girls may have more parental encouragement and different role models, that there were no significant sex differences in ability or attitudes to math.

These studies indicate that as early as elementary school boys and girls perceive math differently and that the girls' attitudes tend to be more negative than the boys'.

Treating Math Anxiety

The treatments for math anxiety have been similar to the treatments for test anxiety. Hendel (1977) offered math anxiety reduction treatments to female college students and 69 enrolled. Three treatments were compared: a diagnostic clinic, math tutoring, and math tutoring combined with a support group. MARS scores decreased for all three groups although the combination treatment resulted in the largest reductions. At the Wesleyan University Math Anxiety Clinic a number of options were offered: supportive classes, workshops, laboratory periods, and individual counseling (Stent, 1977).

The effects of math anxious teachers have prompted courses for students in training as educators. Vance (1978) found that a math content and methods course improved the attitudes to math as a creative discipline. Chapline (1980) offered a two semester course

at Queens College to math anxious college students studying to be elementary school teachers. The course included attitudinal topics as well as math skills instruction. Improvements were noted in achievement as well as in reported math attitudes.

Other treatments have been attempted such as desensitization (eg. Bander et al, 1982), cognitive procedures (eg. Kogelman and Warren, 1979; Genshaft, 1982), and relaxation training (Salholz, 1982). However, according to Genshaft (1982) these ... "remediation programs (for math) anxious women are relatively recent ... (and they) have been neither very systematic or adequately grounded in a theoretical model of anxiety reduction." (p.32)

Evaluative Anxiety and Math Anxiety

There is some evidence that evaluation anxiety is related to mathematics anxiety. Brush (1978) assessed the anxiety levels of 189 undergraduates and found a correlation of .65 between the MARS and the Suinn Test Anxiety Behavior Scale (STABS). Hendel (1980) administered the MARS and the STABS to 69 high math anxious female college students and also found a .65 correlation with the STABS. In the Hendel study, the Alpert-Haber Achievement Anxiety Scales (1960) were also administered: a correlation of .48 was found with the Debilitating Anxiety Scale, and a -.33 correlation was found with the Facilitating Anxiety Scale. These correlations were significant beyond the .001 probability level.

In a study of the prevalence of math anxiety in college students, Betz (1978) tested 655 individuals. The Mathematics

Anxiety Scale (Fennema & Sherman, 1976) was administered; low scores on this scale indicate high math anxiety. The results indicated that math anxiety correlates both with test anxiety (r= -.28 for the Test Anxiety Inventory) and trait anxiety (r= -.42 with the State-Trait Anxiety Inventory).

Math anxiety has also been found to correlate with emotionality. Morris et al. (1978) administered the MARS to 52 psychology students and 54 math students. A correlation of .56 was found between the MARS and Emotionality scores; MARS scores also correlated positively (r=.48) with the Fear of Negative Evaluation Scale.

A factor analysis of the MARS by Rounds and Hendel (1979) labelled the first factor as a Mathematics Test Anxiety (eigenvalue = 29.12). In an analysis by Chapline, Tittle and Denker (1980) a similar first factor explained 55% of the variance.

Summary of mathematics anxiety

Competence in mathematics is a necessary requirement for many careers, and yet a discomfort with math is reported by many people, particularly women. In the last ten years considerable research has focussed on math anxiety. Researchers have developed scales to measure it, have investigated its correlates, have examined sex differences, and have tested a variety of treatments. It has been found to correlate positively with test anxiety, and negatively with attitudes toward math. Sex differences have been found which generally indicate male superiority in math, although this is a controversial area with numerous contradictory findings. Treatments

of math anxiety are varied and many programs report improvements, particularly with college student populations.

Since math anxiety is related to evaluative anxiety, effective treatment of one should provide some benefit to the other regardless of sex differences. Metacognitive skills training should reduce the negative effects of mathematics anxiety as well as evaluative anxiety. A discussion of checking, a metacognitive strategy, is presented in the following section.

Metacognition

Metacognition is a relatively new area for researchers. John Flavell has been one of the prime contributors to this concept which he defined (1976) in this way:

> Metacognition refers to one's knowledge concerning one's own cognitive processes and products or anything related to them, ... For example, I am engaging in metacognition (metamemory, meta-learning, metaattention, metalanguage or whatever) if I notice that I am having more trouble learning A than B; if it strikes me that I should double-check C before accepting it as a fact; if it occurs to me that I had better scrutinize each and every alternative in any multiple choice type task situation before deciding which is the best one; if I sense that I had better make a note of D because I may forget it; ... metacognition refers, among other things to the active monitoring and consequent regulation and orchestration of these processes in relation to the cognitive objects or data on which they bear, usually in the service of some concrete goal or objective (p. 232).

Brown (1977) also has described a conscious control mechanism, or metacognitive ability:

> ... in the majority of human and subhuman intelligence systems some central control processor, interpreter or executive is introduced to oversee the operations of the total system.
>
> An essential characteristic of the control mechanism favored by many current theories is that it must be capable of performing intelligent evaluation of its own operations; ... some basic requirements of such a control system are that it include the ability
>
> a. to predict its own capacity limitations;
> b. to be aware of its repertoire of heuristic routines and their appropriate domain of utility;
> c. to identify and characterize the problem at hand;
> d. to plan and schedule appropriate problem-solving routines.
> e. to monitor and supervise the effectiveness of those routines it calls into service; and
> f. to dynamically evaluate these operations in the face of success or failure so that termination of routines (if not self-terminating) can be strategically timed.

Before presenting some of the research in the area of

metacognition, it is useful to consider the comments by Wertsch (1977) and Cavanaugh and Perlmutter (1982). According to Wertsch (1977), on the distinction between cognitive and metacognitive abilities:

> ... there is not a single well-defined set of abilities we can call metacognitive abilities and that we can make a neat distinction between them and mere cognitive abilities. The only framework in which such a conceptualization could work would be one in which the cognitive abilities are completely well-formed, deterministic 'routines' which always operate in the same way and never need further metacognitive guidance. In such a system, once such routines were selected by metacognitive procedures, they would carry out their portion of the task with no need for further metacognitive control. It turns out, however, that self-monitoring and control procedures seem to operate at almost every level of cognitive functioning. This fact makes it much more difficult for us to make neat analytic distinctions between cognitive and metacognitive abilities (p.5).

In a critique of research in the area of metacognition, Cavanaugh and Perlmutter (1982) concluded that there were several problems in the field. They contended that metamemory is poorly defined and that inadequate research methodology is not uncommon. They also stated that the relationship between memory and metamemory has not been sufficiently clarified. They were particularly critical of the assessment techniques which were found wanting in terms of reliability and validity.

Research in Metacognition

In some of his original work in the area Flavell et al. (1970) noted that young children who studied a set of items claimed they had "learned" them (i.e. could recall them) when, in fact, they were not ready for testing; when the older children (elementary school) claimed to be ready, they were usually able to recall everything.

This awareness of memory phenomena was labelled metamemory (Flavell, 1971).

Other studies of metamemory have produced similar findings. Bray et al. (1977) found that first graders would use mnemonic strategies when explicitly encouraged to do so and most third graders used these strategies on their own. Barclay (1980) also found that young children who were asked to generate a plan for remembering a set of 12 pictures were able to remember a higher percentage than those children who were not prompted to devise a strategy. Levin et al.(1977) found a developmental trend in the accuracy of subjects' own predictions of recalling a list of nouns.

Ann L. Brown and her associates have worked with educable retarded children in the area of metamemory. One study (Brown and Barclay, 1976) found that subjects with a mental age of eight who were trained either to rehearse (add one more word to the memorized list) or anticipate (guess the next item in a previously viewed sequence) were able to improve their performance significantly. This improvement, diminished somewhat, was still evident at a post-test two weeks later. In another study (Brown et al., 1977), it was found that educable retarded children with a mental age of 8 could be trained to improve their span estimation, and that this skill was still evident at a one-year post-test. However, generalization to similar tests was not found.

In another study (Brown et al., 1979), educable retarded children were trained in anticipation and rehearsal memory strategies on a task of memorizing a list. A self-checking component was

included. Performance and ability to estimate readiness for performance improved significantly with training. A post-test one year later found that older students (mental age = 8) maintained the strategies and were able to generalize to a recall task of prose passages. In the one-year follow-up the performance of students trained in memory strategies and self-checking was superior to those who did not receive the training. These "metacognitive skills such as checking, planning, asking questions, self-testing, and monitoring ongoing attempts to solve problems are characteristically lacking in EMR children (Brown et al., 1979, p. 502)."

In a study on error correction, DeLoache, Sugarman, and Brown (1981) presented young children (under 2½ years) with a set of nested cups. The task was to nest all the cups and the youngest children were found to use ineffective strategies for correcting the sequence of the cups, such as brute force or starting all over. The older children were able to insert a cup in the middle of the stack, or reversed two cups as soon as they noticed a problem.

Metamemory is only one area of metacognition. Other researchers have examined cognitive cueing (e.g. Gordon & Flavell, 1977), awareness of reading behaviors (e.g. Hare and Pulliam, 1979), metacommunication (e.g. Wheeler, 1979), and metacomprehension (e.g. Markman, 1977).

Checking as a Metacognitive Strategy

Checking one's own work is a metacognitive strategy which indicates to the student whether a problem has been solved

correctly. If students can be taught to check their own work, identify and correct errors, competence should increase and error rate should diminish. This should be especially true in spelling, mathematics, and other "rule-governed" subjects which have one correct answer and where specific checking routines are appropriate.

A comprehensive search in Psychological Abstracts from 1973 to 1980 indicated that very little research has been done on the effect of checking in math, other than that described above. (Terms searched were: feedback, testwiseness, study habits, review, checking errors, error analysis, knowledge of results, mathematics education.) Similarly ERIC (1977, 1978), Research in Education (1979) and Catalog of Journals in Education (1979, 1980) were examined. One study on checking was found (Clark and Vincent, 1926) and one on answer changing (Mueller and Schwedel, 1975). In addition, mathematics education textbooks were reviewed as well as the 'testwiseness' literature. These are described below.

Clark and Vincent (1926, cited in Underhill, 1977) tested the effectiveness of checking by teaching 5th and 6th graders to verify addition by adding up the column, as well as down. Checkers did not complete as many problems as non-checkers in the daily four minute practice sessions, but checkers had more accurate responses. An index score, designed to combine accuracy with speed, found the checking group to be somewhat "more efficient."

A self-reviewing procedure should result in answer changing when errors are located. On this topic, Mueller and Schwedel (1975) found that 80% of their graduate student sample changed at least one

answer when given the time to review their exams, however, the percent of total answers changed was only 3.7%. Answer changers increased their scores by an average of .98 points. The authors concluded that careful answer changing frequently improves performance on an objective test.

Teachers often encourage students to check their work. According to Riedesel's textbook on Teaching Elementary School Mathematics (1980): "Teachers often say 'My pupils hate to check their work in arithmetic.' This statement is probably true. It is often difficult for children to realize that in most instances when an adult does a computation, he checks the work. This reluctance to check addition (or any other computation) can be partially reduced by ... having pupils compare the accuracy of papers they have checked with those that are not checked. If they see a real value in terms of increased accuracy, the use of checking will be better accepted." (p.171)

Although many of the teacher training texts encourage checking, no research is cited to convince prospective teachers that it is effective. Apparently, the usefulness of checking is considered self-evident. (Ashlock & Herman, 1970; Howard & Dumas, 1966; Krause, 1978; Schminke, Maertens & Arnold, 1978; Vigilante, 1969; Wheeler, 1970; Williams, 1970).

Testwiseness is another area which should have a relationship to checking; students who are "test-wise" should know how to check their answers. However a review of this literature, including a

recent review article by Sarnacki (1979) indicated that checking is only a minor component in this area. The Principles of Testwiseness (Millman et al., 1965) recommend that the test-takers analyze the intent of questions, and try to observe systematic patterns of the test constructor. Other strategies recommended relate to using time, guessing, and deductive reasoning. Checking answers is one of four items included in the general category of error-avoidance strategies. The other three items are paying careful attention to directions, to items, and asking for clarification when necessary. It does not appear that checking strategies have ever been examined by researchers in the area of testwiseness.

Summary of Metacognition

In summary, there is some evidence that improved metacognitive skills and strategies lead to improved performance. Checking is considered a metacognitive strategy, although the empirical evidence that checking diminishes errors in different curriculum areas is scanty. Theory and common practice postulate that checking, and the review of input implied by checking, enables the student to reduce errors and to focus attention. Checking should also enable students to determine when material hasn't been adequately learned. Checking should also decrease the interference of anxiety during the pre-processing and processing stages of learning and thereby improve performance. These basic questions were addressed in the current study.

Hypotheses

The purpose of this study was to clarify the relationship between anxiety and learning. The general hypothesis predicted an interaction between anxiety and instructional strategy such that the achievement of high test anxious learners would increase with training in a metacognitive checking strategy, whereas the achievement of low anxious students would be unaffected.

Two specific hypotheses were tested: 1) high anxious students taught to check their work were expected to perform better on a post-test than high anxious students who were not taught to check. In addition, a format which encouraged checking on the posttest was compared to a standard format. It was hypothesized that 2) high anxious students who were encouraged to check by test format would perform better on an algebra posttest than high anxious students who were not encouraged to check. State and trait anxiety measures were administered and interactions between these and the experimental conditions were investigated.

METHOD

Community college students in a remedial math course participated in this study, which consisted of three sessions. At the first session two trait anxiety measures and an algebra pretest were administered to students. At the second session students were assigned to one of two algebra modules; one taught checking procedures and the other taught a standard procedure. Within these groups, some students were reminded to check on the posttest (third session) and others received no such reminders. State anxiety measures were administered prior to the module, after the module, and after the posttest.

Materials

An algebra module (Appendix A) and an algebra test (Appendix B) were developed for this study.

Algebra Module

A self-instructional module was developed to teach elementary algebraic concepts such as the meaning of x and how to solve for x in simple equations. The module contained two descriptive frames and 10 which required a solution. The first frame contained the statement that in algebra "x" is used to represent the part of the problem that's missing. Four of the frames required only division to determine the value of "x". In four of the frames, there were two "x" terms, which need to be added together prior to division.

There were two frames which contained the "x" term and a whole number on the same side of the equation and therefore subtraction was needed prior to the division. In all cases, the values of "x" were whole numbers and the arithmetic required was approximatey fourth grade level, as determined by three professional educators who were asked to review the material.

The basic algebra module was administered in two forms. In one, checking was taught. In the checking module, in addition to the 12 standard frames, there were two frames which encouraged students to find mistakes, and two frames which requested students to find errors in the printed examples. There were also 8 interspersed frames which guided students to insert their answers in the original equation and check if it was accurate.

For example, one frame asked students to solve the equation 14X=28. The next frame for the checking module asked:

Does 14 times "your answer" = 28?

Check here: 14

x ___ (your answer)

_____

If 14 times "your answer" = 28, you are right. If not, divide again and check again to get the right answer.

The checking module was intended to teach students that finding one's own errors was an accomplishment. An analogy was made to athletes who train by filming themselves and then analyze their errors. The introduction to the student stated "Remember, if you find your own mistake and correct it, it really isn't a mistake."

The module also asked students to repeat the rule for checking algebra (substitute your answer wherever "x" is and see if it works out), and the student was asked how many mistakes were caught by checking.

In the second form of the basic module, checking was not taught. Instead, nine items were added to the end of the module which taught subscripts and superscripts.

Pilot Study

A pilot study was conducted to determine the adequacy of the algebra module, and if checking abilities were acquired by the subjects. The experimental module was administered during the mathematics laboratory period to ten students (6 female) in a summer session of an introductory mathematics class. Students selected for the pilot study were at the same level in mathematics as in the full study and were drawn from the same urban community college which was used as in the full study.

On the 24 items in the module, scores ranged from 69% to 100% correct, with a mean score of 88%. Time on task varied from 20 to 35 minutes, with a mean time of 29 minutes. Nine of the ten students completed all the checking items on the module correctly.

Comments from the students and instructors were solicited. Students reported the material to be interesting and clear, and therefore no revisions were made in the module. (Module appears in Appendix A.)

Algebra Test

Two forms of an algebra test (Appendix B) were developed and administered as pre- and post tests; the items for each frame were identical, but the numbers used in items were different. The posttest was administered in two formats: in the experimental format, checking was encouraged by including a blank column labelled: "Check your work here". The standard format did not have this column. Simple vocabulary was used, although no attempt to assess the readability was made. Both forms appear in Appendix B. Reliability, assessed by Cronbach's alpha (SPSS), of the pretest was .96; on the posttest the reliability was .93.

Measures

Three measures of anxiety were used in this study:

The Mathematics Anxiety Rating Scale

The Mathematics Anxiety Rating Scale (MARS) (short version) (Richardson and Suinn, 1972) is a 24 item instrument measuring trait math anxiety which requests individuals to rate themselves on a five point scale as to 'how frightened they are nowadays' by the situations presented. The situations range from watching someone use a slide rule, to taking a math course, to checking the bill after lunch. Alpha reliability of this form of the MARS was estimated at

.98 (Plake and Parker, 1982). (Appendix C)

The Test Anxiety Scale

The Test Anxiety Scale (TAS) (I. Sarason, 1972) is a 37 item true- false test anxiety scale measuring trait anxiety. Sample item: "During a course examination I frequently get so nervous that I forget facts I really do know." Test-retest reliability correlations over .80 have been reported for periods of several weeks (Sarason, 1978). (Appendix D)

The Worry-Emotionality Scale

The Worry-Emotionality Scale (Liebert and Morris, 1969) is a state anxiety scale, which is derived from Mandler and Sarason's Test Anxiety Questionnaire. This is a ten item scale (5 worry items and 5 emotionality items). Subjects respond to these items on a five point scale from "not at all" to "very strongly so". Sample items are: "I am worrying a great deal about this test." "I feel my heart beating fast." Alpha coefficients for this scale were .83 and .76 for emotionality and .68 and .69 for worry (Morris & Liebert, 1970). (Appendix E)

Procedure

Students were seen on three separate occasions (See Figure 2). At the first session, data were collected from 339 subjects. The scales were administered in the following sequence:

Test Anxiety Scale (TAS) - 37 items
Math Anxiety Rating Scale (MARS) - 24 items
Algebra Pretest - 20 items

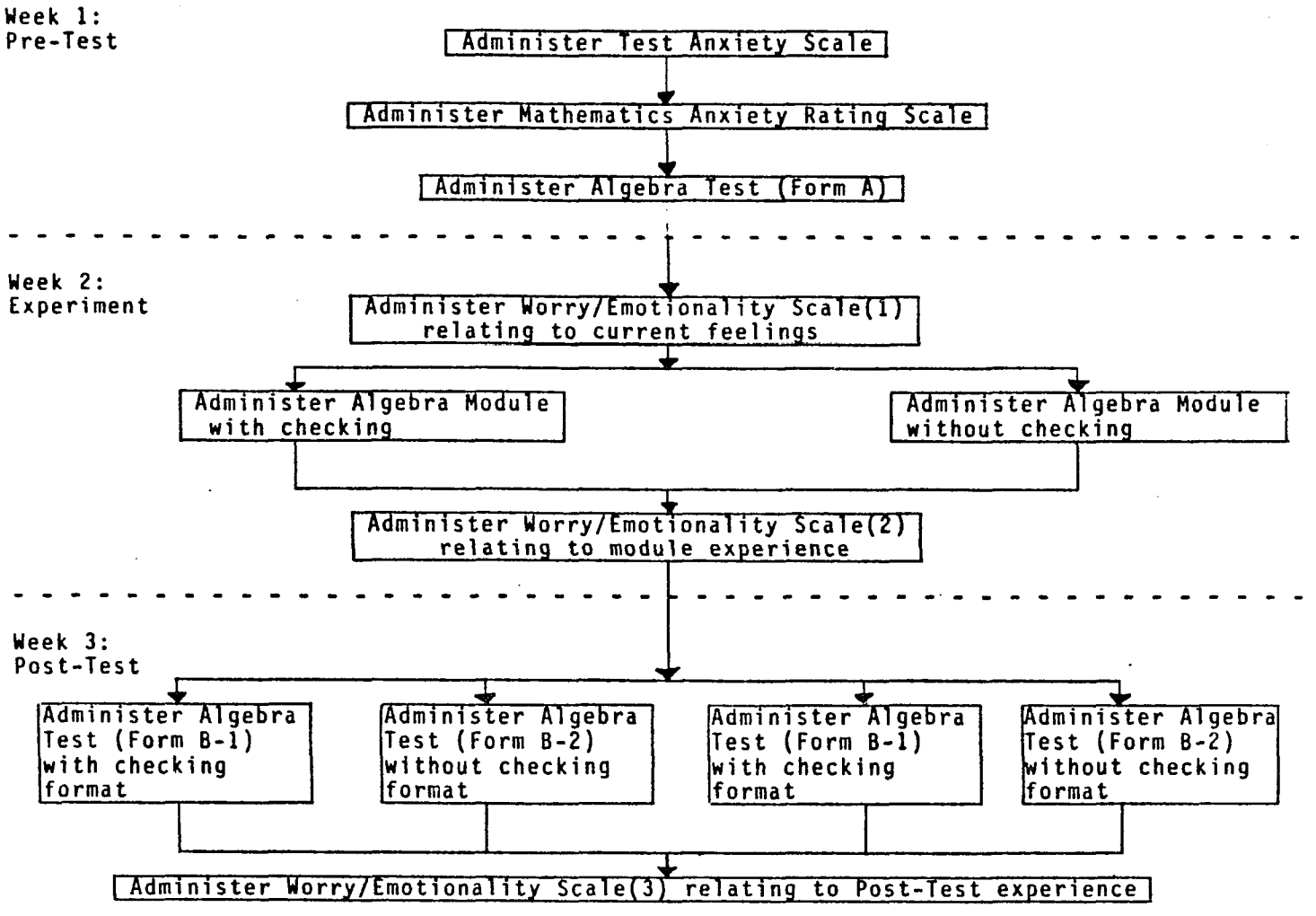


Figure 2. Experimental Procedure

At the second session, students completed a 10 item worry/ emotionality scale (Worry/PreModule & Emotionality/PreModule) regarding their feelings at the moment, prior to the administration of the algebra module. They were randomly assigned to the checking or non-checking module conditions, and then the modules were administered. A second worry/emotionality scale (Worry/PostModule & Emotionality/PostModule) was then administered asking for students' reactions during the algebra lesson. At this session 263 of the students were tested; the other 76 (22%) were absent from their required lab period.

At the third session students completed a 20 item algebra posttest (similar to the pretest). There were two forms of the posttest, one encouraged checking and one did not. Fifteen filler items on math attitudes were added at the end of the non-checking format to equalize time on task. A third administration of the 10 item worry/ emotionality scale (Worry/Posttest & Emotionality/-Posttest) was also administered. Of the 263 students who completed the second session's material, 214 (81%) completed the posttest, or 63% of the original sample.

Sixty-one students whose algebra pretest was over 70% were eliminated from the analysis, leaving a total of 153 students, 45% of the original sample. (The sample was smaller than originally designed due to the high absence rate and the elimination of students who knew some algebra. A determined attempt was made to find a similar sample at another institution, but permission to test was denied because of the three hours of classroom time needed for

the study.) The resulting research design was a 2x2 with two forms of the module (checking or non-checking) and two forms of the posttest (checking or non-checking), with the addition of anxiety as a continuous variable.

Subjects

Data were collected at a community college in New York City. A total of 339 subjects were seen during the laboratory period of a remedial math course; complete data are available for 153 subjects. The lab was a required part of the course during which the students normally completed a worksheet reinforcing the material studied in class. During the experiment these worksheet assignments were eliminated. Of the 153 students, 71% were female. Table 1 indicates the age and sex characteristics of the subgroups.

The mean age of the sample was 21 years, somewhat high for entering freshmen, but typical for a community college. The ages ranged from 17 to 65, with 17 students (11%) over the age of 25.

Table 1
Age and sex characteristics by subgroup.

Subgroup	No. of males	No. of females	Total No.	Mean age
Checking Module/ Checking Posttest	7	30	37	22.5
Checking Module/ Non-Checking Posttest	12	26	38	21.2
Non-checking Module/ Checking Posttest	16	23	39	20.6
Non-checking Module/ Non-Checking Posttest	10	29	39	20.2
TOTAL	45	108	153	21.0

RESULTS

The first hypothesis predicted that high anxious students who were taught to check, would perform better on a posttest than high anxious students who were not taught checking. Of the 153 S's who scored 70% or below, the average score on the pretest was 5.6 (sd = 4.7). The subgroup mean scores ranged from 5.0 to 6.1, of a possible maximum score of 20. The mean posttest score was 16.0, significantly higher than the 5.6 mean on the pretest ($t = 20.78$; $p < .001$), indicating that the module was effective in teaching algebra. Table 2 displays the algebra test data. An analysis of variance indicated no significant differences between groups on either the pretest or the posttest.

Table 2
Means and Standard Deviations for Algebra Tests by Subgroup

Subgroup	PRE TEST Mean	sd	POST TEST Mean	sd
Checking Module/ Checking Posttest	5.5	4.6	16.5	4.5
Checking Module/ Non-Checking Posttest	5.0	5.0	16.2	5.3
Non-checking Module/ Checking Posttest	6.1	4.7	14.8	6.5
Non-checking Module/ Non-Checking Posttest	6.0	4.4	16.4	5.1
Total	5.6	4.7	16.0	5.4

The checking module took an average of 39.10 minutes to complete and a range of 10 to 60 minutes; the non-checking module took an average of 32.67 minutes to complete ($t = 2.54$; $p < .05$) and a range of 12 to 70 minutes. (During the pilot ($n = 10$), the mean time

to complete the module was 29 minutes; times ranged from 10 to 70 minutes.) Additional items should have been added to the control module to equalize time on task. Both modules appear in Appendix A.

In order to test the first hypothesis, the interaction between anxiety measures and type of module (checking or non-checking) was investigated. For the second hypothesis, the interaction between the anxiety measures and posttest format (checking or non-checking) was analyzed. Anxiety was measured eight times: the Math Anxiety Rating Scale, the Test Anxiety Scale, three administrations of the Worry - Emotionality Scale.

Regression analyses were performed with the SPSS "New Regression" program (Hull, C.H. & Nie, N.H., 1981). The analysis followed this format: First the significance of the main effects were determined by computing the effect of anxiety (A), then the effect of condition (C) was added, followed by the effect of format (F). Subsequently, each double interaction was added to determine the significance of additional variance explained, and these were compared to the full equation. The triple interaction was then added to the model with all double interactions, and the significance of the additional variance explained was determined.

The full regression equation was:

$$y_1 = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_1 x_2 + \beta_5 x_1 x_3 + \beta_6 x_2 x_3 + \beta_7 x_1 x_2 x_3 + e$$

where:
y_1 = test score on algebra posttest
x_1 = checking module (yes = 1; no = 0)
x_2 = checking format on posttest (yes = 1; no = 0)
x_3 = anxiety measure (MARS, TAS, or W/E)

Means and standard deviations for the major variables are shown in Table 3. Some of the data relating to these hypotheses will be presented for each of these scales.

Table 3
Means and Standard Deviations for Major Variables

Major Variables	Mean	Standard Deviation
Test Anxiety Scale	19.6	6.4
Math Anxiety Rating Scale	55.8	17.9
Worry/PreModule	8.5	4.3
Worry/PostModule	7.7	3.5
Worry/Posttest	7.2	3.6
Emotionality/PreModule	7.7	3.9
Emotionality/PostModule	7.0	3.7
Emotionality/Posttest	6.5	3.0
Algebra Pretest	5.6	4.7
Algebra Posttest	16.0	5.4

Mathematics Anxiety Rating Scale (MARS)

The mean score on the MARS was 55.8 of a possible 120 (sd = 17.9). Subgroup means ranged from 50.5 to 59.0 with sd's ranging from 14.6 to 18.8. Since this scale was administered prior to any experimental material, no differences between subgroups were expected, and none were found. (See Table 4)

Table 4
Means and Standard Deviations for MARS and Correlations with Algebra Tests by Subgroup (n = 153)

Subgroup	Mean	sd	n	Correlations with Pretest	Posttest
Checking Module/ Checking Posttest	54.9	18.8	37	-.19	-.32**
Checking Module/ Non-Checking Posttest	58.7	18.4	38	-.07	.11
Non-checking Module/ Checking Posttest	50.5	14.6	39	-.13	-.15
Non-checking Module/ Non-Checking Posttest	59.0	18.6	39	.33**	-.11
Total	55.8	17.9	153	-.02	-.02

(* $p < .05$; ** $p < .01$)

Correlations of the MARS with the Algebra pretest indicate a low negative correlation, except for the control checking group where the correlation was .33 ($p < .01$). Correlations of the MARS with the Algebra posttest also indicated primarily low negative correlations.

Regression analysis using the MARS (See Table 5) indicated that the interaction of MARS and condition (A X C), as expected in the first hypothesis, was not significant. There was a significant interaction between MARS x Format, which relates to the second hypothesis. A graph of these results (See Figure 3) demonstrated, contrary to prediction, that high trait anxiety (MARS) students performed better on the posttest with the non-checking format compared to low trait anxiety students under similar conditions. The high anxiety students under the non-checking format condition also obtained higher posttest scores than other high anxiety students who were encouraged to check on the posttest.

Table 5
Results of Regression Analyses, including Beta Weights and the Constant, on Posttest Score for MARS, TAS and WORRY/POSTTEST.

		MARS		TAS		WORRY/POSTTEST	
Effects	df	Beta	F	Beta	F	Beta	F
Anxiety (A)	1	.04	.08	- .02	.85	- .19	15.07***
Condition (C)	1	- .70	.77	.32	.77	1.15	.77
Format (F)	1	4.43	.49	- .89	.49	2.52	.49
A x C	1	.01	.28	- .02	.77	- .17	.30
A x F	1	- .11	5.36*	- .04	.41	- .55	1.17
C x F	1	3.23	1.23	4.52	1.51	-1.23	1.04
A x C x F	1	- .02	.03	- .13	.20	.43	.81
Constant		14.22		16.72		17.65	
Total	143						

(* $p < .05$; ** $p < .01$; ***$p < .001$)

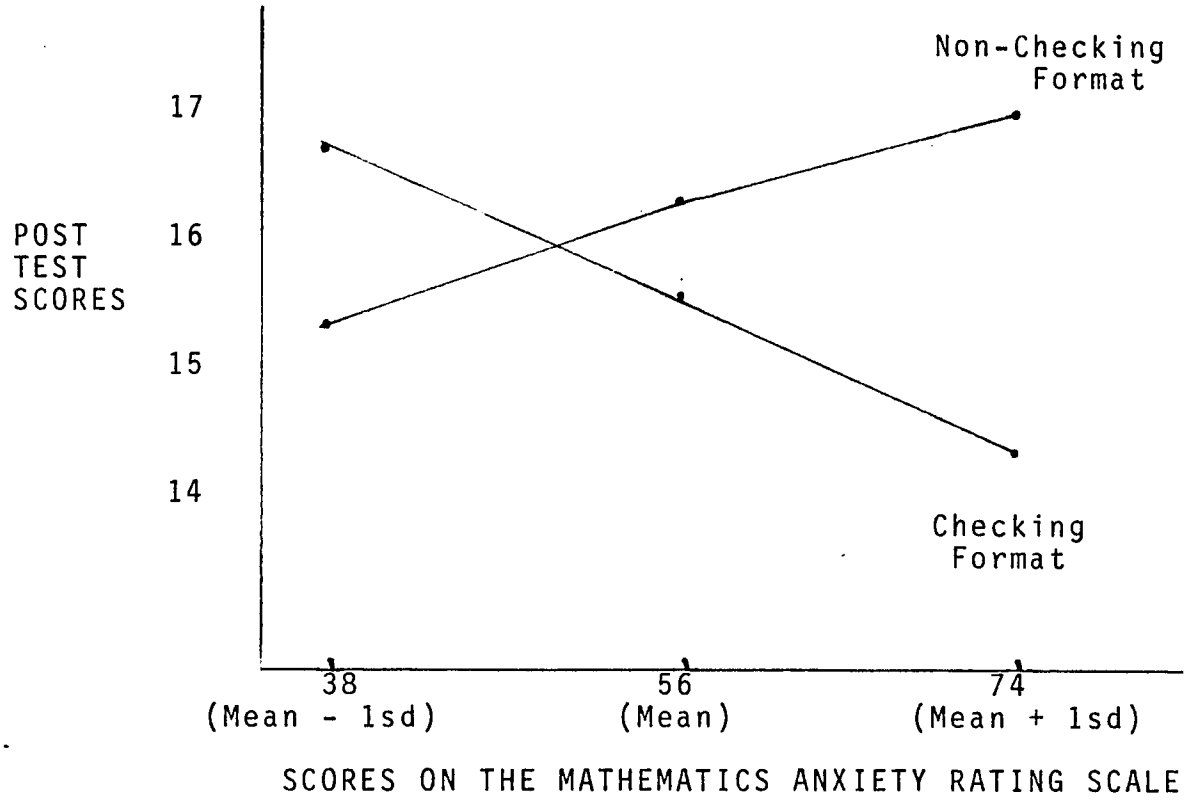


Figure 3. Regression line of MARS and FORMAT on POST-TEST (n = 153) at three points: the mean and ± 1 standard deviation.

Test Anxiety Scale (TAS)

The mean score on the Test Anxiety Scale was 19.6 of a possible 37 (sd = 6.4). The distribution across subgroups was even, with means ranging from 17.3 to 20.8 and sd's ranging from 5.7 to 6.9. Since this scale was administered prior to any experimental material, no differences between subgroups were expected, and none were found.(See Table 6)

Table 6
Means and Standard Deviations for TAS and Correlations with Algebra Tests by Subgroup (n = 153)

Subgroup	Mean	sd	Correlations with Pretest	Posttest
Checking Module/ Checking Posttest	19.9	6.9	-.16	-.34*
Checking Module/ Non-Checking Posttest	20.2	6.3	-.38**	-.07
Non-checking Module/ Checking Posttest	17.3	5.7	-.17	-.01
Non-checking Module/ Non-Checking Posttest	20.8	6.2	-.03	-.05
Total	19.6	6.4	-.19**	-.07

(* $p < .05$; ** $p < .01$)

Correlations of the TAS with the Algebra pretest indicated low to moderate negative correlations (See Table 6). Posttest correlations with the TAS were not significant, except for one group (Checking Module / Checking Posttest) with a correlation of -.34 ($p < .05$). The regression analysis indicated no significant effects of the TAS on posttest either as a main effect or in interaction with module or format.(See Table 5)

Worry/Emotionality Scales

The Worry/PreModule and Emotionality/PreModule directions instructed students to respond according to how they were feeling at the moment, and was administered prior to any of the experimental procedures. The Worry/PostModule and Emotionality/PostModule occurred after the module had been administered and requested information on how students had felt while they were learning the module. The Worry/Posttest and Emotionality/Posttest were administered with directions to respond according to how students had felt during the posttest. Tables 7 and 8 contain the means and standard deviations of the Worry/Emotionality Scales.

A regression analysis indicated that the Worry/Posttest (with instruction to report the way students felt during the posttest) contributed significantly to the posttest score (See Table 5). However, the interaction term of Worry/Posttest with format was not significant. (See Table 5). The other five worry and emotionality scales were significant neither as main effects, nor in interaction with the other variables.

A 2x2x2 Analysis of Variance, with the third level being defined by the Worry and Emotionality Scales as repeated measures, indicated that both Emotionality and Worry had significant main effects, in that the scores consistently decreased with each administration. However condition appeared not to affect the Worry or Emotionality dimensions, and none of the interactions were significant. (See Table 9).

Table 7
Means and Standard Deviations of Worry Scales

	MEAN	sd	n
WORRY/PRETEST			
Checking Module/ Checking Posttest	7.9	3.5	29
Checking Module/ Non-Checking Posttest	8.1	2.9	28
Non-checking Module/ Checking Posttest	8.9	4.1	35
Non-checking Module/ Non-Checking Posttest	7.2	2.9	30
TOTAL	8.5		
WORRY/MODULE			
Checking Module/ Checking Posttest	7.6	4.2	29
Checking Module/ Non-Checking Posttest	7.4	3.6	28
Non-checking Module/ Checking Posttest	7.9	3.2	35
Non-checking Module/ Non-Checking Posttest	7.5	3.4	30
TOTAL	7.7		
WORRY/POSTTEST			
Checking Module/ Checking Posttest	6.8	3.9	29
Checking Module/ Non-Checking Posttest	6.9	3.6	28
Non-checking Module/ Checking Posttest	7.4	3.6	35
Non-checking Module/ Non-Checking Posttest	7.0	3.0	30
TOTAL	7.2		

Table 8
Means and Standard Deviations of Emotionality Scales

	MEAN	sd	n
EMOTIONALITY/PRETEST			
Checking Module/ Checking Posttest	7.4	3.1	29
Checking Module/ Non-Checking Posttest	7.1	3.8	28
Non-checking Module/ Checking Posttest	8.3	4.4	35
Non-checking Module/ Non-Checking Posttest	6.5	1.8	30
TOTAL	7.7		
EMOTIONALITY/MODULE			
Checking Module/ Checking Posttest	7.6	4.9	29
Checking Module/ Non-Checking Posttest	6.9	4.1	28
Non-checking Module/ Checking Posttest	6.9	2.5	35
Non-checking Module/ Non-Checking Posttest	6.2	3.0	30
TOTAL	7.0		
EMOTIONALITY/POSTTEST			
Checking Module/ Checking Posttest	6.9	4.0	29
Checking Module/ Non-Checking Posttest	6.1	2.7	28
Non-checking Module/ Checking Posttest	6.9	3.0	35
Non-checking Module/ Non-Checking Posttest	5.7	1.9	30
TOTAL	6.5		

Table 9
ANOVA on Worry/Emotionality Scale as a Repeated Measure

SOURCE	SS	df	F
WORRY			
Condition	3.4	1	.14
Format	16.0	1	.65
Condition x Format	16.4	1	.66
Worry	59.3	2	4.77**
Worry x Condition	1.5	2	.12
Worry x Format	6.1	2	.49
Worry x Cond. x Format	12.4	2	1.00
EMOTIONALITY			
Condition	6.1	1	.25
Format	74.6	1	3.05
Condition x Format	10.1	1	.41
Emotionality	53.8	2	5.17**
Emot x Condition	8.3	2	.80
Emot x Format	1.9	2	.19
Emot x Cond. x Format	9.0	2	.87

(* $p<.05$; ** $p<.01$)

Posttest Checking

The algebra post-tests were reviewed to identify those students who had some evidence of checking. Because many students did not use traditional notation or approaches, this was a subjective process. There were 47 protocols which showed some multiplication. These 47 were reviewed by three judges who were given the following explanation:

1. These students were taught elementary algebra and some were taught to check.
2. They were taught to do the algebra by division.
   $6x = 12$; $\frac{6x}{6} = \frac{12}{6}$; $x = 2$
3. and to check by multiplication. $6x = 12$; $(6)(2) = 12$
4. But some of the students didn't know division and used multiplication to determine the answer.
5. Please mark the items where you think the student <u>really</u> checked their work.

Students who checked 6 items or more (i.e., more than 25%) were considered checkers. The raters agreed on 88% of the cases. Median interrater reliability was computed at .82. For 6 subjects where there was no consensus among the three raters, the majority ruled. (Five of these were classified as non-checkers and one as a checker.) Seventeen subjects in total were classified as checkers. The mean posttest score of the checkers (16.5) was slightly higher than that of the non-checkers (15.9) ($t=-.9$; ns). The checkers also reported slightly less "worry" during the posttest (6.24) than the non-checkers (7.32) ($t=1.22$; ns). A chi-square analysis was computed to determine the significance of differences in the number of people checking by type of module and posttest format; no significant difference was found ($X^2 = .255$). (See Table 10).

Table 10
Posttest Means and Worry/Posttest Scores for Posttest Checkers

Subgroup	Number of checkers	Posttest Mean	Worry/ Posttest
Checking Module/ Checking Posttest	12	17	6.25
Checking Module/ Non-Checking Posttest	1	15	6.00
Non-checking Module/ Checking Posttest	4	15	6.25
Non-checking Module/ Non-Checking Posttest	0	-	-
Total: Checkers	17 (11%)	16.5	6.24
Total: Non-Checkers	136 (89%)	15.9	7.32
TOTAL	153	16.0	7.20

Additional Variables

Anxiety/sex and anxiety/age interactions were examined because these have been observed in other studies. No evidence for a relationship with sex was found in the present research and therefore these subgroup scores were pooled. (See Appendices G and H.) Interactions with age were found: older students report more test and math anxiety. However, there was no significant difference in the mean ages of the subgroups, so these interactions did not affect the results.

DISCUSSION

This study investigated the relationship between evaluative anxiety and learning. An interaction between anxiety and instructional strategy was hypothesized such that high test anxious learners were expected to increase achievement with training in a metacognitive checking strategy, whereas the achievement of low anxious students would be unaffected. This hypothesis was based on the theories of Wine, Sarason, and Tobias. Wine (1980) and Sarason (1972) proposed an explanation of test anxiety which focussed on the direction of attention. Learning and performing a task require attention; anxiety distracts the individual by diverting attention and reduces the amount of attention devoted to the task. It was therefore postulated that high anxiety students who learned a strategy which helped focus attention would perform better on a task; being able to check their own work would provide high anxious subjects with a useful channel for this self-questioning behavior and would result in the correction of errors.

Tobias (1977c, 1981) suggested that checking one's work is a metacognitive strategy which would improve performance at the pre-processing and processing stages of learning. The current study tested that hypothesis by teaching checking skills in a mathematics context. Checking is an easily implemented metacognitive strategy, particularly in a rule governed subject such as mathematics.

Two specific hypotheses were tested: high anxious students taught to check their work were expected to perform better on a posttest than high anxious students who were not taught to check;

and high anxious students encouraged to check by test format would perform better on a posttest than high anxious students not encouraged to check. Regression analyses indicated no support for the first hypothesis. Some evidence that test format can influence the performance of high anxious students was found, but not in the expected direction.

The primary explanation for these results is that the checking of results, and the review of input implied by checking, may alleviate the negative effects of high anxiety but the present procedure of this experiment did not permit the effects to be demonstrated. Failure to support the hypothesis of the effects of checking instruction may be attributed to a ceiling effect on the posttest and to a low difficulty level of the algebra module. In addition, there was a one week delay between the algebra module and the posttest; with a short treatment (1 hour), any effects may have dissipated during the week. There was no attempt to induce stress in this study and the anxiety levels may have been too low to influence performance. These factors are discussed in detail on the following pages.

Ceiling Effect

Sixty one percent of the subjects (N=93) answered 90% - 100% of the posttest items correctly. This ceiling effect may have made it impossible to observe accurately the effects of the treatment. A ceiling effect obscures results because the real distribution of achievement is not evident. With a more difficult test, the

students who performed well could have demonstrated their full understanding and obtained higher scores than possible on this test. There may then have been greater differences between the medium and high scorers. Without this full range, true effects are hidden.

An analysis of the 60 subjects whose posttest scores were under 80% (Appendix L) indicated a significant interaction between Worry/-Posttest and Format. As can be seen in Figure 4, high state-anxious learners with the checking posttest format outperformed their high state-anxious colleagues who received the standard test format. Low state-anxious learners performed similarly with either format. In addition, under both posttest conditions the low state-anxious learners scored lower than the high anxious learners with the checking format. The data support the possibility that the ceiling effect may have attenuated differences between high and low anxious students attributable to test format.

Lesson Difficulty

An analysis of the errors made by students on the algebra module indicated the material was relatively easy: 109 students (71%) correctly answered 80% or more of the items, and 35% (n=53) of the sample had 100% scores. The difficulty level of tasks differentially affects the performance of high and low anxious people.

In a study on computer-assisted learning by O'Neil, Spielberger & Hansen (1969) it was found that although high state anxious learners made significantly more errors on difficult math problems

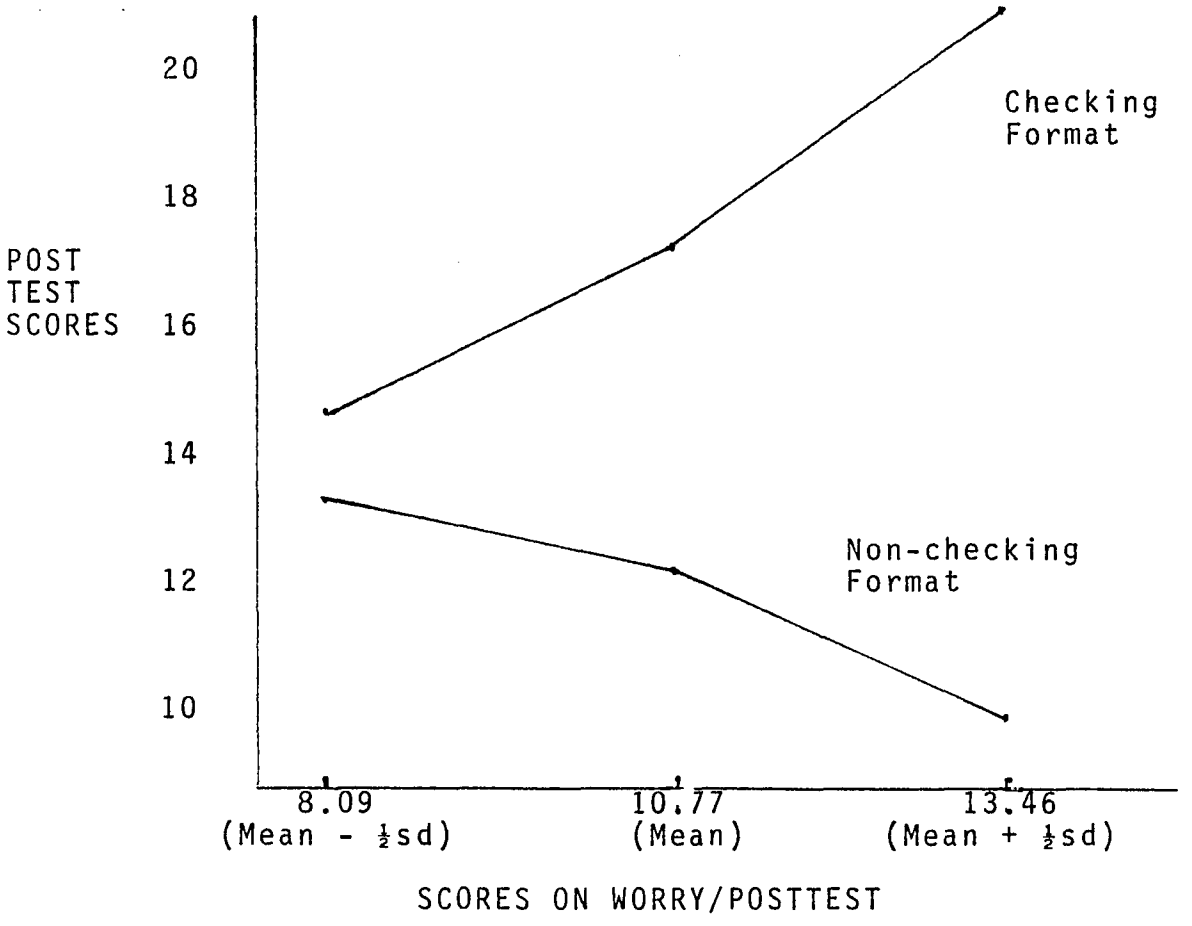


Figure 4. Regression line of WORRY/POSTTEST and FORMAT on POST-TEST for non-ceiling subjects (n = 60) at the mean and ±½ standard deviation.

than did low state anxious learners, the relationship was reversed, (although not significantly), for easy problems. Similarly, findings by Katahn and Branham (1968) indicated that high anxiety did not affect performance during acquisition, a relatively easy task, but did affect generalization of information, a more difficult and complex task (cited by Heinrich and Spielberger, 1982, p. 150). In a review of anxiety and complex learning, Heinrich and Spielberger (1982) stated that "poorer performance for high-anxiety subjects on difficult tasks has been a common finding in the research literature, whereas facilitative effects of anxiety on easy tasks are found less often" (p. 149). As Tobias (1977c) concluded "anxiety interferes with learning only on relatively difficult subject matter"(p. 234). In the current study the material may have been too easy to trigger the debilitative anxiety under scrutiny.

The material was also presented in an organized hierarchical sequence. The first few frames required single digit arithmetic, the next set of frames required double digits, and the last frames had two terms with "x" in the equations. It has been predicted (Tobias, in press) that well organized material lessens the negative effects of anxiety because it requires less processing capacity. In the present study the hierarchical organization of the material may have further equalized the task for high and low anxious students.

Treatment to Posttest Delay

Since the experiment was conducted during a class period, it was not possible to administer the posttest directly after the

treatment; a one week delay was necessary. In the current study, students may have forgotten how to check in the week between treatment and posttest, particularly since the module treatment was short (one hour). No overlearning was possible. The small number of those who checked their work on the posttest (n = 17; 11% of those taught to check) supports this possiblity. A one week delay may have been too long to observe the results of a one hour treatment. This is supported by the finding that test format did have an effect on performance. Students with high math anxiety scores and less than 80% on the posttest performed better on the posttest version with checking than they did with a non-checking format. In this case, although the format treatment was weak, it was simultaneous to the assessment of performance and may have acted as a reminder to students to employ the checking procedure taught.

Absence of Stress and Low Anxiety Levels

In the present study, the atmosphere was non-stressful. The post-test was not labelled a test but rather was titled "Did you learn some algebra?" The atmosphere of the math lab where the study was conducted was a pleasant, unstructured environment. During the lesson, the experimenter was friendly, cooperative and explained the material whenever necessary. In addition, anxiety was low. The group mean scores for the worry/emotionality scales ranged from 5.7 to 8.9, with a minimum possible score of 5 and a maximum of 25. In addition, the worry/emotionality scale administered after the posttest yielded the lowest group mean scores of the three

administrations of this scale (see Tables 7 and 8). These means are consistent with the Tobias (1984) study in which a sample of 69 students responded to the Worry/Emotionality Scale three times; means ranged from 6.74 (sd 2.96) to 8.30 (sd 3.43). These means are somehwat lower than studies which have used the same instrument in a more stressful situation; Morris, Davis and Hutchings (1981), for example, reported a mean of 12.43 (sd 4.68) on the Worry scale and 9.17 (sd 4.37) on the Emotionality scale for a sample of 222 general psychology students who responded to the scale immediately preceeding a regular course examination.

The test anxiety literature indicates that stress reduces performance in high anxious students (Sarason, 1980, p.8). In the absence of stress, however, high anxious students and low anxious students respond comparably (Wine, 1971, p. 96). For example, Hashemian (1977) observed the reactions of 94 undergraduates to high or low stress instructions. Interactions were found indicating that for the low stress group, there was a positive relationship between state anxiety and performance whereas with high stress instructions this relationship was negative. The low stress nature of the current study may have served to reduce the negative effects of anxiety, which would have eliminated treatment effects. As Tobias discussed (1977c, p.233), in order to investigate the effects of checking, a high level of stress needs to be present.

Implications for Further Research

There are six basic recommendations to other researchers

interested in this topic. First, a large sample is needed if the treatment is short and second, the treatment should be longer, perhaps over several sessions. As explained in a previous section, a smaller sample than considered necessary was used for the present study, because no other sample was found which would permit three hours of experimentation during class periods. Third, more difficult material and a more difficult achievement test have to be utilized so that students who learn from the lesson can demonstrate the subtle effects of experimental conditions, and so that the anxiety aroused by difficult instructional material can be induced. This greater range on the module and on the posttest would eliminate the problem of a ceiling effect.

Fourth, a modeling component (as reviewed by Rosenthal, 1980) may be necessary to convince students that finding one's own errors is positive. Rosenthal indicated (p. 246) that modeling is an educational technique which has proven useful with a variety of topics such as social perceptions, how to be a student counselor, or how to study. Horne and Matson (1977), for example, found that college students who listened to tapes in which other students learned to face examinations calmly, indicated a reduction in test anxiety after treatment. Modeling of the checking behavior would be a useful addition to the design.

Fifth, some stress should be incorporated into the design in order to fully engage the students. This could be done by simply labeling the posttest a test, by including the results in a course grade, or by conducting the experiment in an unfamiliar environment.

In some manner the results of the test should be ego-involving. Both a stress group and a non-stress group should be included in the design. Anxious students should perceive checking as a way to reduce anxiety.

The last two recommendations concern the posttest. Instructional support for checking should be provided; this standard or model would serve as a visual reminder to students. The reminder would act as a cue to retrieve previously taught strategies of checking. Some of the students should also be required to check their work in writing. In the present study checking may have been covert, and therefore not evident to the experimenter. A requirement to check would enable a differentiation between those subjects who learned to check and those who didn't. Guided checking could be presented so that for the first few items, checking is demonstrated and gradually the examples of checking fade and the student becomes responsible for the checking routine. For some groups a mastery-based strategy could be employed where non-checkers could then be branched back to a checking routing.

SUMMARY

The present study investigated the effects of checking one's own work (a metacognitive skill) on the performance of high and low anxious students. One of the strengths of the current study was the use of mathematics as the content area. Most of the metacognitive research currently underway (Brown, et. al, 1982) concerns reading comprehension. Mathematics is simpler to manipulate and the checking routines are more straightforward.

Four procedural considerations may have influenced the results. An apparent ceiling effect on the posttest may not have permitted the full range of student achievement to be demonstrated. When the high posttest scorers (80% correct or greater) were eliminated from the analysis, the data indicated that checking format was advantageous to high anxious students and did not help low anxious students. The lack of results concerning the experimental module may have been caused by the material being too easy to trigger anxiety, and a lengthy time-delay between a short treatment and posttest (one week). The algebra module was quite easy and most of the students (71%) answered 80% or more of the items correctly. Previous research indicates that the effects of anxiety are only apparent with difficult material. The time period between the algebra module and the posttest was a week, which may have been too long to still observe the differential effects of the checking and nonchecking modules. Lastly, the state anxiety scales indicated minimal worry and minimal emotionality throughout the sessions, and lowest state anxiety scores at the posttest session. Without stress, achievement

differences between low anxious and high anxious learners have not been found in previous research. It should also be noted that these four procedural considerations are not mutually exclusive. In fact, a combination of all four could readily explain the lack of support for the first hypothesis (module variations) and the contradictory results on the second hypothesis (posttest format variations).

APPENDICES

APPENDIX A:

ALGEBRA MODULE
(CONTROL)

NAME _____

CLASS _____

DATE _____

INTRODUCTION TO ALGEBRA

We have learned that people often make mistakes in math if they do it all in their head. Therefore, make sure you write down all your answers and you'll make less mistakes. Be sure to answer all questions.

1.

In this booklet you will learn a little about algebra.

In algebra a letter (often "X") is used to represent the part of the problem you want to figure out.

'X' can be any part of the problem that's missing.

2.

Here's an example:

If 6 people each have the same number of pencils and they have 42 pencils all together, we want to know how many pencils each person has.

First, we think about the important facts:

6 people with the same number of pencils equals 42 pencils

Next, we write an equation (which is a number sentence):

$6X = 42$ pencils
Where 6 is for the people, and
where 'X' means the number of pencils each person has.

We can divide both sides of the equation by 6:

$\frac{6X}{6} = \frac{42}{6}$ or $\frac{\cancel{6}^{1}X}{\cancel{6}} = \frac{\cancel{42}^{7}}{\cancel{6}}$ or $X = 7$.

In this case,
$X = 7$ pencils, or each person has 7 pencils.

* *

In this example, what did 'X' mean?_____

3.

To find what X is, always do the same thing to both sides of the equation .

If the equation is: $30X = 120$

$X = ?$

If you divide <u>both sides</u> by 30: $\frac{30X}{30} = \frac{120}{30}$

$\frac{1}{\cancel{30}X}{\cancel{30}} = \frac{4}{\cancel{120}}{\cancel{30}}$

then $X = 4$.

4.

If the equation (or number sentence) is: $14X = 28$

$X = ?$

(Please write down all your work)

"Your answer: _____"

---

5. (Remember - write out all your work!)

If the equation is: $91X = 546$

$X = ?$

"Your answer: _____"

6.

If the equation is: $15X = 7500$

$X = ?$

"Your answer: _____"

(Did you write out your work?)

7.

You can also add X's:

3X + 2X is 5X,

20X + 20X is 40X,

What is 3X + 10X? 3X + 10X is _____ .

8.

Sometimes you need to add up the X's on one side.
Look at this equation:
10X + 10X = 60

There are twenty X's, so,
20X = 60
Now it looks like the earlier examples.

X = ?

"Your answer: _____"

9.

Try this equation. (Write all your work).
If 2X + 13X = 45,
15X = 45,
X = ?

"Your answer: _____"

10.

If 22X + 28X = 100

X = ?

"Your answer: _____"

This one is a little more difficult.

11.

Sometimes there are other numbers in the equation.

To get an answer for X, try to get only the X's on one side of the "=" sign.

If $2X + 5 = 17$, first subtract 5 from both sides:

$$\begin{array}{r} 2X + 5 = 17 \\ -\ 5 = -5 \\ \hline 2X \quad = 12 \end{array}$$

$$X = ?$$

"Your answer: _____"

12.

Here's another equation:
(Remember, write all your work!)

If $5X + 7 = 22$
$X = ?$

"Your answer: _____"

13.

In algebra, numbers mean different things, depending where they are.

For example, you can have $3X$

or X_3

or X^3

and they all mean different things.

14.

When the number is in front of the X, like 3X, it means there are three X's.

What does 4X mean?

15.

Can you finish these equations?

$2X + 1X =$ _____

$2X + 3X =$ _____

$1X + 6X =$ _____

16.

When the number is after the X, and a little lower, it acts like a name for the X.

We read X_1 as "X-one".

X_1 is different from X_2, and so on.

17.

How do we read X_3?

18.

When the number is after the X, and a little higher, like X^3, it means you multiply X times itself three times.

What does X^4 mean?

X^4 means: _____

_____

19. What does X^3 equal if X = 2?

X^3 would equal 2^3, and you multiply

2 times 2 times 2.

2 times 2 = 4, and

4 times 2 = 8,

so, $X^3 = 2^3 = 8$, if X = 2.

20.

What does X^3 equal if X = 3?

Can you fill this in?

You multiply _____ times _____times _____.

3 times 3 = _____

9 times 3 = _____,

so $X^3 = 3^3$ = _____ when X = 3.

21.

What is the difference between 2X and X^2 ?

_____

_____

_____

Please write down what time it is now: _____

APPENDIX A:

ALGEBRA MODULE
(EXPERIMENTAL)

Name _____

Class _____

Date _____

INTRODUCTION TO ALGEBRA

We have learned that people often make mistakes in math if they do it all in their head. Therefore, make sure you write down all your answers and you'll make less mistakes. Be sure to answer all questions.

1.

THIS LESSON WILL TEACH YOU HOW TO CHECK.

DO YOU CHECK YOUR OWN WORK?

DO YOU KNOW HOW TO CHECK YOUR OWN WORK?

If you can find your own mistakes and correct them, you can do better. This can help you learn more and get better grades.

Athletes often check their own work.
Basketball players film their practices to find mistakes, and swimmers also watch films so they can do better when the real race comes.

REMEMBER, IF YOU FIND YOUR OWN MISTAKE AND CORRECT IT, IT REALLY ISN'T A MISTAKE.

In order to be sure that you know how to check your work YOU MUST ANSWER ALL THE QUESTIONS.

2.

In math you can often find your own mistakes by checking your work. For example, in division:
Let's say you divided 10 by 2 ($2\overline{)10}$)
and got an answer of 4.

You know you can check yourself by multiplying 4 x 2; since that doesn't equal 10, you know you made a mistake.

* * * * * * * * * * *

Once you find a mistake, you can try the problem again

$$2\overline{)10}$$

This time you got an answer of 5.

Does 5 x 2 = 10? If it does, then 5 is the right answer.

If 5 X 2 = 10, then $2\overline{)10} = 5$.

3.

How many mistakes can you find here?
Circle the examples with the mistakes.

a. $26\overline{)1040}$ b. $34\overline{)548}$ c. $17\overline{)1045}$

4.

To check your answers to Question #3, write these answers:

a. $\begin{array}{r} 40 \\ \times\ 26 \\ \hline \end{array}$ b. $\begin{array}{r} 22 \\ \times\ 34 \\ \hline \end{array}$ c. $\begin{array}{r} 62 \\ \times\ 17 \\ \hline \end{array}$

Did you find two wrong ones? If not, go back and check again.

THESE WERE SOME EXAMPLES OF CHECKING.
THE IDEA IS THE SAME IN ALL OF MATH.

5.
In this booklet you will learn a little about algebra.

In algebra a letter (often "X") is used to represent the part of the problem you want to figure out.

'X' can be any part of the problem that's missing.

6.
Here's an example:

If 6 people each have the same number of pencils and they have 42 pencils all together, we want to know how many pencils each person has.

First, we think about the important facts:

6 people with the same number of pencils equals 42 pencils

Next, we write an equation (which is a number sentence):

$6X = 42$ pencils
Where 6 is for the people, and
where 'X' means the number of pencils each person has.

We can divide both sides of the equation by 6:

$$\frac{6X}{6} = \frac{42}{6} \quad \text{or} \quad \frac{\cancel{6}^{1}X}{\cancel{6}} = \frac{\cancel{42}^{7}}{\cancel{6}} \quad \text{or } X = 7.$$

In this case,
$X = 7$ pencils, or each person has 7 pencils.

7.

In Question #6, 'X' stands for _____

8.

To find what X is, always do the same thing to both sides of the equation.

If the equation is: $30X = 120$
$X = ?$

If you divide <u>both sides</u> by 30: $\frac{30X}{30} = \frac{120}{30}$

$\frac{1}{\cancel{30}X}{\cancel{30}} = \frac{4}{\cancel{120}}{\cancel{30}}$

then X = 4.

9.

If the equation (or number sentence) is: $14X = 28$

$X = ?$

(Please write down all your work)

"Your answer: _____"

10.

To check your answer to Question #9, start with 14X = 28. Use the answer you found:

Does 14 times "your answer" = 28 ?

Check here: 14

x ☐ (Your answer)

If 14 times "your answer" = 28, you are right. If not, divide again and check again to get the right answer.

REMEMBER, IF YOU DIDN'T CHECK YOUR ANSWER, YOU DON'T KNOW IF ITS RIGHT.

11. Remember - write out all your work!

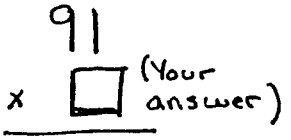
If the equation is : 91X = 546
X = ?

"Your answer: _____"

12.

To check your answer to Question # 11,
does 91 times "your answer" = 546?

Check here:



If 91 times "your answer" equals 546, you are right.
If not, divide again to get the right answer.

13.

If the equation is: 15X = 7500
X = ?

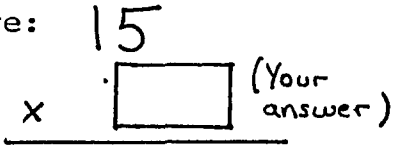
"Your answer: _____"

(Did you write out your work?)

14.

To check your answer to Question #13,
does 15 times "your answer" = 7500?

Check here:



If 15 times "your answer" equals 7500, you are right.
If not, divide again to get the right answer.

15.

You can also add X's:

3X + 2X is 5X,

20X + 20X is 40X,

What is 3X + 10X?

3X + 10X is _____ .

16.

Sometimes you need to add up the X's on one side.
Look at this equation:
10X + 10X = 60

There are twenty X's, so,
20X = 60
Now it looks like the earlier examples.

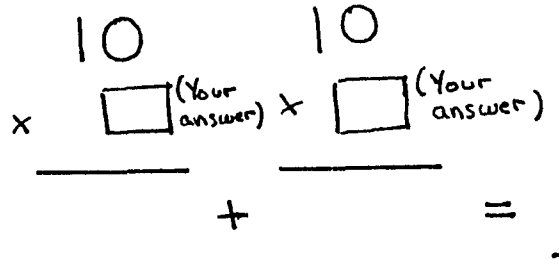
X = ?

"Your answer: _____"

17.

To check your answer to Question # 16,
does ten times "your answer" + ten times "your answer" = 60?

Check here:



If you did not get the right answer, try it again.

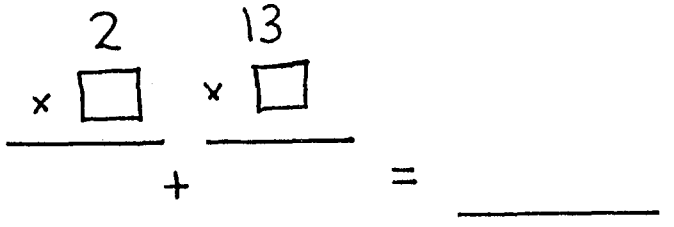
18.
Try this equation. (Write all your work.)
If 2X + 13X = 45,
15X = 45
X = ?

"Your answer: _____"

19.

To check your answer to Question #18,
does 2 times "your answer"
+ 13 times "your answer" = 45?

Check here:



If you did not get the right answer, try it again.

20.

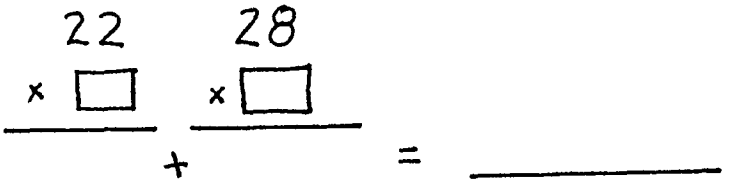
If 22X + 28X = 100
X = ?

"Your answer: _____"

21.

To check your answer to Question # 20,
does 22 times "your answer"
+ 28 times "your answer" = 100?

Check here:



If you did not get the right answer, try it again.

This one is a little more difficult.

22.

Sometimes there are other numbers in the equation.

To get an answer for X, try to get only the X's on one side of the "=" sign.

If $2X + 5 = 17$, first subtract 5 from both sides:

$$\begin{array}{rl} 2X + 5 & = 17 \\ - 5 & = -5 \\ \hline 2X & = 12 \end{array}$$

$$X = ?$$

"Your answer: _____"

23.

To check your answer to Question #22,
does 2 times "your answer" plus 5 = 17?

Check here:

$$2 \times \square + 5 = \_\_\_\_$$

If you did not get the right answer, try it again.

24.

Here's another equation:
(Remember, show all your work!)

If 5X + 7 = 22
X = ?

"Your answer: _____"

25.

To check your answer to Question #24,
does 5 times "your answer" plus 7 = 22?

Check here:

$5 \times \square + 7 = \_\_\_\_\_$

If you did not get the right answer, try it again.

26.

REMEMBER: TO CHECK YOUR WORK, SUBSTITUTE "YOUR ANSWER" WHEREVER X IS, AND SEE IF IT WORKS OUT. IF NOT, TRY IT AGAIN AND THEN CHECK AGAIN.

This helps you catch your own mistakes.

27.

HOW MANY MISTAKES DID YOU CATCH BY CHECKING? _____

28.

PLEASE WRITE THE RULE FOR CHECKING.

To check, substitute _

_ _

_ _

_ .

Please write down what time it is now: _____

Name: _____

Class: _____

Date: _____

APPENDIX B:

ALGEBRA TEST
(EXPERIMENTAL)

DID YOU LEARN SOME ALGEBRA?

Can you figure out what X equals?

Please write the answer in the blank.
MAKE SURE TO SHOW ALL YOUR WORK.

1. If $10X = 40$ X = _____ Check your answer:	2. If $6X = 42$ X = _____ Check your answer:
3. If $8X = 104$ X = _____ Check your answer:	4. If $13X = 26$ X = _____ Check your answer:

5. If $34X = 204$ X = _____ Check your answer:	6. If $2X + 3X = 10$ X = _____ Check your answer:
7. If $4X + 1X = 40$ X = _____ Check your answer:	8. If $1X + 3X = 28$ X = _____ Check your answer:
9. If $7X + 12X = 190$ X = _____ Check your answer:	10. If $18X + 12X = 90$ X = _____ Check your answer:

11. If $3X + 6 = 18$ X = _____ Check your answer:	12. If $10X + 7 = 37$ X = _____ Check your answer:
13. If $6X + 9 = 45$ X = _____ Check your answer:	14. If $12X + 8 = 92$ X = _____ Check your answer:
15. If $25X + 40 = 140$ X = _____ Check your answer:	16. If $33X + 1 = 100$ X = _____ Check your answer:

17. If 10 + 3X = 31 X = _____ Check your answer:	18. If 127 + 3X = 136 X = _____ Check your answer:
19. If 2000 + 2X = 2040 X = _____ Check your answer:	20. If 22 + 33X = 55 X = _____ Check your answer:

Please write down what time it is now: _____

Name: _____

Class: _____

Date: _____

APPENDIX B:

ALGEBRA TEST
(CONTROL)

DID YOU LEARN SOME ALGEBRA?

Can you figure out what X equals?

Please write the answer in the blank.
MAKE SURE TO SHOW ALL YOUR WORK.

1. If 10X = 40 X = _____	2. If 6X = 42 X = _____
3. If 8X = 104 X = _____	4. If 13X = 26 X = _____

5. If $34X = 204$ X = _____	6. If $2X + 3X = 10$ X = _____
7. If $4X + 1X = 40$ X = _____	8. If $1X + 3X = 28$ X = _____
9. If $7X + 12X = 190$ X = _____	10. If $18X + 12X = 90$ X = _____

11. If $3X + 6 = 18$ $X =$ _____	12. If $10X + 7 = 37$ $X =$ _____
13. If $6X + 9 = 45$ $X =$ _____	14. If $12X + 8 = 92$ $X =$ _____
15. If $25X + 40 = 140$ $X =$ _____	16. If $33X + 1 = 100$ $X =$ _____

17. If 10 + 3X = 31 X = _____	18. If 127 + 3X = 136 X = _____
19. If 2000 + 2X = 2040 X = _____	20. If 22 + 33X = 55 X = _____

Please write down what time it is now: _____

HOW DO YOU FEEL ABOUT MATHEMATICS?

The items in the Questionnaire refer to things and experiences that may cause fear or apprehension. For each item, place a (✓) in the box under the column that describes how much you are frightened by it nowadays. Work quickly but be sure to consider each item individually.

	not at all	a little	a fair amount	much	very much
1. Thinking about an upcoming math test one day before.					
2. Taking an examination (quiz) in a math course.					
3. Listening to a lecture in a math class.					
4. Starting a new chapter in a math book.					
5. Signing up for a course in Statistics.					
6. Picking up a math textbook to begin working on a homework assignment.					
7. Being given a homework assignment of many difficult problems which is due the next class meeting.					
8. Being given a 'pop' quiz in a math class.					
9. Listening to another student explain a math formula.					
10. Working on an abstract mathematical problem, such as: "If x = outstanding bills, and y = total income, calculate how much you have left for recreational expenditures."					
11. Getting ready to study for a math test.					
12. Reading the word 'Statistics.'					
13. Waiting to get a math test returned in which you expected to do well.					
14. Walking on campus and thinking about a math course.					
15. Taking an examination (final) in a math course.					
16. Reading a formula in chemistry.					
17. Watching a teacher work an algebraic equation on the blackboard.					
18. Looking through the pages of a math text.					
19. Solving a square root problem.					
20. Walking into a math class.					
21. Having to use the tables in the back of a math book.					
22. Reading and interpreting graphs or charts.					
23. Buying a math textbook.					
24. Being told how to interpret probability statements.					

Name: _____ Sex: M F

Class: _____ Age:

HOW DO YOU FEEL ABOUT TESTS?

Please read the questions below and decide if, for you, they are TRUE or FALSE. Please circle your answer.

1. While taking an important exam I find myself thinking of how much brighter the other students are than I am.	TRUE	FALSE
2. If I were to take an intelligence test, I would worry a great deal before taking it.	TRUE	FALSE
3. If I knew I was going to take an intelligence test, I would feel confident and relaxed, beforehand.	TRUE	FALSE
4. While taking an important examination I perspire a great deal.	TRUE	FALSE
5. During course examinations I find myself thinking of things unrelated to the actual course material.	TRUE	FALSE
6. I get to feel very panicky when I have to take a surprise exam.	TRUE	FALSE
7. During tests I find myself thinking of the consequences of failing.	TRUE	FALSE
8. After important tests I am frequently so tense that my stomach gets upset.	TRUE	FALSE
9. I freeze up on things like intelligence tests and final exams.	TRUE	FALSE
10. Getting a good grade on one test doesn't seem to increase my confidence on a second.	TRUE	FALSE
11. I sometimes feel my heart beating very fast during important tests.	TRUE	FALSE
12. After taking a test I always feel I could have done better than I actually did.	TRUE	FALSE
13. I usually get depressed after taking a test.	TRUE	FALSE
14. I have an uneasy, upset feeling before taking a final examination.	TRUE	FALSE
15. When taking a test my emotional feelings do not interfere with my performance.	TRUE	FALSE
16. During a course examination I frequently get so nervous that I forget facts I really know.	TRUE	FALSE
17. I seem to defeat myself while working on important tests.	TRUE	FALSE

18. The harder I work at taking a test or studying for one, the more confused I get.	TRUE	FALSE
19. As soon as an exam is over I try to stop worrying about it, but I just can't.	TRUE	FALSE
20. During exams I sometimes wonder if I'll ever get through college.	TRUE	FALSE
21. I would rather write a paper than take an examination for my grade in a course.	TRUE	FALSE
22. I wish examinations did not bother me so much.	TRUE	FALSE
23. I think I could do much better on tests if I could take them alone and not feel pressured by a time limit.	TRUE	FALSE
24. Thinking about the grade I may get in a course interferes with my studying and my performance on tests.	TRUE	FALSE
25. If examinations could be done away with I think I would actually learn more.	TRUE	FALSE
26. On exams I take the attitude, "If I don't know it now there's no point in worrying about it."	TRUE	FALSE
27. I really don't see why some people get so upset about tests.	TRUE	FALSE
28. Thoughts of doing poorly interfere with my performance on tests.	TRUE	FALSE
29. I don't study any harder for final exams than for the rest of my course work.	TRUE	FALSE
30. Even when I'm well prepared for a test I feel very anxious about it.	TRUE	FALSE
31. I don't enjoy eating before an important test.	TRUE	FALSE
32. Before an important examination I find my hands or arms trembling.	TRUE	FALSE
33. I seldom feel the need for "cramming" before an exam.	TRUE	FALSE
34. The college ought to recognize that some students are more nervous than others about tests and and that this affects their performance.	TRUE	FALSE
35. It seems to me that examination periods ought not to be made the tense situations which they are.	TRUE	FALSE
36. I start feeling very uneasy just before getting a test paper back.	TRUE	FALSE
37. I dread courses where the professor has the habit of giving 'pop' quizzes.	TRUE	FALSE

APPENDIX E:

WORRY/EMOTIONALITY SCALE

HOW DID YOU FEEL?

REMEMBER, EVERY PERSON FEELS DIFFERENTLY.

PLEASE ANSWER THE WAY YOU FELT DURING THE LESSON.

	NOT AT ALL	BARELY SO	MODERATELY SO	STRONGLY SO	VERY STRONGLY SO
I FELT MY HEART BEATING FAST.					
I FELT REGRETFUL.					
I WAS SO TENSE THAT MY STOMACH WAS UPSET.					
I AM AFRAID THAT I SHOULD HAVE STUDIED FOR THIS LESSON.					
I HAD AN UNEASY, UPSET FEELING.					
I FELT THAT OTHERS WOULD BE DISAPPOINTED IN ME.					
I WAS NERVOUS.					
I FELT I MAY NOT HAVE DONE AS WELL ON THIS LESSON AS I COULD.					
I FELT PANICKY.					
I DID NOT FEEL VERY CONFIDENT ABOUT MY PERFORMANCE ON THIS LESSON.					

Appendix F

Correlations with Age by Subgroup

	Checking Module		Non-checking Module		
Measure	Checking Format	Non-check Format	Checking Format	Non-check Format	Total Group
Worry1	.32*	.52***	.37*	.03	.32***
Worry2	.54***	.11	.40**	.10	.34***
Worry3	.54***	.23	.25	.25	.38***
Emot1	.49***	.46**	.19	.21	.34***
Emot2	.60***	.21	.19	.13	.40***
Emot3	.69***	.23	-.04	.61***	.43***
MARS	.33*	.13	.11	.12	.18*
TAS	-.10*	.34*	-.14	.08	.18*
Pre-test	-.04	-.37*	.08	.22	-.08
Post-test	.04	-.52***	-.16	.15	-.12*

(* $p < .05$; ** $p < .01$; *** $p < .001$)

Appendix G
Sex Differences in Anxiety and Achievement Measures

Measures		Males (n = 45)	Females (n = 108)	T Value
MARS	X	53.7	73.5	-1.05
	SD	15.5	14.9	
TAS	X	18.3	20.1	-1.59
	SD	6.3	6.4	
WORRY1	X	8.3	8.6	-0.35
	SD	3.7	4.5	
WORRY2	X	8.0	8.5	-0.29
	SD	3.9	9.8	
WORRY3	X	6.6	8.5	-1.31
	SD	2.7	9.8	
EMOT1	X	7.1	7.9	-1.10
	SD	3.1	4.2	
EMOT2	X	6.6	7.9	-0.80
	SD	3.1	9.8	
EMOT3	X	5.8	7.6	-1.26
	SD	2.0	9.5	
PRETEST	X	6.8	5.9	0.58
	SD	4.9	9.5	
POSTTEST	X	16.2	15.8	0.35
	SD	5.4	5.5	

Appendix H
ANOVA on Post Test Scores by Condition, Format & Sex.

SOURCE	SS	df	F
Condition	33.1	1	1.11
Format	16.8	1	.56
Sex	9.4	1	.31
Condition x Format	13.3	1	.45
Condition x Sex	19.5	1	.65
Format x Sex	4.8	1	.16
Condition x Format x Sex	12.0	1	.40

Appendix I

Intercorrelation Matrix of Anxiety Measures

	MARS	W1	E1	W2	E2	W3	E3
MARS	-						
WORRY1	.32						
EMOT1	.35	.72					
WORRY2	.22	.62	.43				
EMOT2	.24	.55	.60	.76			
WORRY3	.30	.49	.32	.38	.34		
EMOT3	.27	.47	.48	.42	.57	.71	
TAS	.49	.39	.39	.28	.31	.26	.28
	MARS	W1	E1	W2	E2	W3	E3

Appendix J
Correlations of Anxiety Scales with Pretest Score by Subgroup.

Measure	Checking Module		Non-checking Module		
	Checking Format	Non-check Format	Checking Format	Non-check Format	Total Group
Worry1	-.10	-.21	-.18	-.32*	-.20**
Worry2	-.18	-.35*	-.07	-.16	-.19*
Worry3	-.11	-.24	-.38*	-.00	-.20**
Emot1	-.14	-.25	-.11	.05	-.14*
Emot2	-.07	-.29	-.03	-.05	-.12
Emot3	.02	-.26	-.34**	-.00	-.16*
MARS	-.19	-.07	-.13	.33*	-.02
TAS	-.16	-.38**	-.17	-.03	-.19**
Pre-test X	5.5	5.0	6.1	6.0	5.6
n	37	38	39	38	152

(* $p<.05$; ** $p<.01$)

Appendix K

Correlations of Anxiety Scales with Posttest Score by Subgroup.

Measure	Checking Module		Non-checking Module		
	Checking Format	Non-check Format	Checking Format	Non-check Format	Total Group
Worry1	-.20	-.37*	-.19	-.02	-.18*
Worry2	.01	-.05	-.10	.17	.00
Worry3	-.29*	-.26	-.66***	.05	-.31***
Emot1	-.07	-.33*	.17	.14	-.01
Emot2	.12	-.13	.04	.06	.03
Emot3	.15	-.33*	-.35*	.10	-.11
MARS	-.32	.11	-.15	-.11	-.02
TAS	-.34*	-.07	-.01	-.05	-.07
Post-test X	16.5	16.2	14.8	16.4	16.0
n	37	38	39	38	152

(* $p<.05$; **$p<.01$: *** $p<.001$)

Appendix L.

Correlations between Time to Complete Algebra Module and Certain Measures by Experimental Condition. (n = 153)

Subgroup		WORRY/ POSTMODULE	EMOTIONALITY/ POSTMODULE	WORRY/ POSTTEST	EMOTIONALITY/ POSTTEST	POSTTEST	TIME
Checking Module/ Checking Format	X	7.7	7.8	7.6	6.9	16.5	35.2
	r^2	.51**	.45**	-.01	.12	.12	
Checking Module/ Non-checking Format	X	7.5	7.1	7.3	6.5	16.2	43.1
	r^2	.11	.24	.11	.03	-.19	
Non-checking Module/ Checking Format	X	7.8	6.8	7.3	6.8	14.8	35.3
	r^2	-.15	-.11	.07	.09	.04	
Non-checking Module/ Non-checking Format	X	10.5	9.1	9.3	8.2	16.4	30.5
	r^2	.25	.17	.04	-.09	-.28	

(** p .01)

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