

To the Graduate Council:

I am submitting herewith a dissertation written by Keith Allen Kline entitled "Threat Versus Challenge: The Effects of Different Cognitive Appraisals of a Mental Arithmetic Stressor on Cardiovascular Responses, State Affect, Task-Involvement, Effort and Performance in Male College Students." I have examined the final copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Psychology.

Kathleen A. Lawler
Kathleen A. Lawler, Major Professor

We have read this dissertation
and recommend its acceptance:

Jim E. Allen

Daryl R. Burnett, Jr.

John R. Padgett

Accepted for the Council:

Cowminkel
Associate Vice Chancellor and
Dean of The Graduate School

THREAT VERSUS CHALLENGE: THE EFFECTS OF DIFFERENT COGNITIVE
APPRAISALS OF A MENTAL ARITHMETIC STRESSOR ON CARDIOVASCULAR
RESPONSES, STATE AFFECT, TASK-INVOLVEMENT, EFFORT
AND PERFORMANCE IN MALE COLLEGE STUDENTS

A Dissertation
Presented for the
Doctor of Philosophy
Degree
The University of Tennessee, Knoxville

Keith Allen Kline
August 1998

Copyright © 1998 by Keith Allen Kline

All rights reserved

DEDICATION

This dissertation is dedicated to my wife and inspiration, Kelli Kline, whose continuous love and support and countless personal sacrifices enabled me to achieve this goal, and to my parents, Cheryl Kline and the late Ronald Kline, who instilled in me a strong work ethic and provided me with quality educational opportunities, as well as unconditional love and support.

ACKNOWLEDGMENTS

I owe a great deal of thanks to a number of individuals who have guided and assisted me in the completion of this dissertation. First and foremost, I would like to thank my major professor, committee chairperson and dedicated mentor, Dr. Kathleen Lawler. Without her constant encouragement, advice and prompt, instructive feedback, from the development of my research proposal to the completion of the study, I could have never possibly reached this goal. I would also like to thank my other committee members: Dr. James Lawler, Dr. Debora Baldwin, and Dr. David Bassett, whose insightful suggestions have been invaluable in the preparation of this manuscript, and whose advice has helped me throughout the entire dissertation process. Each of my committee members has had a positive influence on my personal and professional development.

I would also like to take this opportunity to say a special thanks to Rachel Anderson and Shana Hamilton, who along with myself, served as the primary data collectors for this study. Finally, I would like to thank Adam Foxworthy, Alison Mielniczuk, Summer Tidwell, Chris Holloman, and Emily Arney for their assistance in various capacities with regard to the collection and recording of data.

ABSTRACT

Stress-induced cardiovascular reactivity has traditionally been viewed as negative or harmful. However, there is increasing evidence that this conception of reactivity may be too simplistic and that, in some instances, certain patterns of reactivity may actually be adaptive. A number of recent investigations indicate that different cognitive appraisals of the same situation may be associated with different hemodynamic response patterns. Specifically, there is evidence that individuals who appraise a stressor as a challenge may display a response pattern characterized by increased myocardial reactivity (e.g., cardiac output) and decreased vascular resistance, while individuals who appraise the stressor as a threat display a vascular or mixed pattern (e.g., increased vascular resistance and moderate myocardial reactivity). Furthermore, based on evidence that challenge appraisals may be associated with greater effort and performance, as well as less stress and greater perceived performance than threat appraisals, it has been suggested that the hemodynamic pattern associated with challenge may be adaptive, while the pattern associated with threat may be maladaptive. In the present study, we manipulated threat and challenge appraisals of a mental arithmetic task and then assessed heart rate, blood pressure, cardiac output and total peripheral resistance responses to that task, as well as state affect, task-involvement and perceived and actual effort and performance, in a sample of 60 male undergraduates. These responses were then assessed for a second math task, following performance feedback. Cardiovascular recovery following the stressors was also assessed. Despite displaying greater challenge appraisal, less threat appraisal, greater task-involvement and greater perceived and actual effort and performance than the Threat group, the Challenge group did not differ from the Threat group in state affect or cardiovascular reactivity. The Challenge group also tended to display poorer cardiac output recovery following both tasks, but better vascular resistance recovery following the second task than the Threat group. Findings are interpreted as either supporting a "nonspecific" stress-response model, or as resulting from some common underlying emotion(s) or the specific response-eliciting properties of the stressor. Health implications are discussed, as well as issues pertaining to the definition and manipulation of threat and challenge appraisals.

TABLE OF CONTENTS

CHAPTER	PAGE
I INTRODUCTION	1
Hypotheses	24
II METHOD	26
Subjects	26
Apparatus	26
Self-report measures	27
Behavioral measures	31
Experimental design	32
Procedure	33
Data quantification	40
Manipulation check	40
III RESULTS	42
Preliminary analyses and the removal of outliers	42
Demographic characteristics	42
Background stress and physical symptoms	44
Psychological traits	44
Cognitive appraisal	44
Perceived coping ability and additional measures reflecting stress appraisals	46
State affect	47
Task-involvement, perceived effort and perceived performance	48
Actual effort and performance	49
Physiological variables	50

CHAPTER	PAGE
IV DISCUSSION	54
Summary of major findings	60
Conclusions	61
REFERENCES	66
APPENDIX: Tables and Figures	73
VITA	82

LIST OF TABLES

TABLE		PAGE
1	Experimental design.	74
2	Demographic characteristics and measures of physical symptoms, background stress and psychological traits for Threat and Challenge groups (n = 54).	74
3	Descriptive statistics for cognitive appraisal ratios, primary threat and challenge appraisals and secondary appraisals of coping ability.	75
4	Descriptive statistics for the Positive (PA) and Negative (NA) Affect subscales of the Positive and Negative Affect Schedule (PANAS).	76
5	Descriptive statistics for task-involvement, perceived effort and perceived performance for the mental arithmetic tasks.	76
6	Descriptive statistics for behavioral measures of actual effort and performance for the mental arithmetic tasks.	77
7	Descriptive statistics for absolute baseline, task and recovery levels of physiological variables.	77
8	Descriptive statistics for physiological task-reactivity (percentage change scores).	78
9	Descriptive statistics for physiological recovery from tasks (percentage change scores).	78

LIST OF FIGURES

FIGURE		PAGE
1	Mean ($\pm$ SEM) systolic blood pressure levels during rest, tasks and recovery for Threat and Challenge groups.	79
2	Mean ($\pm$ SEM) diastolic blood pressure levels during rest, tasks and recovery for Threat and Challenge groups.	79
3	Mean ($\pm$ SEM) heart rate levels during rest, tasks and recovery for Threat and Challenge groups.	80
4	Mean ($\pm$ SEM) cardiac output levels during rest, tasks and recovery for Threat and Challenge groups.	80
5	Mean ($\pm$ SEM) total peripheral resistance levels during rest, tasks and recovery for Threat and Challenge groups.	81

CHAPTER I: INTRODUCTION

Stress-induced cardiovascular reactivity has traditionally been viewed in a negative light. The primary basis for this perspective is known as the "reactivity hypothesis," i.e., the notion that individuals ("hyperreactors") who tend to exhibit exaggerated cardiovascular responses to stressful or challenging behavioral stimuli may be at increased risk for the development of hypertension and/or coronary heart disease (Pickering & Gerin, 1990; Manuck, 1994). However, within the psychophysiological literature, there is increasing evidence and sentiment suggesting that this pathological conception of reactivity may be too simplistic and that, in some instances, reactivity (or at least certain patterns of reactivity) may represent an adaptive response to situational demands which is not necessarily harmful. First and foremost, several recent reviews of the literature have concluded that reactivity cannot yet be considered an established risk factor for either hypertension or coronary heart disease (e.g., Krantz & Manuck, 1984; Manuck, 1994; Pickering & Gerin, 1990). In a recent article entitled "Why Study Blood Pressure Reactivity to Stress?", Dr. Thomas Pickering (1996), one of the leading critics of the reactivity hypothesis, goes a step further than expressing mere dissatisfaction with the existing empirical evidence. In discussing a recent study in which blood pressure reactivity to psychological and physical stressors was found to be unrelated to left ventricular mass, "a marker of the cumulative effects of blood pressure on the target organs" (p. 941), Pickering (1996) concludes that this null finding "can thus be regarded as another nail in the coffin of the reactivity hypothesis, if such be needed" (p. 942). Nevertheless, the assumption that acute, stress-induced cardiovascular responses are predictive of future illness continues to drive much of the current research in cardiovascular behavioral medicine. Further justification for an alternative, positive view of reactivity comes from a series of recent studies indicating that whether an individual evaluates or "appraises" an upcoming, potentially stressful situation as a "threat" (associated with negative emotions) or a "challenge" (associated with positive emotions), may be related to the pattern of cardiovascular responses displayed in that situation. (Tomaka, Blascovich, Kelsey, & Leitten, 1993; Tomaka, Blascovich, Kibler, & Ernst, 1997). Coupled with the frequently proposed notion that one or more hemodynamic

response patterns may have greater pathophysiological implications than others (e.g., Julius & Esler, 1975; Obrist, 1981; Blascovich & Katkin, 1993), as well as the well-documented association of negative emotions with unfavorable health outcomes (e.g., for a review, see Booth-Kewley & Friedman, 1987), these findings may have important implications for the reactivity hypothesis.

In discussing hemodynamic response patterns, we are primarily referring to stress-induced changes in the two underlying components of blood pressure, cardiac output (CO) and total peripheral resistance (TPR). Differences in responding with respect to these variables characterize the two most widely recognized reactivity patterns in the literature: (1) a beta-adrenergic (i.e., myocardial or cardiac) pattern marked by "skeletal muscle vasodilation, blood pressure increases primarily due to elevations in cardiac output, tachycardia, increased β 1-adrenergic activity, and decreased vagal tone," and (2) an alpha-adrenergic (i.e., vascular) pattern associated with "muscle vasoconstriction, blood pressure increases primarily due to elevations in total peripheral resistance, bradycardia, increased α -adrenergic activity, and increased vagal tone" (Saab & Schneiderman, 1993, pp. 66-67). There is considerable evidence not only that these patterns are differentially elicited by certain stressors/tasks, but also that there are individual differences in the propensity to respond as a "myocardial reactor" or as a "vascular reactor" (e.g., Sherwood, 1993).

With regard to stressor differences on hemodynamic response patterns, Obrist (1981) used the terms active and passive coping, to refer to tasks that provide an opportunity for active engagement of goal-directed skill or require passive endurance of a stressor (vigilance), respectively. Active coping tasks, such as aversive or appetitive reaction time tasks, mental arithmetic and video games, tend to evoke a beta-adrenergic pattern of responding apparently associated with the mobilization of the cardiovascular system to meet task demands. However, according to Obrist (1981), this mobilization of resources is in excess of metabolic requirements and these "metabolically inappropriate cardiovascular adjustments may prove to be one of the necessary conditions by which behavioral events could be involved in the etiology of pathophysiological conditions" (p. 83). Evidence of the metabolic inappropriateness of such responses comes from studies

demonstrating the “uncoupling” of heart rate (HR) or CO from oxygen consumption (VO_2) during active coping tasks relative to the linear relationship (coupling) between HR or CO and VO_2 during graded exercise (e.g., Sherwood, Allen, Obrist, & Langer, 1986; Turner, 1989). However, while there is evidence of an association between cardiovascular responses to active coping tasks and blood pressure levels 10 to 15 years later (Light, Dolan, Davis, & Sherwood, 1992), the relationship between these responses and future pathophysiology is by no means a settled matter. In contrast to active coping tasks, passive coping tasks such as classical aversive conditioning, cold pressor, mirror tracing and viewing graphic films tend to elicit an alpha-adrenergic response pattern. Consistent with Obrist’s (1981) emphasis on the role of cardiovascular responses associated with active coping in the development of essential hypertension, with the exception of the cold pressor test, which is itself problematic because it involves both psychological and physical components, the health implications of responses to passive coping stressors have traditionally received less attention.

While beta-adrenergic and alpha-adrenergic response patterns are frequently associated with active and passive coping tasks, respectively, there is evidence that some tasks elicit “purer” beta- or alpha-adrenergic response patterns than others. For example, reaction time and cold pressor usually evoke relatively pure beta- and alpha-adrenergic responses, respectively, with mental arithmetic often being associated with more of a mixed response pattern, although typically more reflective of beta-adrenergic activation (e.g., Allen, Obrist, Sherwood, & Crowell, 1987; Manuck, 1994). Furthermore, as mentioned previously, there is considerable individual variability in hemodynamic response patterns, with some persons displaying a tendency toward myocardial, vascular, or mixed reactivity patterns, or even nonreactivity, across tasks.

Regardless of whether one is speaking of individual or task differences in hemodynamic response patterns, the primary concern, for our purposes, is with the relative health implications of these patterns. Obrist’s (1981) view suggests that, in terms of predicting future illness, heightened myocardial reactivity may be the more detrimental response pattern. This notion is consistent with Julius’ theory of the pathogenesis of

essential hypertension (e.g., Julius & Esler, 1975; Julius & Cottier, 1983; Julius, 1992). Julius and his colleagues have studied individuals with borderline hypertension, a known risk factor for future development of essential hypertension. In doing so, these authors, among others, have noted that, for a significant portion of patients with borderline hypertension, CO is elevated at rest, while TPR is within a normal range (Julius & Esler, 1975). This "hyperkinetic" form of borderline hypertension is proposed to be primarily due to increased sympathetic tone, and more specifically, to neurogenic effects on the heart (Julius & Esler, 1975). According to Julius' theory, the progression from hyperkinetic borderline hypertension to the development of essential hypertension is associated with a transition in the mechanism driving the blood pressure elevation from a high CO to a high TPR, the latter being the hallmark of essential hypertension (Julius & Esler, 1975). Perhaps the best evidence for this theory is offered by a series of longitudinal studies by Lund-Johansen and colleagues (as cited in Julius, 1992) in which hyperkinetic borderline hypertensives displayed gradual decreases in CO and increases in TPR over time. Initially, these changes occurred without any increase in the mean blood pressure level, but after 15 years, there was an additional increase in TPR, while CO remained at low levels, and most subjects developed sustained hypertension. A few points pertaining to Julius' theory seem particularly noteworthy. First, the theory focuses on CO and TPR levels, and gradual changes in these levels over time, rather than stress-reactivity *per se*. In a recent meta-analysis, Fredrikson & Matthews (1990) concluded that borderline hypertensives tend to display greater systolic (SBP) and diastolic (DBP) blood pressure reactivity and greater HR reactivity than normotensive controls, particularly in response to active coping tasks; however, it is not clear what proportion of these borderline hypertensive individuals were characterized by the hyperkinetic state. While data are not provided regarding the underlying hemodynamic response patterns responsible for the blood pressure reactivity in these borderline hypertensives, the finding that these individuals were much more likely to display exaggerated reactivity to active coping stressors is suggestive of a myocardial reactivity pattern. Furthermore, there is some evidence that blood pressure reactivity in borderline hypertensives is associated with CO increases (Sherwood, Royal, & Light,

1993). The second point that should be made regarding Julius' theory is that only approximately one-third of all borderline hypertensives are characterized by the hyperkinetic state (Julius, 1992), and not all borderline hypertensives develop essential hypertension. In fact, in reviewing the borderline hypertension literature, Julius and Hansson (1983) report that while, in all studies reviewed, the prevalence of later (10-20 years) established hypertension was twice as great for individuals initially displaying borderline hypertension relative to initially normotensive individuals, the highest reported proportion of borderline hypertensives who subsequently developed established hypertension was 26 percent. Furthermore, in a study conducted by Madsen and Buch (as cited in Kaplan, Lieberman, & Neal, 1994), involving "a particularly fit, low-risk group of air cadets with borderline pressures, only 12% developed sustained hypertension over the subsequent 20 years" (p. 15). Thus, Julius' theory leaves a considerable amount of unexplained variance in the pathogenesis of essential hypertension. In addition, Lund-Johansen (as cited in Marrero, al' Absi, Pincomb, & Lovallo, 1997) has noted that most of the evidence for a high CO in hyperkinetic borderline hypertension comes from studies involving invasive methods of CO measurement, which may have served as stressors themselves, thus contaminating "resting" levels with cardiovascular responses indicative of the "fight or flight" response. Lastly, although TPR is within normal limits in hyperkinetic borderline hypertension, according to Julius and Esler (1975), "the elevated blood pressure stems from an inappropriate adjustment of the peripheral resistance to the increased tissue perfusion accompanying the increased cardiac output" (p. 689). In other words, hyperkinetic borderline hypertension is characterized not only by an elevated CO, but also by a lack of compensatory vasodilation for this high CO. This observation is consistent with recent suggestions that either vascular reactivity or myocardial reactivity without an accompanying decrease in TPR may be the most detrimental pattern(s) in terms of future health outcomes (Tomaka et al., 1993; Blascovich & Katkin, 1993; Saab & Schneiderman, 1993).

While some of the evidence of the pathophysiological implications of myocardial reactivity comes from studies of borderline hypertensives, support for the role of vascular

reactivity as a risk factor for hypertension development comes from studies involving other at-risk groups. For example, numerous studies have consistently shown that African-Americans, who are at greater risk for essential hypertension, display exaggerated vascular reactivity to a variety of stressors, relative to their White counterparts (e.g., Saab et al., 1992; Treiber et al., 1990). Furthermore, in a recent study, Marrero et al. (1997) found that a group of "high risk" males with a resting SBP ≥ 125 mmHg and a positive parental history of hypertension (i.e., one or both parents) displayed elevated blood pressure levels, associated with elevated TPR levels, across baseline, mental arithmetic, reaction time, and recovery periods, relative to their low risk counterparts (resting SBP < 125 and either none or one parent with essential hypertension). There were, however, no significant high/low risk group differences for HR, cardiac index (i.e., CO adjusted for body surface area), or stroke volume index. Additionally, there is some evidence that males are more likely to be vascular reactors while females are more likely to be myocardial reactors (Girdler, Turner, Sherwood, & Light, 1990; Allen, Stoney, Owens, & Matthews, 1993), although other findings have indicated the reverse association (Lawler, Wilcox, & Anderson, 1995). If such gender differences do exist, they may be important given that "women show lower average blood pressures and lesser prevalence of hypertension than do men until approximately age 50, when this trend reverses" (Sherwood, 1993, p. 184). According to Saab and Schneiderman (1993), findings regarding race and gender differences in hemodynamic response patterns such as those discussed above suggest "that earlier descriptions of hypertensive development that were based primarily on examination of White men" such as those consistent with Julius' theory may present an incomplete picture, and that "hypertensive risk may be related to the tendency of elevating blood pressure in challenging situations by increasing peripheral resistance" (p. 73). Consistent with this view, Blascovich and Katkin (1993) have cited evidence that myocardial reactivity peaks and habituates quickly, while vascular reactivity increases during stressful tasks (Kelsey, 1993) and that vascular responses are associated with greater perceived stress and threat (e.g., Tomaka et al., 1993), in concluding that "... high myocardial reactivity in the absence of vascular reactivity during active coping may be benign pathophysiologically,

whereas the reverse pattern may be malignant” (p. 232). With regard to the putative health implications of myocardial reactivity in the absence of a compensatory decrease in TPR, in a recent study, Lawler and Kline (1998) reported that the greatest DBP and SBP increases to mental arithmetic and anger recall tasks were displayed by “extreme mixed reactors” (characterized by large increases in either CO or TPR and no decrease in the other). In order of decreasing reactivity, these extreme mixed reactors were followed by extreme vascular reactors, extreme myocardial reactors, mild vascular reactors, mild myocardial reactors, and nonreactors, with each group displaying significantly greater SBP and DBP reactivity than the group below them. While these data are intriguing, as are all of the data regarding myocardial and vascular reactivity patterns described above, it should be noted that, as suggested by Sherwood (1993), what is truly needed to shed light on the relative pathophysiological implications of these patterns are longitudinal studies of associations between hemodynamic responses to a variety of stressors and future health outcomes. However, because these types of studies are often unfeasible, approaches such as Tomaka, Blascovich and colleagues’ (e.g., Tomaka et al., 1993, 1997) investigations of the cardiovascular correlates of threat and challenge appraisals provide a useful alternative. We will now discuss the theoretical basis for these studies.

Lazarus and Folkman’s (1984) theory of psychological stress and coping has become one of the most influential theories in psychology. According to these authors, *“Psychological stress is a particular relationship between the person and the environment that is appraised by the person as taxing or exceeding his or her resources and endangering his or her well-being”* (Lazarus & Folkman, 1984, p. 19). At the heart of the theory is the concept of cognitive appraisal, “the process of categorizing an encounter, and its various facets, with respect to its significance for well-being” (Lazarus & Folkman, 1984, p. 31). It is this appraisal process that ultimately determines whether a given encounter is experienced as stressful. Lazarus and Folkman (1984) distinguish between two major types of cognitive appraisal: *primary* and *secondary*.

Primary appraisal refers to the evaluation of “what is at stake?” for an individual in an encounter, i.e., “whether something of relevance to the person’s well being has

occurred” (Lazarus, 1991, p. 133). It should be noted that the term, primary is not meant to imply that these appraisals are more important or must occur before secondary appraisals; rather, they are called primary appraisals because they provide the “emotional heat” (Lazarus, 1991, p. 145) in a given encounter (Lazarus & Folkman, 1984; Lazarus, 1991). Having a personal stake in an encounter can include not only one’s own physical or psychological well-being (e.g., preservation of self-esteem), but also the well-being of a loved one (Lazarus, 1991). Lazarus and Folkman (1984) originally proposed three kinds of primary appraisal: *irrelevant*, *benign-positive*, and *stressful*. In broadening the scope of this theory to explain not only stress but emotions, Lazarus (1991) has since expanded this initial conceptualization to include additional primary appraisal decisions, in order to adapt the concept of appraisal to account for the experience of specific emotions. However, because we are primarily interested in the stress-related primary appraisals of threat and challenge, we will restrict our discussion to the original distinction. According to Lazarus and Folkman (1984), an encounter is appraised as irrelevant when an individual has nothing at stake. In other words, “the person has no investment in the possible outcomes . . . [and] nothing is to be lost or gained in the transaction “ (Lazarus & Folkman, 1984, p. 32). In order for stress to be experienced, an encounter must first be appraised as relevant (i.e., something must be at stake). Simply being relevant, however, is not sufficient for an encounter to be stressful. A situation may be appraised as relevant to one’s well-being, but as having an enhancing or preserving effect, in this regard. This is what is meant by a benign-positive appraisal. Finally, stressful appraisals can be of three subtypes: *harm/loss*, *threat*, or *challenge*. (Lazarus & Folkman, 1984). Harm/loss refers to the assessment of physical or psychological damage, after the fact, i.e., the evaluation of damage already done. Conversely, threat and challenge appraisals, are anticipatory in nature. When an encounter is appraised as a threat, future harms or losses are anticipated. Threat appraisals lead to the experience of negative emotions such as anxiety, fear, anger, and jealousy (Lazarus & Folkman, 1984; Lazarus, 1991). According to Lazarus & Folkman (1984), the distinguishing characteristic of threat as opposed to harm/loss, is that it “permits anticipatory coping” (Lazarus & Folkman, 1984, p. 33). Like threat appraisals, challenge

appraisals involve “mobilization of coping efforts” (Lazarus & Folkman, 1984, p. 33); however, challenge appraisals occur when a demanding situation is appraised as potentially providing an opportunity for growth or gain, resulting in positive emotions such as excitement, eagerness, exhilaration, enthusiasm, and possibly even happiness or joy (Lazarus, 1991). As one might guess, challenge and threat appraisals are “not necessarily mutually exclusive.” (Lazarus & Folkman, 1984, p. 33). There are many situations which may involve a mixture of threat and challenge, such as competing in a sporting event, taking an exam, performing in front of an audience, or accepting new job responsibilities. Furthermore, Lazarus and Folkman (1984) are quick to point out that they view threat and challenge as separate, but related constructs, and not as two opposing ends of a continuum. The relationship between threat and challenge appraisals is further complicated by Lazarus’ (1991) assertion that cognitive appraisal is a dynamic process that is constantly changing over the course of an encounter, as the person-environment interaction itself changes, and as the individual receives feedback from the environment. An appraisal that is changed “on the basis of new information from the environment . . . and/or information from the person’s own reactions [to the environment]” (Lazarus & Folkman, 1984, p. 38) is known as a *reappraisal*. With regard to threat and challenge appraisals, this means that the degree to which an encounter is appraised as threatening or challenging may shift over time, as the individual receives more and more information, particularly with regard to his or her ability to cope with the situation (i.e., secondary appraisal). The last point I wish to mention regarding threat and challenge appraisals is particularly relevant for our purposes. According to Lazarus and Folkman (1984), “challenge, as opposed to threat, has important implications for adaptation” (p. 34). In other words, people who tend to appraise demanding encounters as challenges rather than threats may experience better psychological and physical well-being. These individuals should feel “more confident, less emotionally overwhelmed, and more capable of drawing on available resources . . . Finally, it is possible that the physiological stress response to challenge is *different* [italics added] from that in threat , so that diseases of adaptation are less likely to occur” (Lazarus & Folkman, 1984, p.34). Note the use of the term different, as opposed to less than, by these authors

in describing physiological responses to challenge relative to responses to threat. This is a subtle, but critical, distinction (that may or may not have been intentional) because it suggests that, if indeed a tendency to appraise potentially stressful situations as challenges rather than threats is less likely to result in stress-related illnesses, it is not necessarily because of lower physiological reactivity associated with challenge appraisals; rather, it may be due to a different pattern of physiological reactivity, not necessarily lower in magnitude, that is pathophysiologically benign. This point is central to the contention that in certain situations, such as those appraised as a positive challenge, cardiovascular reactivity may be adaptive rather than harmful. Furthermore, findings from the cardiovascular reactivity studies of Tomaka and his associates (Tomaka et al., 1993; Tomaka et al., 1997) are supportive of such a view of reactivity.

While primary appraisals pertain to "what is at stake?" in an encounter, secondary appraisals are concerned with the following question: "what, if anything, can I do about it?". More specifically, secondary appraisals involve the evaluation of what "coping options are available, the likelihood that a given coping option will accomplish what it is supposed to, and the likelihood that one can apply a particular strategy or set of strategies effectively [perceived coping efficacy (ability)]" (Lazarus & Folkman, 1984, p. 35). Like primary appraisals, secondary appraisals can change over the course of an encounter (i.e., they are subject to reappraisal). According to Lazarus and Folkman (1984), primary and secondary appraisals interact to determine the "degree of stress and the strength and quality (or content) of the emotional reaction" (p. 35) experienced by the individual. Two examples of such an interaction given by these authors concern the relationships of the secondary appraisals of perceived control (the belief that outcomes are contingent upon one's behavior; Rotter, 1966) over a situation and perceived coping efficacy (i.e., self-efficacy--the belief that one can successfully carry out the behaviors necessary to achieve these outcomes; Bandura, 1977) to the primary appraisals of threat and challenge. According to Lazarus and Folkman (1984), when one has high perceived control in an encounter, challenge appraisals are more likely to occur, but only if, despite being perceived as controllable, the situation is still viewed as demanding. In other words, as

stated by Lazarus and Folkman (1984), "The joy of challenge is that one pits oneself against the odds" (p. 36). However, according to Folkman (1984), it may also be important that efforts to control the situation result in minimal additional distress. Folkman (1984) has also discussed the effects of secondary appraisals of perceived control on threat appraisals. She suggests that threat appraisals may be more likely in situations where the individual would prefer to be in control but does not anticipate being able to control the situation, or when attempts to control the situation create further distress. Similarly, an individual's perceived coping efficacy in a given encounter influences "the extent to which a person feels threatened [and presumably challenged] and, in the presence of incentives [i.e., stakes], influence coping behavior" (Lazarus & Folkman, 1984, p. 70). More specifically, "people fear and tend to avoid threatening situations they believe exceed their coping skills, whereas they get involved in activities and behave assuredly [and presumably feel challenged] when they judge themselves capable of handling situations that would otherwise be intimidating" (Lazarus & Folkman, 1984, p. 70). Consistent with this notion, Blascovich and Tomaka (1996) offer a slightly different definition of threat and challenge appraisal than Lazarus and Folkman (1984), emphasizing the influence of both primary and secondary appraisal. Specifically, Blascovich and Tomaka (1996) propose that threat appraisals occur when comparison of primary appraisals of perceived demand with secondary appraisals of perceived resources or ability (i.e., coping efficacy), results in the "perception of demand that cannot be overcome by perceived resources" (p. 12). Conversely, challenge appraisals result from the "perception of resources that can overcome the perceived demand" (p. 12).

While many studies have provided support for the notion that cognitive appraisal of a potential stressor can affect emotional and physiological responses to that stressor (see Lazarus, 1991, for a review), as pointed out by Tomaka et al. (1993), "these studies actually demonstrate that only manipulations of *primary appraisal of threat* alter the experience and report of stress in a predictable manner" (p. 249). Only recently, have the concepts of threat and challenge appraisal, conceptualized as involving both primary and secondary appraisal processes, been applied directly to investigations of cardiovascular

reactivity. In a series of three studies, Tomaka et al. (1993) assessed subjects' threat and challenge appraisals of an upcoming task, and then examined the relationship between these appraisals and cardiovascular responses during the task. Blascovich and Tomaka (1996) refer to these investigations as "Free Appraisal Studies" (p. 25), because subjects are free to arrive at their own perceptions of the situation, as opposed to having their appraisals experimentally manipulated. In each of the first two studies, male college students were asked to perform two very similar mental arithmetic tasks. Subjects' primary appraisals of perceived demand and secondary appraisals of perceived coping ability were assessed after they received instructions for each task, but before they actually performed the task. For the first study, primary appraisal was determined by responses to the following question: "How stressful do you expect the upcoming task to be?" (Tomaka et al., 1993, p. 250), while for the second study "threatening" was substituted for "stressful." In both studies, secondary appraisal was assessed by asking subjects the following question: "How able are you to cope with this task?" (Tomaka et al., 1993, p. 250). In addition to cognitive appraisal, in both studies, the subjective experience of stress was measured following each of the two mental arithmetic tasks, by asking subjects, "How stressful was the task you just completed?" (Tomaka et al., 1993, p. 250). Threat and challenge appraisals were defined based on the ratio of primary to secondary appraisal, with subjects being divided into post hoc threat and challenge groups formed by a median split of the distribution of primary/secondary appraisal ratios. Specifically, threat appraisal was operationalized as "high perceived threat relative to perceived coping ability" (Tomaka et al., 1993, p. 251), while challenge appraisal was defined as "low perceived threat relative to perceived coping ability" (Tomaka et al., 1993, p. 251). Thus the threat and challenge appraisal groups consisted of subjects falling above or below the median of primary to secondary appraisal ratios, respectively. The purpose of exposing subjects to essentially the same mental arithmetic task twice was to examine the effects of prior experience and reappraisal on subsequent cardiovascular and subjective stress responses.

In Tomaka et al.'s (1993) initial study, skin conductance, pulse transit time (PTT) and HR were the physiological measures, and three psychological trait measures (locus of

control, self-esteem and depression) considered by the authors to be related to cognitive appraisals, were used as covariates. For this study, as well as the other two in this series, reactivity change scores were computed for each of the physiological measures. Results of this study indicated that subjects appraising the math task as a challenge displayed significantly decreased PTT (i.e., greater reactivity), for the first task, and reported significantly less subjective stress for the second task, than those appraising the task as a threat. This pattern of a closer relationship between cognitive appraisal and the subjective experience of stress for the second task, and a closer relationship between appraisal and physiological responses for the first task is consistent with Tomaka et al.'s (1993) hypotheses. These authors' note that experience with the task should lead to decreased uncertainty regarding task demands and increased ability to evaluate one's coping abilities; thus reappraisal (i.e., appraisal of a similar second task) of the degree of threat or challenge expected should be more accurate, and hence more closely linked to self-reported stress. Conversely, based on Obrist's (1981) notion that the cardiovascular responses associated with active coping are more likely when uncertainty is high, Tomaka et al. (1993) suggest that appraisal group differences in reactivity should decrease (habituate) for the second task (following reappraisal). With regard to the subjective stress findings, however, it should be noted that, as recently pointed out by K.A. Lawler (personal communication, 1996), there is a striking similarity between the wording of the primary appraisal question and the question intended to assess the subjective experience of stress, which basically differ only in that the former is anticipatory while the latter is reflective of the task just completed. This suggests that the latter question may actually be measuring reappraisal; thus, any findings associating appraisal and subjective stress should be interpreted with caution.

While Tomaka et al.'s (1993) initial study demonstrated that challenge appraisals were associated with greater cardiovascular reactivity than threat appraisals, because PTT, as defined by Tomaka et al. (1993) as "the interval between the EKG R-wave and the rise of the finger pulse wave" (p. 250), is thought to reflect both myocardial and vascular influences (Obrist, 1981), the relative contributions of these influences are unclear. Consequently, in the second study in this series, Tomaka et al. (1993) measured and

reported changes in CO and TPR, as well as HR and preejection period (PEP), an index of myocardial performance or contractility. As with PTT, decreases in PEP (i.e., shortening) indicate greater reactivity. In addition to these cardiovascular measures, self-reports of perceived effort and performance during the two tasks were assessed, as well as actual effort (the number of verbal subtraction attempts per minute) and performance (the number of correct subtractions). The results of this study indicated that, for the first math task only, subjects appraising the task as a challenge exhibited significantly greater CO, HR, and PEP reactivity, but significantly reduced TPR relative to those appraising the task as a threat. Thus the challenge appraisal group displayed a myocardial reactivity pattern (increased CO and HR, decreased PEP, and decreased TPR), while the threat appraisal group displayed more of a vascular or mixed pattern (increased TPR, less of an increase in CO and HR, and less of a decrease in PEP than the challenge group). It should be noted here that, inexplicably, Tomaka et. al. (1993) do not report blood pressure data despite reporting TPR, the calculation of which necessitates blood pressure measurement. In fact, the authors do mention blood pressure recording in their "Method" section. This omission of blood pressure data is unfortunate, because it is important to know whether the threat and challenge groups differ in terms of blood pressure reactivity, or whether they are displaying comparable blood pressure responses that are mediated by different hemodynamic mechanisms. Evidence that the myocardial reactivity pattern associated with appraising the task as a challenge may have been adaptive comes from the behavioral and self-report data. Specifically, during the first math task, while exhibiting greater myocardial reactivity than the threat appraisal group, the challenge appraisal group also demonstrated significantly greater effort and performance, and reported less subjective stress and greater perceived performance (although self-report findings were only marginally significant). With regard to the second task, subjects appraising the task as a challenge reported experiencing significantly less stress and significantly greater performance, and displayed trends toward greater actual effort and performance than those appraising the task as a threat, but there were no group differences in cardiovascular responses.

The third study in this series differed from the first two in that both male and female subjects were used, and subjects were randomly assigned to participate in either: (1) two mental arithmetic (active coping) tasks, as in the earlier studies, or (2) two passive coping tasks, involving the viewing of graphic photographs of accident and crime victims and medical patients undergoing surgery. Unlike active coping tasks, according to Tomaka et al. (1993), passive coping tasks “may inhibit challenge [appraisal] (other than any challenge associated with merely enduring the task) as a relevant consideration because passive stressors, by definition, preclude coping through direct task-relevant action” (p. 249); thus, for these types of stressors, “non-task-related coping strategies such as denial, rationalization, and distraction may be more functional” (p. 249). In other words, in passive coping situations, the perception of resources that can overcome task demands (i.e., challenge), does not seem likely. In fact, according to Tomaka et al. (1993), secondary appraisal of coping resources should be irrelevant in these situations. With this in mind, it was predicted that only primary appraisal of threat would be important in terms of predicting physiological and psychological responses to passive coping tasks. Thus, for the passive coping tasks, in addition to calculating primary/secondary appraisal ratios, Tomaka et al. (1993) computed ratios of high/low primary appraisal using only responses to the question, “How *threatening* do you expect the upcoming task to be?” (p. 252), for the purpose of forming high and low primary threat appraisal groups. The physiological measures for the third study included CO, TPR, HR, PEP and skin conductance responses. In addition, the subjective experience of stress, perceived effort and perceived performance were again assessed (but not actual effort or performance). Results for the mental arithmetic tasks were nearly identical to the results of the second study. Once again, for the first task only, subjects appraising the task as a challenge displayed significantly greater myocardial reactivity (increased CO and HR, decreased PEP) and significantly reduced TPR, relative to the threat appraisal group. Furthermore, for both of the math tasks, the threat appraisal group reported significantly greater subjective stress than the challenge appraisal group. Finally, during the second math task only, the threat group reported significantly lower perceived performance but higher perceived effort than the

challenge group, the latter finding being unexpected. For the passive coping tasks, preliminary analyses using threat and challenge appraisal groups revealed no group differences in physiological measures; thus the same analyses were performed using the high/low primary threat appraisal group classification. Results of these analyses indicated that, particularly for the first minute of the first passive coping task, the high primary threat appraisal group exhibited significantly greater CO and PEP reactivity (i.e., decreased PEP) than the low threat group, and that while HR did not change for the high threat group, it declined significantly for the low threat group. Thus, in contrast with the mental arithmetic results described earlier, we have evidence of myocardial reactivity associated with threat appraisals (primary only) of a passive coping task. The decline in HR for the low threat appraisal group was interpreted by Tomaka et al. (1993) as indicative of the parasympathetic-mediated reduction in HR characteristic of "sensory intake" tasks (e.g., Lacey, Kagan, Lacey, & Moss, 1963), while the lack of such a decline for the high threat group was interpreted as resulting from greater inhibition of the parasympathetic influence on HR in this group. Furthermore, there was also a marginally significant finding of greater skin conductance responses for the high threat group (across all minutes of the first task). There was no significant group difference for TPR reactivity. With regard to the self-report data, relative to the low threat group, the high threat group reported marginally greater subjective stress and significantly lower perceived performance, for the first task, and significantly more stress and perceived effort, for the second task.

In summary, the "free appraisal" studies conducted by Tomaka and his colleagues demonstrate that, for an active coping task involving motivated performance, appraising the situation as a challenge rather than a threat is associated with greater cardiovascular reactivity, and more specifically, with a myocardial pattern of response. Furthermore, as stated by Tomaka et al. (1993), "That individuals evidencing the greatest cardiac reactions and the greatest decline in vascular resistance . . . were also the least stressed has practical value for the future study of cardiovascular reactivity . . . as a predictor of disease outcomes" (p. 259). This may be a bit of an overstatement, however, in light of the problems with the stress measure discussed earlier, as well as the fact that, for all three

studies, in only two instances (one of which involved marginally significant findings for stress), were lower stress ratings and greater myocardial reactivity/reduced TPR simultaneously associated with challenge appraisals. With regard to the subjective stress measure, perhaps a state affect scale would have provided more information about the extent to which the hemodynamic patterns associated with threat and challenge appraisals reflected “good” or “bad” reactivity. Consistent with this point, Tomaka et al. (1993) suggest “that researchers interested in stress reactivity should pay closer attention to the affective responses evidenced by subjects in their experiments” (p. 259). Nevertheless, the association of myocardial reactivity and decreased vascular resistance with high perceived resources relative to perceived threat or demand (i.e., challenge appraisal), greater task-related effort and performance (study 2), and, to some extent, lower perceived stress and higher perceived performance, provides at least indirect evidence for the adaptiveness of this hemodynamic response profile. Tomaka et al. (1993) suggest that this pattern of responding may allow “for the efficient and speedy distribution of metabolic resources throughout the body” (p. 259). Conversely, the association of increased vascular resistance and moderate myocardial reactivity with high perceived threat relative to perceived resources (i.e., threat appraisal), less effort and poorer performance, and, to some extent, greater perceived stress and lower perceived performance, suggests that this pattern of cardiovascular responding may be maladaptive.

While the findings for the active coping tasks are more relevant to the present discussion, because they provide clearer opportunities for either threat or challenge appraisals, the findings for the passive tasks, utilized in the third study, deserve mention. The association of greater myocardial reactivity with high relative to low primary appraisal of threat clouds the picture of the putative adaptiveness of this reactivity pattern somewhat. While many interpretations are possible, in light of the active coping findings, the fact that there were no group differences in TPR response between the high and low threat groups for the passive task, again suggests that myocardial reactivity may be adaptive only when accompanied by a compensatory decrease in vascular resistance. While data regarding the direction of the TPR responses of the high and low threat groups are not provided, it is

likely that both groups showed increases or at least no decreases, given the tendency for viewing graphic films (e.g., Obrist, 1976) to evoke more of a vascular response (as with all passive coping tasks). Assuming this to be the case, the critical difference between the high and low threat groups may be that the high threat group is increasing CO against this (presumably) elevated resistance.

While the "free appraisal" studies described above are valuable contributions to the reactivity literature, by allowing subjects to "self-select into appraisal groups" (Tomaka et al., 1993, p. 258), such studies preclude inferences about causality with regard to the effects of cognitive appraisal on subsequent physiological and psychological responses, as acknowledged by Tomaka and his colleagues. In a recent study, Tomaka et al. (1997; "Study 1") addressed this issue by experimentally manipulating subjects' threat and challenge appraisals of an upcoming mental arithmetic task, using two different instructional sets. Specifically, 70 subjects (gender not reported) were randomly assigned to listen to audiotaped instructions designed to induce either threat or challenge appraisal of the task. According to Tomaka et al. (1997), the challenge appraisal instructions "encouraged participants to 'think of the task as a challenge' and to 'think of yourself as someone capable of meeting that challenge'" (p. 65). On the other hand, threat appraisal instructions "emphasized the importance of completing the task 'as quickly and accurately as possible' and that responses would be 'scored for speed and accuracy'" (p. 65). Primary and secondary appraisal were assessed with single item measures very similar to those used in the studies described previously, and cognitive appraisal ratios were again computed, this time as a manipulation check for the effectiveness of the threat and challenge manipulations. Dependent variables included PEP, HR, CO and TPR change scores, as well as task performance (actual, rather than perceived) measures. Analyses of the effects of instructional set on appraisal ratios confirmed that the threat group reported significantly greater perceived threat relative to coping ability (i.e., greater threat appraisal) than the challenge group. Results for the physiological measures were generally consistent with those of the free appraisal studies described earlier. Specifically, while the overall multivariate effect (i.e., from a one-way MANOVA) was only marginally significant,

univariate ANOVAs performed on each physiological measure indicated that subjects receiving the challenge appraisal instructions displayed significantly greater CO and PEP reactivity, moderately greater HR reactivity and significantly reduced TPR relative to those receiving threat instructions. The threat group, once again, displayed increased TPR, accompanied by moderate increases in HR and CO and moderate decreases in PEP. Thus, once again we have evidence of high myocardial reactivity and decreased vascular resistance associated with challenge appraisals, and high vascular resistance and moderate myocardial reactivity associated with threat appraisals. It should be noted, however, that follow-up step-down analyses indicated that only the PEP effect was significant. This finding was interpreted by Tomaka et al. (1997) as "suggesting that a single-dimension, most likely SNS, beta-adrenergic activation underlies the physiological effects" (p. 66). With regard to the performance data, there were no significant differences between the two appraisal groups. The explanation offered by Tomaka et al. (1997) for this null finding is that the example of someone performing serial subtractions that was presented to subjects in the threat condition was inadvertently set at a faster pace than the example for the challenge group. I would add that the content of the instructions presented to the threat condition emphasized speed in addition to accuracy, whereas those presented to the challenge condition did not. Therefore, any tendency for the challenge group to exhibit better performance may have been negated by subjects in the threat group performing at a faster pace. Furthermore, it seems noteworthy that the instructions for Tomaka et al.'s (1997) threat condition are quite similar to the instructions we routinely present to subjects in our laboratory, when we are not necessarily interested in making the mental arithmetic task threatening. In my view, instructing people to work quickly and accurately does not preclude, and may even induce, challenge appraisals. Furthermore, the threat appraisal instructions do not seem to be consistent with Tomaka and colleagues' (1993, 1997) definition of threat appraisals as high primary appraisal of threat relative to secondary appraisal of perceived coping ability. More specifically, to the extent that primary appraisal of threat is conceptualized as evaluating a situation as potentially leading to harm or loss, as proposed by Lazarus and Folkman (1984), Tomaka et al.'s (1997) manipulation does not

seem to reflect this construct, because there is no mention of potential harm or loss. Furthermore, Tomaka et al.'s (1997) threat manipulation also involves no attempt to deflate one's perceived coping ability. Conversely, while the challenge manipulation also fails to explicitly mention opportunity for gain or growth (e.g., Lazarus & Folkman, 1984), this possibility is at least alluded to with statements like, "... We want you to really try hard to do your best ..." and "Try to think of the task as a challenge to be met and overcome" (Tomaka et al., 1997, p. 72). In addition, secondary appraisal of perceived coping efficacy is explicitly encouraged by the following statement: "... Think of yourself as someone capable of meeting that challenge" (p. 72). Thus it seems that primary, and especially secondary, appraisal may have been differentially manipulated for the challenge and threat conditions. This point may be particularly relevant given the relatively weak between-groups differences observed for the physiological data. Nevertheless, despite the criticisms outlined above, the appraisal ratio data from Tomaka et al.'s (1997) study certainly support their manipulation.

The assertion that the pattern of high myocardial reactivity and reduced vascular resistance associated with challenge appraisals is adaptive receives support from Dienstbier's (1989) theory of physiological toughness, which provides a theoretical framework for positive views of arousal. Dienstbier (1989) reviewed "literatures whose basis is an assumption of the harmfulness of peripheral physiological arousal and those whose basis is not" (p. 84), emphasizing sympathetic-adrenomedullary arousal and pituitary-adrenocortical arousal, rather than cardiovascular reactivity, *per se*. In doing so, Dienstbier (1989) concludes that "... the typical arousal pattern for an emotionally stable and competent individual" (p. 88) is one in which sympathetic-adrenomedullary and pituitary-adrenocortical base rates are low, but in a potentially stressful situation, "... SNS-adrenal-medullary arousal onset is fast and strong, whereas cortisol remains relatively low; arousal decline is fast with stressor offset; and across repeated similar episodes, arousal levels for both kinds of peripheral arousal decline more quickly [especially for cortisol] ... than in less fit controls" (p. 88). Furthermore, when faced with continuous stress, "fit" individuals maintain sympathetic-adrenomedullary arousal longer, and both the

depletion of catecholamines and large increases in cortisol are delayed. The arousal pattern described above is the prototypical response profile of the "toughened" individual and, according to Dienstbier (1989), is associated with enhanced performance, positive (stable) temperament and stress tolerance. Dienstbier (1989) is quick to point out that this pattern of responding may not be "... uniformly experienced as pleasant . . ." (p. 87), but when these responses are "... elicited in the context of potential control, for which effective instrumental coping responses are likely to lead to success [e.g., when the situation is appraised as a challenge], then positive emotional attributions and responses are likely" (p. 87). While Dienstbier does not make explicit predictions regarding cardiovascular reactivity in describing his model, he does include beta-adrenergic receptor sensitivity as one of the major physiological mediators of the toughness response pattern. This suggests that there may be adaptive value in displaying a beta-adrenergic (myocardial) hemodynamic response pattern characterized by low base rates, sharp increases at the onset of a stressful/challenging situation, rapid recovery following stressor offset, and habituation with repeated encounters with the stressor. The importance of low baseline cardiovascular levels and recovery following stressful episodes is alluded to by Dienstbier (1989), in a rare reference to the reactivity literature, when he points out that, "Reviewers of studies of monkeys . . . and of humans . . . have agreed that health risks follow heightened arousal over long time periods (months or years)" (p. 95). Moreover, he adds that, although researchers often find greater reactivity to a variety of stimuli in Type A individuals, recovery data is rarely even mentioned. According to Dienstbier (1989), this may be particularly important given evidence that "Type As seem to have slower SNS-adrenal-medullary recovery" (p. 95). Thus, Dienstbier's model suggests that the extent to which the hemodynamic response pattern typically associated with challenge appraisals is adaptive may also depend on how quickly responses return to baseline levels, as well as the magnitude of these baseline levels.

In this section I have reviewed literature which I believe provides compelling theoretical and empirical support for the view that, in certain situations (i.e., those appraised as a challenge rather than a threat), some pattern or patterns of cardiovascular

reactivity may be adaptive, and thus not necessarily predictive of poor health. I will now describe my own study designed to address further this issue.

The present study is a partial replication and extension of the work of Tomaka and colleagues (1993; 1997) described earlier in this paper. Similar to the Tomaka et al. (1997; Study 1) study, the present investigation involved the experimental manipulation of subjects' threat and challenge appraisals of a mental arithmetic task. However, our study differs from, and improves upon, earlier studies in a number of ways. One major difference is that our threat/challenge manipulation is more firmly grounded in theory and more clearly addresses both primary and secondary appraisal than that used by Tomaka et al. (1997). Specifically, as discussed previously, Lazarus and Folkman (1984) define primary appraisal of challenge and threat in terms of the anticipation of potential growth or gain and harm or loss, respectively. This definition of challenge versus threat is conceptually similar to the long-recognized "approach-avoidance" distinction in motivation theory. Given that mental arithmetic is a motivated performance or achievement situation, what better place to turn for insight into how to manipulate primary threat or challenge appraisals of this type of task than to the achievement motivation literature? A recent study in this area, by Elliot and Harackiewicz (1996; "Experiment 1"), may be instructive. These authors note that the majority of contemporary achievement goal theorists posit two classes of achievement-related goals: performance goals and mastery goals. Elliot and Harackiewicz (1996), however, argue for the readoption of an earlier achievement goal model distinguishing between two classes of performance goals, and thus consisting of a total of three types of goals (and hence three goal orientations): *mastery*, *performance-approach*, and *performance-avoidance*. It is the performance-approach versus performance-avoidance distinction which is of primary interest here, because of its conceptual similarity to challenge versus threat appraisal, in that the two goal orientations differ only in that the former is "directed toward the demonstration of competence [i.e., growth or gain]" (p. 462), while the latter is "aimed at avoiding the demonstration of incompetence [i.e., harm or loss]" (p. 462). According to Elliot and Harackiewicz (1996), the performance-approach (and mastery) goal orientation is associated with "a host of

affective and perceptual-cognitive processes that facilitate optimal task engagement (e.g., *challenge construal* [italics added], sensitivity to success-relevant information, cognitive and affective immersion in the activity . . .)” (p. 462), as well as “. . . persistence in the face of failure . . . and enhanced task enjoyment” (p. 462). A performance-avoidance orientation, on the other hand, “evokes self-protective processes that interfere with or preclude optimal task engagement (e.g., *threat construal* [italics added], sensitivity to failure-relevant information, anxiety-based preoccupation with self-presentational rather than task concerns)” (p. 462), as well as “. . . effort withdrawal in the face of failure, attribution of failure to lack of ability, and decreased task enjoyment” (p. 462). Based on this theorization, Elliot and Harackiewicz (1996) developed instructional sets aimed at inducing mastery, performance-approach and performance-avoidance goal orientations in subjects with respect to a puzzle solving task. It is interesting to note that in their study, performance-approach subjects were significantly more likely to appraise the task as a positive challenge and reported greater task engagement than performance-avoidance subjects. The instructional sets for primary appraisal of challenge and threat which were utilized in the present study were adapted from Elliot and Harackiewicz’s (1996; Experiment 1) performance-approach and performance-avoidance instructions, respectively. In addition to this primary appraisal manipulation, in keeping with Tomaka et al.’s (1993) conceptualization of overall threat and challenge appraisal resulting from ratios of primary appraisal of threat relative to secondary appraisal of perceived coping ability, subjects self-efficacy for performing the mental arithmetic task was manipulated via false feedback regarding their performance on a pretest.

Relative to past investigations, additional unique features of the present study include the following: (1) examination of the effects of positive (for Challenge subjects) and negative (for Threat subjects) performance feedback presented before the second half of the task on subsequent changes in cardiovascular response patterns; (2) reporting of blood pressure data in addition to data regarding its underlying hemodynamic components; (3) assessment of cognitive appraisal using a more reliable multi-item scale in addition to single item measures; (4) assessment of cardiovascular recovery data; and (5) measurement

of positive and negative affect, as well as task-involvement.

Hypotheses

For the first of two experimental blocks, higher self-reported ratios of primary appraisal of threat relative to secondary appraisal of perceived coping ability were expected for the threat appraisal group relative to the challenge group. Additionally, the challenge group was expected to report greater primary appraisal of challenge (from a challenge subscale) and less primary appraisal of threat (threat subscale) than the threat group. With regard to the physiological data, the challenge group was expected to display greater myocardial reactivity (HR, CO) and a decline in TPR, relative to the threat group. In contrast, the threat group should show increased TPR and moderate myocardial reactivity. For the blood pressure data, we made no a priori predictions regarding group differences. One might expect greater DBP reactivity for the threat group, given that DBP largely reflects vascular influences. On the other hand, in a recent study in which subjects' self-efficacy for performing a computer game was manipulated, Gerin, Litt, Deich, & Pickering (1996) reported greater SBP and DBP reactivity for subjects with high relative to low self-efficacy. This increased reactivity for subjects high in self-efficacy was interpreted as indicative of greater effort. Thus, based on these findings, in the present study, the challenge group might be expected to display greater SBP and DBP reactivity than the threat group. With regard to the recovery data, following the first task, we expected the threat group to display delayed recovery, relative to the challenge group, for some or all of the cardiovascular responses which increased during the task period. For the state affect data, relative to threat subjects, challenge subjects were expected to report higher levels of positive affect and lower levels of negative affect during the tasks. Furthermore, the challenge group was expected to report greater task-involvement, and to show greater performance and effort (actual and perceived) than the threat group. The second block of the experiment was largely exploratory. While Tomaka et al. (1993) predicted and demonstrated the absence of free appraisal group differences in physiological responses with repeated exposure to a highly similar task, Tomaka et al. (1997) did not include a second task in their study of the effects of experimentally manipulated threat and challenge

appraisals. We predicted that this habituation effect would not be as pronounced in the present study because of the powerful nature of our threat/challenge manipulation, and in particular, the perceived coping efficacy manipulation (i.e., performance feedback). Thus, we expected threat/challenge group differences in cognitive appraisals, as well as hemodynamic and emotional responses and physiological recovery, as described above, to persist during the second block of the experiment. Furthermore, we also expected findings similar to the first block with regard to task-involvement, performance and effort data.

CHAPTER II: METHOD

Subjects

The participants in this study were 65 male undergraduate students at the University of Tennessee. Subjects were given the opportunity to participate in order to earn extra credit in undergraduate psychology courses. Of the original 65 subjects, four were excluded from data analysis on the basis of equipment malfunction and one due to borderline hypertension, based on both self-report and an average resting SBP > 140 mmHg. The remaining 60 subjects ranged in age from 18 to 28, with a mean of 20.3 (SD = 2.15) years.

Apparatus

Blood pressure was measured with a DINAMAP 1846 SX/P Vital Signs Monitor (Critikon, Inc., Tampa, FL). This noninvasive device is controlled by a microprocessor and automatically measures systolic blood pressure (SBP), diastolic blood pressure (DBP), mean arterial pressure (MAP) and pulse rate using the oscillometric technique. The monitor is equipped with a thermal matrix printer that outputs time of day, in addition to blood pressure and pulse rate.

A BoMed NCCOM-3 Cardiovascular Monitor (Medex, Inc., Hilliard, OH) was used to collect impedance data. Evidence of the validity of this device comes from significant positive correlations obtained between its readings and simultaneously-determined measurements of cardiac output using thermodilution and the Fick method (Braden, Leatherbury, Treiber, & Strong, 1990). The NCCOM-3 records impedance data via eight spot electrodes placed on the subject's neck and sides; six parameters of cardiovascular performance are displayed (averaged over 12 heart beats): thoracic fluid index, ventricular ejection time, ejection velocity index, stroke volume, HR, and CO. Of primary interest are HR and CO, which is automatically computed by the NCCOM-3 ($CO = HR * \text{stroke volume}$). Due to a problem with the NCCOM-3-computer interface normally used to transfer raw impedance data to the computer's hard drive, impedance data were recorded by hand as they appeared on the NCCOM-3 display.

Self-report measures

Demographic information

Each subject was asked to complete a demographic information sheet. This sheet included questions regarding the subject's age, medications, prior illnesses, personal blood pressure history, smoking history and extent of caffeine and alcohol consumption. This questionnaire also contained spaces for height and weight that were filled in by an experimenter.

Family health history

Subjects' family history of hypertension and cardiovascular disease were assessed via a family health history questionnaire.

Background stress

The extent to which the participants experienced their lives as stressful over the last month was assessed via the Perceived Stress Scale (PSS; Cohen, Kamarck, & Mermelstein, 1983). According to Cohen et al. (1983), this measure was "designed to tap the degree to which respondents found their lives unpredictable, uncontrollable, and overloading" (p. 387). For two college student samples (n 's = 332 and 114) and one sample of participants in a smoking-cessation program (n = 64), coefficient alphas were .84, .85 and .86, respectively. The test-retest reliability for a sample of 82 college students, over a two day period, was .85, while the test-retest reliability for 64 smoking-cessation program participants, over a six week interval, was .55. Furthermore, the PSS has been shown to correlate significantly with self-ratings of the impact of stressful life events (r s ranging from .24 to .49), physical symptomatology (r s ranging from .52 to .70), use of health services (r = .20, for one sample) and social anxiety (r s = .37 and .48, for two samples), for various samples (Cohen et al., 1983).

Physical symptoms

The frequency and severity of physical symptoms experienced by the subject during the previous month was measured using the Cohen-Hoberman Inventory of Physical Symptoms (CHIPS; Cohen & Hoberman, 1983). The internal reliability (Cronbach's alpha) of this measure was .88, for a sample of 70 college students. In two college student

samples (n 's = 331 and 114), the CHIPS was found to be significantly correlated (r 's = .22 and .29) with the use of health facilities.

Primary and secondary appraisal

The effectiveness of our experimental manipulation of threat and challenge appraisals (primary) and secondary appraisals of perceived coping efficacy, was evaluated using both the Stress Appraisal Measure (SAM: Peacock & Wong, 1990) and adaptations of the Threat (How threatening do you expect the 1st (last) 4 minutes of the mental arithmetic task to be?) and Coping Ability (How able are you to cope with the 1st (last) 4 minutes of the mental arithmetic task?) items used by Tomaka and his colleagues (1997). The instructions for the SAM were also worded so that the potentially stressful event being appraised was either the first 4 minutes or the last 4 minutes of the mental arithmetic task. In a recent review of methods for stress appraisal measurement, Monroe and Kelley (1995) concluded the following: "With regard to measures of stressor-specific appraisals, there is a need to move beyond single-item ad hoc measures that vary from study to study. The SAM . . . may be a promising development in this regard, but it requires more extensive research." (p. 142). The SAM consists of subscales that assess three primary appraisal dimensions (Threat, Challenge, Centrality), three secondary appraisal dimensions (Controllable-by-self, Controllable-by-others, Uncontrollable-by-anyone) and overall perceived Stressfulness, for a specific anticipated event. Of particular interest are the Threat and Challenge subscales, the Controllable-by-self scale which seems to provide the best index of perceived coping ability, and the Centrality subscale which assesses the extent to which an event is perceived to be important or relevant for the individual's well-being (Peacock & Wong, 1990). While the scale's authors acknowledge that, "There is the need for further psychometric data, especially those obtained in differing contexts and with a broader range of respondents." (Peacock & Wong, 1990, p. 235), preliminary findings from several studies with college student samples indicate that the scale possesses good psychometric properties. The internal consistencies (alphas) for each of the seven SAM scales, obtained from three studies with undergraduate samples (n 's = 100, 151, and 144, respectively), ranged from: .65 - .75 for Threat, .66 - .79 for Challenge, .84 - .90 for

Centrality, .84 - .87 for Controllable-by-self, .84 - .85 for Controllable-by-others, .51 - .82 for Uncontrollable-by-anyone, and .75 - .81 for overall Stressfulness. Furthermore, the six appraisal subscales were only moderately intercorrelated (mean $r = .22$), suggesting that each scale assesses a relatively independent dimension of appraisal (Peacock & Wong, 1990). The authors point out that "examination of test-retest reliability [for the SAM] is not appropriate because appraisals are expected to change over time [i.e., reappraisal]" (p. 235). Evidence of the validity of the SAM was obtained from these same three studies, with various appraisal dimensions (especially Threat and Centrality) being associated with overall stressfulness and psychological symptoms.

State affect

State affect was assessed using the Positive and Negative Affect Schedule (PANAS; Watson, Clark, & Tellegen, 1988) with instructions adapted for use in the present experiment. The PANAS is one of the most popular and well-established state affect measures (Stone, 1995). This instrument has strong psychometric qualities, with coefficient alphas ranging from .86 - .90 for the Positive Affect (PA) scale and from .84 - .87 for the Negative Affect (NA) scale, for samples consisting of university students and employees (with n 's ranging from 586 to 1,002), depending on the type of "time instructions" used (e.g., moment, today, past few weeks) (Watson et al., 1988). Also, consistently low intercorrelations (ranging from $r = -.12$ to $-.23$) between the PA and NA scales obtained with the same samples provide evidence of the relative independence of the two scales. Test-retest reliabilities for a sample of 101 undergraduates over an 8-week time period ranged from .47 to .68 for the PA scale and from .39 to .71 for the NA scale, again varying somewhat as a function of time instructions (Watson et al., 1988). Evidence of the validity of the PA and NA scales comes from correlations, in the expected direction, between these scales and measures of depression, state anxiety, and psychological/physical symptoms (Watson et al., 1988).

Task-involvement

The extent to which subjects were engaged/involved in the mental arithmetic tasks was measured via subjects' responses to the following items (adapted from Elliot &

Harackiewicz, 1996), each beginning with the stem, “While performing the 1st (last) 4 minutes of the mental arithmetic task, I . . .”: “was totally absorbed in the task,” “lost track of time,” “concentrated on coming up with the correct answer for each subtraction,” “had trouble focusing my attention on the task,” “felt self-conscious,” and “thought about things unrelated to the task or the experiment.” (p. 465, 469). As suggested by Elliot & Harackiewicz (1996), subjects were asked to respond to these items using a 7-point scale, ranging from 1= strongly disagree to 7 = strongly agree, and scores on the items were summed to yield a total task-involvement score.

Perceived effort

Subjects’ perceived effort expenditure was assessed via their responses (on a 7-point scale ranging from 1 = strongly disagree to 7 = strongly agree) to the following item (adapted from Elliot & Harackiewicz, 1996): “I put a lot of effort into performing the 1st (last) 4 minutes of the mental arithmetic task.”

Perceived Performance

Participants were asked to rate their performance on the first (last) 4 minutes of the mental arithmetic task (“How do you think you did on the 1st (last) 4 minutes of the mental arithmetic task?”) on a scale from 1 to 7, where 1 = very poorly and 7 = very well (adapted from Elliot & Harackiewicz, 1996). Not only did this item enable us to examine group differences in perceived performance, but, more specifically, it provided a manipulation check for the effectiveness of performance feedback.

Relevant psychological traits

As suggested by Tomaka et al. (1993), the following trait measures, which appear to be related to cognitive appraisals, were included in the present study: locus of control (I-E Scale: LOC; Rotter, 1966), self-esteem (Self-Esteem Scale: SE; Rosenberg, 1965) and depression (Beck Depression Inventory: BDI; Beck, 1967). In addition, another psychological trait measure which seems to be conceptually related to threat and challenge appraisals, dispositional optimism (Revised Life Orientation Test: LOT-R; Scheier, Carver, & Bridges, 1994), was also included. Each of these measures is well-established. Rotter’s (1966) LOC scale has an internal consistency (Cronbach’s alpha) of .73, and the

test-retest reliabilities after one month were .72 and .78, respectively, for two separate studies. This scale has been shown to correlate ($r_s = .55 - .60$) with the James-Phares Likert-type scale, an earlier measure of internal-external control, and was found to be significantly related to a projective test of tendency to view punishment for moral transgression as resulting from internal versus external causes (as cited in Rotter, 1966). A median correlation of $-.22$ between the LOC (high scores indicating an external locus of control) and social desirability has been reported for samples of college students. Rosenberg's (1965) SE scale has a reproducibility coefficient of .92 and a scalability coefficient of .72. Rosenberg (1965) devotes almost a whole chapter of his book to evidence for the construct and criterion validity of his scale, including a significant ($p < .05$) inverse relationship between the SE scale and a Guttman scale of depressive affect. As for the BDI, the mean coefficient alpha (internal consistency) within 15 nonpsychiatric samples was .81 (Beck, Steer, & Garbin, 1988), and the test-retest reliabilities, in six studies using nonpsychiatric subjects, ranged from .60 to .83 (Beck et al., 1988). For three studies reporting correlations between the BDI and clinical ratings of depression in nonpsychiatric samples, the mean correlation was $r = .60$ (Beck et al., 1988). Furthermore, the BDI has also been reported to be positively correlated with suicidal behaviors, alcohol consumption, maladjustment, and anxiety (see Beck et al., 1988 for review). Finally, the LOT-R had an internal consistency (Cronbach's alpha) of .78 for a sample of 2,055 undergraduates, and over periods of 4 months ($n = 96$), 12 months ($n = 96$), 24 months ($n = 52$), and 28 months ($n = 21$), the test-retest correlations for this scale were .68, .60, .56 and .79, respectively (Scheier et al., 1994). Evidence of the convergent and discriminant validity of the LOT-R comes from correlations, in the expected direction, with Rosenberg's SE scale ($r = .50$), a self-mastery scale ($r = .48$), a measure of anxiety ($r = -.53$) and two measures of neuroticism ($r_s = -.43$ and $-.36$).

Behavioral measures

Effort

In addition to perceived effort, subjects' actual effort was examined by recording

(by hand and via audiotape) the number of verbal responses (i.e., subtraction attempts) to the first 4 minutes and the last 4 minutes of the math task and operationalizing effort as the number of subtraction attempts per minute, as well as the total number of subtraction attempts (from Tomaka et al., 1993; 1997).

Performance

Similarly, in addition to self-reports of perceived performance, subjects' actual performance for the first 4 minutes and the last 4 minutes of the math task was evaluated by determining the: (1) total number of correct subtractions, (2) number of correct subtractions per minute and (3) percentage of correct subtractions ((total correct / total attempts) * 100%) (from Tomaka et al., 1993; 1997).

Experimental design

Subjects were randomly assigned to one of two conditions: (1) Challenge (primary challenge appraisal/high coping efficacy manipulation), or (2) Threat (primary threat appraisal/low coping efficacy manipulation). Each of these two groups consisted of 30 subjects. It should be noted that the experimental manipulations of cognitive appraisal described above did not permit us to determine the independent effects of primary appraisals of threat/challenge and secondary appraisals of perceived coping efficacy. However, in the present study, our goal was to maximize the extent to which subjects appraised the task at hand as a positive challenge or as a negative threat, and to examine the emotional and physiological consequences of these very different ways of perceiving the same event. We believed that it was necessary to stimulate high coping efficacy for Challenge subjects and low coping efficacy for Threat subjects, in order to accomplish this goal. Furthermore, this manipulation is consistent with Tomaka et al.'s (1993; 1997) conceptualization of threat and challenge in terms of primary/secondary appraisal ratios.

The experimental stress period (i.e., the mental arithmetic task) was divided into two treatment blocks, each 4 minutes in duration, separated by a 5-minute recovery period. The complete experimental protocol consisted of the following: 1 min. mental arithmetic practice test, 10 min. baseline, 4 min. mental arithmetic, 5 min. recovery, 4 min. mental

arithmetic, and 5 min. recovery. The overall design of the experiment is depicted in Table 1¹.

Procedure

Each student was tested individually at the Health Psychology Laboratory, which consists of one large room surrounded by five smaller testing rooms or offices. All subjects were tested by a male experimenter. Upon arriving at the laboratory, subjects were greeted and asked to be seated at a large table in order to read and sign an informed consent form, and to complete the demographic information sheet. Due to time constraints in scheduling subjects, the family health history sheet, the CHIPS and PSS, and all psychological trait measures, were completed either before, after, or before and after, the physiological recording session. For the recording session, the subject was escorted by an experimenter into a smaller testing room containing a reclining chair, a lap-top desk, a small table equipped with two tape recorders (A and B: for communicating instructions to the subject and for recording subjects' verbal responses to the mental arithmetic task, respectively), calibrated scales, and a two-way intercom system used to provide instructions to participants and to monitor their well-being throughout the experiment. The experimenter first asked the subject to sit in the reclining chair and then explained that the subject would receive instructions over both an audiotape (A) and an intercom, and that, during the course of the experiment, he may be asked to start or stop the tape or to communicate with the experimenter by pressing and holding the "Talk" button on the intercom. The experimenter asked the subject to listen to the instructions on the tape and then, after starting the tape (A), the experimenter left the room. All subjects then heard the following general instructions over the audiotape (adapted from Elliot & Harackiewicz, 1996; see also Wright & Dill, 1993; Wright & Dismukes, 1995):

Our research group studies problem solving, and the focus of today's session is on mental arithmetic problems. The purpose of this project is to compare college students to one another in their ability to perform our 8-minute mental arithmetic task. So that you are familiar with what the task is like, we would like you first to perform a 1-minute practice task.

¹ All tables and figures are included in the Appendix.

At this point, the information presented to the subject on the audiotape differed slightly according to group. Subjects in the Challenge condition heard the following practice test instructions:

These are the instructions for the 1-minute mental arithmetic practice task. This task involves performing rapid serial subtractions by steps of 4. Your task is to count backwards, aloud, by 4s from a starting number that we give to you. For example, if we asked you to count backwards from 1000 by 4s, you would reply "996, 992, 988, 984, 980, etc." Please respond as quickly and accurately as possible. If you make a mistake on a particular subtraction, the experimenter will ask you to try again, until you respond with the correct answer. AT THIS TIME, PLEASE PRESS THE "STOP" BUTTON ON TAPE RECORDER "A".

The practice test instructions for the Threat group were as follows:

These are the instructions for the 1-minute mental arithmetic practice task. This task involves performing rapid serial subtractions by steps of 17. Your task is to count backwards, aloud, by 17s from a starting number that we give to you. For example, if we asked you to count backwards from 1000 by 17s, you would reply "983, 966, 949, 932, 915, etc." Please respond as quickly and accurately as possible. If you make a mistake on a particular subtraction, the experimenter will ask you to try again, until you respond with the correct answer. AT THIS TIME, PLEASE PRESS THE "STOP" BUTTON ON TAPE RECORDER "A".

The purpose of changing the subtraction number from 4 to 17 was to increase the difficulty of the practice test for the Threat group, and as a result, to increase the plausibility of subsequent negative performance feedback, thus, hopefully, decreasing perceived coping efficacy for the task. Conversely, the hope was that the relatively less difficult practice test for the Challenge condition would make positive performance feedback more believable for these subjects and increase their perceived coping efficacy. A subtraction number of intermediate difficulty (7) was used for the 8-minute task. While different practice task difficulties for the two groups could have conceivably led to differential physiological activation, in our view, the short duration of the task, in conjunction with the length of time and considerable distraction associated with the equipment application that followed, made it doubtful that any differences that occurred would be present by the end of the 10-minute baseline period. Because the difficulty level of the practice test administered to the subject varied as a function of condition, it was not possible for the experimenter to be blind to the subject's group assignment. Thus, in an attempt to minimize the possibility of an experimenter expectancy bias, through instructions presented on the audiotape and

feedback given over the intercom, every effort was made to limit the amount of interaction between the subject and the primary experimenter.

Following the practice test instructions, the experimenter entered the room, and asked the subject, "Do you have any questions?". After answering any questions that the subject may have had, the experimenter instructed the subject to "Please count backwards by 4s(17s) from 1,250." During the practice test, if the subject made an error, the experimenter responded by saying, "Incorrect. Please try again. _____ minus 4 (17).".

After one minute, the experimenter asked the subject to stop subtracting, measured and recorded his height and weight, and then prepared him for recording of the impedance-derived physiological measures by placing surface electrodes on the individual's neck and sides, following skin preparation with alcohol. Then the subject was asked to sit in the reclining chair, after which he was fitted with an automated blood pressure cuff on his upper, nondominant arm. The blood pressure and cardiovascular impedance monitors were located in an adjacent equipment room.

After equipment application and an initial test reading of cardiovascular measures, a lap-top desk was placed across the subject's lap. A pencil and a stack of five large envelopes labeled Envelope # 1, 2, 3, 4, and 5, respectively, were placed on the lap-top desk. The participant was asked to rest alone for 10 minutes, while baseline physiological measurements were obtained, and then to listen to instructions presented to him via intercom and audiotape. The experimenter then left the room.

When 10 minutes had passed, the following standardized instructions were given to the subject, by the experimenter, over the intercom (for similar instructions, see Wright & Dill, 1993):

O.K., at this time, I'd like you to open Envelope 1, fill out the questionnaire you'll find inside, and then, when you're finished, put the questionnaire back in the envelope and then press the "Play" button on tape recorder "A". The instructions on the tape will tell you when to stop it again.

For this particular administration, the questionnaire consisted only of the PANAS, with written instructions to "Indicate to what extent you feel this way right now, that is, at the present moment.".

Upon completing the PANAS, subjects in the Challenge condition heard the following instructions over the tape (adapted from Elliot & Harackiewicz, 1996; also influenced by Wiebe, 1991, and Wright & Dill, 1993):

Before you hear the instructions for the 8-minute mental arithmetic task, it may be helpful to know that, in our previous work, we have found that most UT students are fairly comparable in their ability to perform this task, but some students stand out because they do quite well on the task. Performing well on this type of task may be related to future financial success. This session will give you the opportunity to demonstrate that you have good mental arithmetic ability. If you solve correctly 72 or more problems over the entire 8-minute mental arithmetic task or, in other words, 9 or more correct solutions per minute, your name will be entered into a drawing. Three names will be drawn, and a 25-dollar monetary prize will awarded to each of the three people.

Conversely, subjects in the Threat condition heard these instructions (see Elliot & Harackiewicz, 1996; Wiebe, 1991; Wright & Dill, 1993):

Before you hear the instructions for the 8-minute mental arithmetic task, it may be helpful to know that, in our previous work, we have found that most UT students are fairly comparable in their ability to perform this task, but some students stand out because they do quite poorly on the task. Performing poorly on this type of task may be related to future financial failure. This session will give you the opportunity to demonstrate that you do not have poor mental arithmetic ability. If you solve correctly less than 72 problems over the entire 8-minute mental arithmetic task or, in other words, less than 9 correct solutions per minute, this level of performance may be indicative of a need for remedial mathematical help.

While Elliot & Harackiewicz (1996) reported findings consistent with the manipulation of threat and challenge appraisals by simply emphasizing performing well or avoiding performing poorly with their instructional sets, in our view, this manipulation alone would not be powerful enough to induce changes in physiology. Thus, to our instructional sets, we added the use of a monetary performance incentive for the Challenge group, in an attempt to induce subjects to view the task as a positive challenge providing an opportunity for gain. Similarly, for the Threat group, we added the incentive to avoid demonstrating a need for remedial help, to induce subjects to view the task as potentially leading to harm or loss (e.g., of self-esteem). In reality, while Challenge subjects solving 72 or more problems correctly will, in fact, be entered into a drawing and prizes will be awarded, performing below this criterion is not necessarily indicative of a need for remedial help. The same performance criterion was used for both groups in order to minimize the

differences between the two instructional sets. Pilot testing indicated that the chosen level of performance was a challenging, yet still quite achievable, goal. Furthermore, we believed that defining the criterion in terms of combined performance for the first 4 minutes and the last 4 minutes of the task would make it very difficult for subjects to know if they had already surpassed this criterion.

Following the Threat or Challenge appraisal instructions, all subjects heard these general instructions for the first 4-minutes of the math task, via audiotape:

These are the instructions for the 8-minute mental arithmetic task. The task will be broken down into two 4-minute time blocks, separated by a 5-minute rest period and a brief questionnaire response period. For the first 4 minutes, the task involves performing rapid serial subtractions by steps of 7. Your task is to count backwards, aloud, by 7s from a starting number that we give to you. For example, if we asked you to count backwards from 1000 by 7s, you would reply "993, 986, 979, 972, 965, etc." Please respond as quickly and accurately as possible. If you make a mistake on a particular subtraction, the experimenter will ask you to try again, until you respond with the correct answer. AT THIS TIME, PLEASE PRESS THE "STOP" BUTTON ON TAPE RECORDER "A".

After stopping the tape, subjects in the Challenge condition received the following performance feedback (for similar feedback instructions, see Wright & Dill, 1993; Wright & Dismukes, 1995) from the experimenter, over the intercom:

OK. In a few minutes we will begin the 8-minute mental arithmetic task, and based on your performance on the practice test, you should do great! You scored in upper 87th percentile of all subjects.

Conversely, subjects in the Threat group were told the following (see Wright & Dill, 1993; Wright & Dismukes, 1995):

OK. In a few minutes we will begin the 8-minute mental arithmetic task, and--um--based on your performance on the practice test, you may have your work cut out for you. You scored in the lower 12th percentile of all subjects.

We decided to communicate the practice test feedback and subsequent Block 2 feedback over the intercom, rather than include it on the audiotape, in order to make the feedback appear plausible and not scripted, because this information was supposedly unique to the individual.

At this point, the subject was asked via intercom to remove a questionnaire from Envelope 2, complete it, return it to the envelope, as described previously, and then to let

the experimenter know when he was finished, using the intercom. This particular questionnaire consisted of the SAM and the Tomaka et al. (1997) Threat and Coping Ability items, with instructions worded with respect to the first 4 minutes of the math task.

Upon completion of the questionnaire by the subject, the experimenter reentered the room and asked the subject if he had any questions regarding the mental arithmetic task. The experimenter then pressed "Record" on tape recorder "B" and then instructed the subject to "Please count backwards by 7s from 2,737." (this starting number was used by Tomaka et al., 1993). Each participant's assigned subject number was prerecorded on tape B prior to the experiment, so that it could be matched with the subject's verbal responses. During the task, if the subject made a mistake, the experimenter responded with the same scripted statements as in the practice test.

As mentioned earlier, the first block of the mental arithmetic task lasted 4 minutes. After 4 minutes, the subject was asked to stop subtracting and the tape (B) which had been recording his verbal responses was stopped. The experimenter then asked the subject to rest for 5 minutes and left the room. Following the rest period, the subject was asked, over the intercom, to remove the questionnaire from Envelope 3, complete it, return it to the envelope and then start tape "A." The questionnaire in Envelope 3 consisted of the PANAS, as well as the task-involvement and perceived effort and performance items. For this administration of the PANAS, subjects received written instructions to "Indicate to what extent you felt this way during the first 4 minutes of the mental arithmetic task". The task-involvement, effort and performance items were also phrased with respect to the first 4 minutes of the task. We realize that in asking subjects to report their feelings during the math task following the 5-minute rest period, there was the possibility of a self-report memory bias, but this risk seemed minimal given the short duration of the rest period and is one that we were willing to take because of our desire to include an immediate, uninterrupted recovery period following the stressor. Following completion of these self-report measures, all subjects listened to the following general instructions for the last 4 minutes of the mental arithmetic task:

For the last 4 minutes of the mental arithmetic task, your task is, once again, to count backwards, aloud, by 7s, this time from a new starting number that we give

to you. Please remember to respond as quickly and accurately as possible. Once again, if you make a mistake on a particular subtraction, the experimenter will ask you to try again, until you respond with the correct answer. Your score will be based on your combined performance during the first 4 minutes and the last 4 minutes of this task. AT THIS TIME, PLEASE PRESS THE "STOP" BUTTON ON TAPE RECORDER "A."

After stopping the tape, subjects in the Challenge condition received the following Block 2 Challenge/Positive Feedback: (stated by the experimenter over the intercom):

Before you begin the second part of the task, I just wanted to let you know--so far you're doing great! Try to do even better, so that you can get a high score.

Conversely, Threat subjects were exposed to the following Block 2 Threat/Negative Feedback manipulation:

Before you begin the second part of the task, I just wanted to let you know--um--so far I'm afraid you're not doing very well. Try to do better so that you don't get a low score.

Following the Block 2 manipulation, all subjects were asked via intercom to open Envelope 4, complete the questionnaire inside, return the questionnaire to the envelope, and then let the experimenter know when they were finished. The questionnaire in Envelope 4 consisted of the SAM and the Tomaka et al. (1997) items, with instructions phrased with respect to the last 4 minutes of the math task. Following completion of these items by the subject, the experimenter reentered the testing room, asked the subject if he had any questions, pressed "Record" on tape recorder B, and then asked the subject to begin counting backwards by 7s from 2,758 (from Tomaka et al., 1993).

After 4 minutes, the experimenter again stopped the tape (B) that had been recording the subject's responses, asked him to rest alone for 5 minutes, and then left the room. Following the recovery period, the subject was, once again, asked over the intercom to remove a questionnaire from Envelope 5, complete it, return it to the envelope and then let the experimenter know when he had finished. The questionnaire in this final envelope consisted of the PANAS, with instructions to "Indicate to what extent you felt this way during the last 4 minutes of the mental arithmetic task," as well as the task-involvement, effort and performance items.

After the subject completed these last self-report measures, all physiological

equipment was removed and he was thoroughly debriefed. He then received a receipt indicating the amount of extra credit he had earned for his participation.

Data quantification

Blood pressure readings were taken initially, and during minutes 3, 5, 7, and 9 of the baseline period. During both 4-minute portions of the mental arithmetic task, blood pressure readings were taken at 30 seconds into the task, and then at 1-minute intervals for the remainder of the task (i.e., 3 additional readings.) Finally, for both 5-minute recovery periods, blood pressure readings were taken at 30 seconds into the rest period, and then again at 2 1/2 minutes and 4 1/2 minutes.

Heart rate and CO were recorded continuously throughout the experiment. Also, CO and MAP, obtained from comparable blood pressure readings, were used to calculate TPR using the following formula: $TPR = (MAP/CO) * 80$, in units of $\text{dyne} \cdot \text{sec}/\text{cm}^5$.

In addition to obtaining mean absolute levels of SBP, DBP, CO, HR and TPR during the task and rest periods, we also tested our specific hypotheses regarding CO, HR and TPR task-reactivity, using change scores. More specifically, given the controversy surrounding the measurement of absolute values of the impedance-derived measures, CO and TPR, and suggestions that measures of relative change may be more reliable (e.g., Sherwood, 1993), CO and TPR, as well as HR, were analyzed as percentage change scores, using the following formula: $[(\text{mean task level} - \text{mean baseline level}) / \text{mean baseline level}] * 100\%$. Furthermore, physiological recovery from the tasks was also examined with percent change scores, which were computed using a formula similar to that used for reactivity: $[(\text{mean recovery level} - \text{mean baseline level}) / \text{mean baseline level}] * 100\%$. Because there were no specific hypotheses pertaining to recovery for any particular variable(s), all physiological variables were included in recovery analyses.

Manipulation check

As stated previously, the effectiveness of our experimental manipulation of primary threat and challenge appraisals and secondary appraisals of perceived coping efficacy was evaluated using the SAM, as well as the Tomaka et al. (1997) Threat and Coping Ability

items. Specifically, in an effort to remain consistent with the work of Tomaka et al. (1993; 1997), we operationalized subjects' cognitive appraisal as the ratio of primary appraisal of perceived threat to secondary appraisal of perceived coping efficacy. In terms of the SAM, subjects' scores on the Threat subscale were considered representative of their perceived threat, while, as mentioned earlier, we viewed the Controllable-by-self scale as a good index of perceived coping ability. Subjects' scores on the Challenge subscale were also used to assess (primary) challenge appraisal. For example, with regard to the first 4 minutes of mental arithmetic, subjects in the Challenge group would be expected to report lower perceived threat relative to perceived coping ability and higher perceived challenge than subjects in the original Threat condition. Cognitive appraisal ratios were also computed using the Tomaka et al. (1997) items (ratio of response to the Threat item to response to the Coping Ability item).

CHAPTER III: RESULTS

Preliminary analyses and the removal of outliers

For the original sample of 60 subjects, preliminary analyses indicated that there was a significant group difference [$t(58) = -2.37, p = .02$] between Threat and Challenge subjects on body mass index (BMI: kg/m^2), with Challenge subjects, on the average, having greater BMI. In part because of this difference, the two groups differed in baseline levels of physiological variables. A one-way multivariate analysis of variance (MANOVA), with Group (Threat vs. Challenge) as the between-subjects factor and baseline levels of SBP, DBP, HR, CO and TPR as the dependent variables, yielded a significant multivariate effect for Group (Wilks's lambda = .82), $F(5, 54) = 2.40, p = .05$. Separate follow-up one-way analyses of variance (ANOVAs) for each physiological variable, with Group as the between-subjects factor, revealed marginally significant univariate main effects of Group for TPR, $F(1, 58) = 3.81, p = .06$, SBP, $F(1, 58) = 2.77, p = .10$ and CO, $F(1, 58) = 2.60, p = .11$. There was also a nonsignificant trend toward a Group effect for DBP, $F(1, 58) = 2.36, p = .13$. For HR, the effect of Group was not significant, $F(1, 58) = .81, p = .37$. Inspection of means indicated that, to varying degrees, the Challenge group displayed higher baseline levels of TPR, SBP and DBP, while the Threat group displayed higher resting levels of CO. In order to determine whether outliers contributed to any of the unexpected baseline differences described above, boxplots were examined for BMI and baseline levels of each physiological variable. Three subjects from each group were identified as outliers on one or more of these measures. With these six subjects excluded, analyses of BMI [$t(52) = -1.50, p = .14$] and baseline cardiovascular variables indicated that there were no longer any significant group differences (see later section of this paper entitled, *Physiological variables: Response levels during baseline, tasks and recovery periods*). Thus, all data analyses that follow were performed on this reduced sample of $n = 54$ subjects (27 Threat, 27 Challenge).

Demographic characteristics

Demographic data pertaining to BMI and self-reported age, race, family history of

hypertension and cardiovascular disease, medication use and smoking status, for Threat and Challenge groups, are presented in Table 2 ($n = 54$). Independent t -tests indicated that the Threat and Challenge groups did not differ in age ($t(52) = -1.45, p = .15$) or BMI ($t(52) = -1.50, p = .14$). For race, there was an equivalent number of Caucasian subjects in the Threat and Challenge conditions ($n = 25$) and the remaining two subjects in the Challenge group were African American, while the other two Threat subjects were African American and Asian, respectively. Subjects were considered to have a positive family history of hypertension and/or cardiovascular disease (FH+) if they reported at least one parent having one or more of the following: high blood pressure, heart attack, hardening of the arteries, coronary artery disease and/or stroke. All subjects reporting none of these health problems for both parents were considered to have a negative family history (FH-). Eight subjects reported being unsure about the health status of one or both parents; hence, these subjects were excluded from all analyses involving family history. There were thirteen FH+ and ten FH- subjects in the Threat condition, while the Challenge group consisted of fifteen FH+ and eight FH- subjects. A Chi-square analysis indicated that the number of FH+ or FH- subjects did not differ between Threat/Challenge groups [Chi-square (1) = .37, $p = .55$]. Because parental history of hypertension is a risk factor for the subsequent development of hypertension in offspring, FH+ and FH- Threat and Challenge subjects were compared on resting levels of SBP and DBP, via 2 x 2 ANOVAs, with Group (Threat vs. Challenge) and FH (+ vs. -) as between-subjects factors. There was no significant Group x FH interaction for SBP, $F(1, 42) = .11, p = .73$ or DBP, $F(1, 42) = .18, p = .68$, indicating that FH did not differentially effect resting blood pressure for the Threat and Challenge groups. The Group and FH main effects also failed to reach significance for SBP and DBP, all F s < 2.5, p s > .12. As can be seen in Table 2, three subjects in each of the Threat and Challenge conditions reported being on some form of medication. Baseline cardiovascular values for these subjects were carefully examined, and appeared to be within normal range and consistent with the rest of the sample. Twenty-one subjects in the Threat condition and twenty-five in the Challenge group reported being nonsmokers. Fisher's exact test showed no group differences in the numbers of smokers

or nonsmokers ($p = .25$).

Background stress and physical symptoms

Between-groups comparisons were also made on subjects' PSS and CHIPS scores using independent t-tests (Table 2). Threat and Challenge subjects did not differ in their self-reports of perceived stress ($t(52) = -.81, p = .42$) or physical symptoms ($t(52) = -.59, p = .56$).

Psychological traits

To investigate possible group differences in psychological traits related to cognitive appraisals, independent t-tests were performed (Table 2). There were no significant differences between Threat and Challenge groups on depression [$t(52) = .78, p = .44$], locus of control [$t(52) = 1.60, p = .12$], or optimism [$t(52) = -1.37, p = .18$] measures. However, there was a marginally significant difference for SE [$t(52), p = .08$], with subjects in the Challenge condition tending to report higher self-esteem than subjects in the Threat condition.

Cognitive appraisal

The effectiveness of the experimental manipulation of threat and challenge appraisals was evaluated using a variety of self-report measures. Table 3 gives group means and standard deviations for SAM- and Tomaka et al. (1997)-derived cognitive appraisal ratios, as well as for the SAM Threat subscale (primary threat appraisal), Tomaka et al.'s (1997) Threat item (primary threat appraisal), and the SAM Challenge subscale (primary challenge appraisal). Inspection of these means suggests that the Threat group reported greater primary appraisal of threat relative to secondary appraisal of coping ability (i.e., greater ratios) on both cognitive appraisal ratio measures for both mental arithmetic tasks, relative to the Challenge group. Furthermore, the Threat group also reported greater levels of primary threat appraisal and lower levels of primary challenge appraisal across both tasks. To test the significance of these observed differences, a doubly multivariate repeated measures MANOVA was performed, with Group (Threat vs. Challenge) as the

between-subjects factor and with both appraisal ratio measures, the SAM Challenge subscale and both the SAM Threat subscale and Tomaka et al.'s (1997) Threat item, as the dependent variables. This analysis, and all repeated measures analyses reported in this paper, reflect conservative tests (Greenhouse & Geisser, 1959).

The MANOVA revealed a significant multivariate effect for Threat/Challenge Group [(Wilks's lambda = .82), $F(5, 48) = 2.05$, $p = .04$ (one-tailed)], as well as a marginally significant effect for Task [(Wilks's lambda = .80), $F(5, 48) = 2.34$, $p = .06$]. Follow-up repeated measures ANOVAs indicated that both cognitive appraisal ratio measures contributed to the multivariate Group effect with $F(1, 52) = 3.54$, $p = .03$ (one-tailed), for SAM-derived ratios and $F(1, 52) = 2.92$, $p = .05$ (one-tailed), for Tomaka et al. (1997)-derived ratios. Additional repeated measures ANOVAs revealed a significant Group effect for the SAM Threat subscale [$F(1, 52) = 2.92$, $p = .05$ (one-tailed)], and a marginally significant Group effect for the SAM Challenge subscale [$F(1, 52) = 2.64$, $p = .06$ (one-tailed)]. The Group effect for Tomaka et al.'s (1997) Threat item failed to reach significance [$F(1, 52) = .89$, $p = .18$ (one-tailed)]. As for the multivariate Task effect, the follow-up ANOVAs revealed only a marginally significant Task effect [$F(1, 52) = 3.44$, $p = .07$] for cognitive appraisal ratios based on the Tomaka et al. (1997) items. As can be seen in Table 3, subjects in both the Threat and Challenge conditions tended to report higher appraisal ratios for the first math task relative to the second task.

To summarize, as expected from Table 3, the Threat group reported significantly higher ratios of primary threat appraisal to secondary appraisal of coping ability than the Challenge group, for both ratio measures, across both math tasks. Furthermore, relative to Challenge subjects, Threat subjects also reported significantly greater levels of primary threat appraisal for the SAM Threat subscale, but not for Tomaka et al.'s (1997) Threat item. Also consistent with our expectations, the Challenge group reported greater levels of primary challenge appraisal than the Threat group, although this finding was only marginally significant. Lastly, there was a marginally significant trend toward higher Tomaka et al. (1997)-derived ratios of perceived threat to perceived coping ability for the first task, relative to the second task, regardless of group assignment, suggesting decreased

overall threat appraisals of the task with repeated exposure.

With regard to cognitive appraisal ratios, it is important to note that, for both ratio measures, group means of ratios were all less than 1, indicating that, while the amount of perceived threat relative to coping ability was greater for the Threat group, even these subjects did not report demand in excess of resources, although the mean of Math 1 Tomaka et al. (1997)-derived ratios did approach 1 for the Threat group ($\underline{M} = 0.91$, $\underline{SD} = 0.63$). Comparing Math 1 means obtained in the present study for the Tomaka et al. (1997) measure with those obtained by Tomaka et al. (1997) themselves, our mean ratios of threat to coping ability were lower for both the Threat group ($\underline{M} = 0.91$, $\underline{SD} = 0.63$ vs. $\underline{M} = 1.47$, $\underline{SD} = 1.30$) and the Challenge group ($\underline{M} = 0.68$, $\underline{SD} = 0.36$ vs. $\underline{M} = 0.95$, $\underline{SD} = 0.42$). This would seem to suggest that Tomaka et al.'s (1997) threat manipulation may have been more effective in inducing greater appraisals of threat relative to coping ability, while our Challenge manipulation may have been more effective in inducing lower appraisals of threat relative to coping ability. However, it should be noted that, while Tomaka and his colleagues were able to induce primary threat appraisals that, on the average, were in excess of perceived coping ability, the standard deviation for these ratios was considerably higher than that obtained in the present study, indicating greater variability in responses.

Perceived coping ability and additional measures reflecting stress appraisals

Although only relevant to our investigation of threat and challenge appraisals as a component of cognitive appraisal ratio, perceived coping ability was also analyzed separately, because mental arithmetic performance feedback was expected to enhance or decrease self-efficacy for Challenge and Threat subjects, respectively. A repeated measures MANOVA was performed, with Group (Threat vs. Challenge) as the between-subjects factor, and with scores for the SAM Controllable-by-self subscale and Tomaka et al.'s (1997) Coping Ability item as dependent variables. This analysis revealed a marginally significant multivariate effect of Group (Wilks's lambda = .94), $F(2, 51) = 1.68$, $p = .10$ (one-tailed). Follow-up repeated measures ANOVAs indicated that there was a significant Group effect for the Tomaka et al. (1997) Coping Ability item, $F(1, 52) = 3.31$, $p = .04$

(one-tailed), and a nonsignificant trend toward a Group effect for the SAM Controllable-by-self subscale, $F(1, 52) = 1.49, p = .11$ (one-tailed). As shown in Table 3, both effects were in the expected direction of greater perceived coping ability for the Challenge group than for the Threat group.

All of the remaining SAM subscales (Centrality, Controllable-by-others, Uncontrollable-by-anyone, overall Stressfulness) were analyzed for potential group differences using a repeated measures MANOVA with Group (Threat vs. Challenge) as the between-subjects factor. The multivariate effect of Group was not significant (Wilks's $\lambda = .87$), $F(4, 49) = 1.81, p = .14$. Separate repeated measures ANOVAs for each subscale revealed only a marginally significant main effect of Group for Controllable-by-others, $F(1, 52), p = .06$. Inexplicably, relative to Challenge subjects, Threat subjects tended to report more help available from others in coping with the mental arithmetic stressors.

State affect

In Table 4, the means and standard deviations for baseline and task levels of positive and negative state affect (PA and NA subscales of the PANAS) are presented, by Threat/Challenge group. Looking at the means, Challenge subjects reported higher levels of PA than Threat subjects at baseline and across both math tasks. In contrast, relative to the Threat group, the Challenge group reported slightly higher NA levels at baseline but lower NA during the two tasks. As with the appraisal data, a repeated measures MANOVA was used to analyze these data with Threat/Challenge Group as the between-subjects factor and with baseline and task levels of PA and NA as the dependent variables.

The MANOVA indicated that the multivariate effects for Group (Wilks's $\lambda = .93$), $F(2, 51) = 1.81, p = .18$, and Group $\times$ Time Period (i.e., baseline, first task, second task) (Wilks's $\lambda = .90$), $F(4, 49) = 1.35, p = .27$, were not significant. There was, however, a significant multivariate main effect for Time Period (Wilks's $\lambda = .70$), $F(4, 49) = 5.20, p = .001$. Separate follow-up repeated measures ANOVAs for PA and NA yielded a significant Time Period effect for NA, $F(1, 78) = 10.07, p = .001$, but not for PA, $F(2, 86) = .18, p = .80$. Within-subjects contrasts indicated that, regardless of group

assignment, NA levels were significantly higher during the first math task than at baseline or during the second task, $F_s(1, 53) = 14.03$ and 17.47 , respectively, $p_s < .001$ (Table 4). Negative affect levels for the second task did not differ significantly from baseline levels, $F(1, 53) = 2.25$, $p = .14$. As suggested by the results of the multivariate analysis, the univariate effects of Group were not significant for PA or NA, $F_s(1, 52) = 2.19$ and $.39$, $p_s = .15$ and $.39$, respectively. Similarly, the Group $\times$ Time Period effects also failed to reach significance: for PA, $F(2, 86) = 3.26$, $p = .19$; and for NA, $F(1, 78) = 1.81$, $p = .18$. Thus, there were no significant differences between Threat and Challenge subjects in levels of positive or negative emotions at baseline or during either mental arithmetic task, but both groups showed a significant increase in NA from baseline to the first task, followed by a decrease from the first task to the second task.

Task-involvement, perceived effort and perceived performance

Self-reports of involvement in each of the two mental arithmetic tasks, as well as perceived effort and performance were expected to be higher for the Challenge group than the Threat group. As shown in Table 5, group means for each of these variables followed the expected pattern. These differences were verified by a repeated measures MANOVA with Group as the between-subjects factor, and with task-involvement, perceived effort and perceived performance as the dependent variables, as well as by separate follow-up repeated measures ANOVAs for each variable.

The MANOVA yielded a significant multivariate effect for Group (Wilks's lambda = .87), $F(3, 50) = 2.42$, $p = .04$ (one-tailed), as well as a significant effect for Task (Wilks's lambda = .72), $F(3, 50) = 6.38$, $p = .001$. Follow-up ANOVAs indicated that all three variables contributed to the multivariate Group effect: for task-involvement, $F(1, 52) = 3.54$, $p = .03$ (one-tailed); for perceived effort, $F(1, 52) = 3.64$, $p = .03$ (one-tailed); and for perceived performance, $F(1, 52) = 5.76$, $p = .01$ (one-tailed). Thus, as expected from Table 5, subjects in the Challenge condition reported significantly greater task-involvement, perceived effort and perceived performance than those in the Threat condition. In addition, there were also significant main effects of Task for both task-involvement, $F(1, 52) = 16.68$, $p < .001$ and perceived performance, $F(1, 52) = 5.41$, p

= .02. As can be seen in Table 5, subjects reported greater task-involvement and perceived performance for the second mental arithmetic task than for the first task, regardless of Threat/Challenge group assignment.

Actual effort and performance

In addition to self-reports of perceived effort and performance, two behavioral indices of effort (number of attempts, number of attempts per minute) and three measures of performance (number of correct subtractions, number of correct subtractions per minute, percentage of correct subtractions) for each of the two math tasks were also examined for potential group differences. As illustrated in Table 6, the Challenge group exhibited greater total numbers of subtraction attempts and correct subtractions, and more attempts per minute and correct subtractions per minute, but not a greater percentage of correct subtractions than Threat subjects, across both math tasks. These data were analyzed via a repeated measures MANOVA with Threat/Challenge Group as the between-subjects factor and with effort and performance measures as dependent variables.

The results of the MANOVA indicated that the multivariate effect for Group approached significance, (Wilks's lambda = .92), $F(3, 50) = 1.47$, $p = .12$ (one-tailed), and there was also a significant effect for Task, $F(3, 50) = 29.06$, $p < .001$. Follow-up repeated measures ANOVAs yielded marginally significant Group effects for number of subtraction attempts and number of attempts per minute, $F_s(1, 52) = 1.93$, $p_s = .09$ (one-tailed), as well as, number of correct subtractions and number of correct subtractions per minute, $F_s(1, 52) = 1.67$, $p_s = .10$ (one-tailed). As expected from the data in Table 6, there was no group difference in percentage of correct subtractions [$F(1, 52) = 0.01$, $p = .46$ (one-tailed)]. Finally, there were main effects of Task for all effort and performance variables: for number of attempts and number of attempts per minute, $F_s(1, 52) = 67.25$, $p_s < .001$; for number correct and number correct per minute, $F_s(1, 52) = 59.31$, $p_s < .001$; and for percent correct, $F(1, 52) = 11.83$, $p = .001$. As can be seen from Table 6, for all measures, there was a significant increase in effort and performance from the first task to the second task.

Physiological variables

Response levels during baseline, tasks and recovery periods

In Table 7 and Figures 1- 5, the means and standard deviations (or standard errors) for SBP, DBP, HR, CO and TPR levels at rest (Baseline) and during both mental arithmetic tasks (Math 1 and 2) and both recovery periods (Recovery 1 and 2), are presented for Threat and Challenge groups. In examining these data, it is immediately evident that both tasks elevated SBP, DBP, HR and CO relative to baseline and recovery levels. For TPR, on the other hand, task levels generally appear to be comparable to or below baseline levels and at or above recovery levels. With regard to group differences, it appears that the Challenge group had higher levels of SBP, DBP and TPR than the Threat group at baseline, and that these differences were maintained across both math tasks and both recovery periods. On the other hand, Threat subjects had higher CO and HR than Challenge subjects at baseline and during Math 1, and they maintained levels at least as high as Challenge subjects throughout the remainder of the protocol. A repeated measures MANOVA performed on absolute levels of SBP, DBP, HR, CO and TPR, with Threat/Challenge Group as the between-subjects factor, revealed a significant multivariate main effect for Time Period (i.e., Baseline, Math 1, Recovery 1, Math 2, Recovery 2) (Wilks's lambda = .08), $F(20, 33) = 19.97$, $p < .001$, and a marginally significant Group x Time Period interaction (Wilks's lambda = .49), $F(20, 33) = 1.70$, $p = .09$. Because preliminary analyses indicated that BMI was significantly correlated with SBP levels at baseline and across both tasks and recovery periods (all $ps < .002$), SBP was analyzed using a repeated measures analysis of covariance (ANCOVA), with BMI as the covariate. This analysis indicated that the effect of Time Period was not significant for SBP [$F(2, 94) = 1.33$, $p = .27$], with BMI covaried. Separate follow-up repeated measures ANOVAs for DBP, HR, CO and TPR indicated that each of these variables contributed to the aforementioned multivariate Time Period effect: for DBP, $F(3, 133) = 188.66$, $p < .001$; for HR, $F(1, 71) = 133.08$, $p < .001$; for CO, $F(2, 107) = 74.45$, $p < .001$; and for TPR, $F(2, 129) = 3.75$, $p = .02$. Within-subjects contrasts revealed that both math tasks significantly elevated DBP, HR and CO relative to baseline and pre- and post-task recovery

levels (all p s < .001). For TPR, on the other hand, levels for Math 1 and Math 2 did not differ from Baseline values (p s > .13), and Math 1 levels did not differ from Recovery 1 levels (p = .21). However, TPR levels were significantly higher during the second math task than during the recovery periods immediately before (p = .02) and after (p = .04) the task. For DBP, HR, and CO, Recovery 1 and 2 values were significantly higher than baseline levels, while for TPR, recovery levels were lower than those displayed at baseline (all p s < .06).

In following up the multivariate Group x Time Period effect, the repeated measures ANOVAs resulted in no significant univariate Group x Time Period interactions: for SBP (with BMI covaried), $F(2, 94) = .20$, $p = .80$; for DBP, $F(3, 133) = 1.13$, $p = .34$; for HR, $F(1, 71) = .48$, $p = .55$; for CO, $F(2, 107) = 1.45$, $p = .24$; and for TPR, $F(2, 129) = .59$, $p = .59$. As expected based on the results of the multivariate analysis, the effect of Group was not significant for SBP (BMI covaried), $F(1, 51) = .09$, $p = .77$, DBP, $F(1, 52) = 1.93$, $p = .17$, HR, $F(1, 52) = .47$, $p = .50$, CO, $F(1, 52) = .43$, $p = .51$, or TPR, $F(1, 52) = 1.62$, $p = .21$. Thus, despite the aforementioned trends (Table 7; Figures 1 - 5), Threat and Challenge groups did not differ in baseline, task or recovery levels of any physiological variable.

Reactivity to tasks

In Table 8, means and standard deviations for HR, CO and TPR percentage change (from baseline) scores, are presented for Threat and Challenge groups. At first glance, the data suggest that the Challenge group displayed tendencies toward greater HR increases than the Threat group for both math tasks and greater CO increases for the second task. In contrast, for TPR, the Threat group showed almost no change for Math 1 and a slight increase for Math 2, while the Challenge group exhibited a slight decrease for Math 1 and virtually no change for Math 2. These data were analyzed using a repeated measures multivariate analysis of covariance (MANCOVA) performed on HR, CO, and TPR percent change scores², with Group (Threat vs. Challenge) as the between-subjects factor, and with baseline levels of HR, CO, and TPR as the covariates. This analysis yielded no

² These data were also analyzed using raw (delta) change scores. The results of these analyses were nearly identical to those presented here.

significant effects for Group [(Wilks's lambda = .99), $F(3, 47) = .10$, $p = .48$ (one-tailed)] or Task [(Wilks's lambda = .92), $F(3, 47) = 1.44$, $p = .24$]. There was, however, a marginally significant multivariate Group x Task interaction (Wilks's lambda = .86), $F(3, 47) = 2.54$, $p = .07$. Separate follow-up repeated measures ANCOVAs performed on percent change scores for each physiological variable, with Group as the between subjects factor and with baseline level as the covariate, yielded significant Group x Task interactions for both HR [$F(1, 51) = 5.42$, $p = .02$] and CO [$F(1, 51) = 5.72$, $p = .02$], but not for TPR [$F(1, 51) = 1.35$, $p = .25$]. In order to determine whether the Threat and Challenge groups differed in HR or CO reactivity to one task, but not to the other, separate (alpha-controlled) one-way ANCOVAs for Math 1 and Math 2 were performed on HR and CO percent change scores, with Group as the between-subjects factor and with baseline level as the covariate. These analyses revealed no significant Group main effects for either task (all p s > .27). To examine the possibility that either the Threat or Challenge group may have responded differentially to the two tasks, post-hoc (alpha-controlled) repeated measures ANCOVAs were performed separately for Threat and Challenge subjects on Math 1 and Math 2 HR and CO percent change scores, with baseline level as the covariate and with no between-subjects factors. These analyses yielded only a nonsignificant trend toward a main effect of Task for CO percent change scores, for the Challenge group only [$F(1, 25) = 4.12$, $p = .05$], due to a tendency for Challenge subjects to exhibit greater CO reactivity (with baseline covaried) to the second task than to the first task (Table 8).

To summarize, contrary to our expectations, there were no significant differences between Threat and Challenge subjects in HR, CO or TPR reactivity to either task. There was a tendency for Challenge subjects to display greater CO responses to the second task, relative to the first task, but this finding also failed to reach significance.

Recovery from tasks

Means and standard deviations for task-recovery percentage change (from baseline) scores are given in Table 9, with lower values indicating better recovery. From these data, it appears that the Challenge group generally displayed poorer HR and CO recovery, but better TPR recovery, than the Threat group, while the two groups seem to have shown

comparable recovery for SBP and DBP. In order to test for possible differences between Threat and Challenge groups in physiological recovery from the two tasks, separate one-way MANCOVAs were performed for each recovery period, with Group as the between-subjects factor and with percent change scores for SBP, DBP, HR, CO and TPR as the dependent variables. Absolute levels of physiological variables for the task immediately preceding the recovery period (Math 1 or 2) served as the covariates in these analyses. For the first recovery period, the multivariate Group effect was not significant (Wilks's lambda = .96), $F(5, 43) = .39$, $p = .86$. However, separate one-way ANCOVAs performed on Recovery 1 percent change scores for each physiological variable, with Math 1 level as the covariate, yielded a marginally significant main effect of Group for one variable, CO, with $F(1, 51) = 3.17$, $p = .08$. As indicated in Table 9, for the first recovery period, the Challenge group displayed a trend toward poorer recovery (greater percent change scores) than the Threat group. The MANCOVA for the second recovery period also failed to produce a significant multivariate Group effect (Wilks's lambda = .90), $F(5, 43) = .99$, $p = .44$. However, follow-up univariate ANCOVAs revealed a marginally significant Group effect for CO [$F(1, 51) = 3.39$, $p = .07$], once again, reflecting a tendency for the Challenge group to exhibit poorer CO recovery than the Threat group (Table 9). Furthermore, in contrast to the results for Recovery 1, there was also a marginally significant main effect of Group for Recovery 2 TPR percent change scores, $F(1, 51) = 3.41$, $p = .07$. As expected from Table 9, Challenge subjects tended to display greater TPR recovery than Threat subjects following the second mental arithmetic task (lower percent change scores).

In summary, relative to the Threat group, the Challenge group displayed trends toward better TPR recovery following the second mental arithmetic task and poorer CO recovery following both tasks. However, these findings should be interpreted with caution, given the absence of significant multivariate Group effects.

CHAPTER IV: DISCUSSION

The primary purpose of this research was to examine the relationship of experimentally-manipulated cognitive appraisals of a standard laboratory stressor to hemodynamic responses to that stressor. Specifically, this study was intended to replicate the recent work of Tomaka and his colleagues (1993; 1997), who have shown that individuals who appraise a potentially stressful situation as a positive challenge, either on their own or as a result of experimental manipulation, tend to exhibit a myocardial pattern of cardiovascular activation, while individuals appraising the same event as a threat display a vascular or mixed response. Consistent with the work of Tomaka's group, using different instructional sets, we manipulated threat and challenge appraisals of a mental arithmetic task and then assessed CO, TPR and HR responses to that task, as well as perceived and actual effort and performance. In addition, the present investigation was designed to improve upon and extend these earlier studies in a number of ways, including: (1) use of a more theory-driven threat/challenge manipulation, taking into account both primary and secondary appraisal; (2) measurement of cognitive appraisals using a more reliable multi-item instrument; (3) examination of group differences in task-involvement and positive and negative affect; (4) inclusion of blood pressure data in addition to data pertaining to its underlying hemodynamic components; (5) repeated assessment of cardiovascular responses following performance feedback to reinforce initial experimentally-manipulated cognitive appraisals ; and (6) assessment of cardiovascular stress-recovery. Briefly, to review, we expected our Threat group to report higher ratios of primary threat appraisal to secondary appraisal of coping ability, higher primary threat appraisal and lower primary challenge appraisal, relative to the Challenge group. We also anticipated that the Threat group would report greater negative affect and less positive affect, in response to the mental arithmetic tasks, as well as lower task-involvement, perceived effort and perceived performance. Furthermore, relative to Challenge subjects, we expected Threat subjects to display lower levels of actual effort and performance on the math tasks. As for the physiological data, we predicted that subjects in the Threat condition would display increased TPR and moderate myocardial reactivity in response to the tasks,

while the Challenge group would exhibit greater myocardial reactivity and decreased TPR. Finally, relative to Challenge subjects, we expected the Threat group to show delayed recovery on some or all cardiovascular measures. We will now proceed to discuss and interpret the findings pertaining to each of these hypotheses, as well as those for which no specific a priori predictions were made (e.g., blood pressure data).

The cognitive appraisal data from the present study clearly indicate that, based on our operational definitions, we were successful in manipulating two distinct types of stress-related appraisals, threat and challenge. As expected, subjects in the Threat condition reported higher ratios of perceived threat to perceived coping ability, higher primary appraisal of Threat (SAM only) and lower primary appraisal of Challenge, than subjects in the Challenge condition. That these appraisal patterns were maintained across both mental arithmetic tasks suggests that our initial manipulation of threat and challenge appraisals was quite potent and/or that our Block 2 positive/negative feedback was successful in reinforcing the original appraisals. That there was also a tendency for both groups to report higher ratios of perceived threat to perceived coping ability for the first task, relative to the second task, suggests that the first task may have been more threatening due to novelty. As noted previously, while Threat subjects displayed greater ratios of perceived threat to perceived coping ability than Challenge subjects, on the average, they did not report threat in excess of ability, as evidenced by ratios of less than 1, although the mean for Math 1 ratios (threat/coping ability) was nearly one ($\bar{M} = 0.91$). While Tomaka et al. (1997) obtained a mean ratio of greater than 1 for subjects receiving their threat manipulation, the standard deviation was notably high relative to that of subjects in their challenge condition, as well as that of both our Threat and Challenge groups, on the same ratio measure. Given this relatively high variability, with mean values being particularly sensitive to outliers, one wonders whether a few individuals with especially high appraisal ratios may have inflated the average ratio of Tomaka et al.'s (1997) threat group. On the other hand, while the mean appraisal ratio was considerably less than one for our Challenge group on both ratio measures, for both tasks, indicating coping ability in excess of threat, the mean for Tomaka et al.'s (1997) challenge group was nearly 1 ($\bar{M} = 0.95$). As alluded to earlier, considered

together, the cognitive appraisal ratio data suggest that the challenge appraisal manipulation used in the present study may have been more effective than that of Tomaka et al. (1997), while their threat manipulation may have been more effective than ours. These data also raise an interesting question: Is it sufficient to demonstrate that an experimental manipulation results in higher ratios of perceived threat to perceived coping ability for one group, relative to another, or is it necessary for threat and challenge appraisals to be strictly defined as perceived threat in excess of ability and perceived ability in excess of threat, respectively? As described previously, Blascovich and Tomaka (1996) define threat ["perception of demand that cannot be overcome by perceived resources" (p. 12)] and challenge ["perception of resources that can overcome the perceived demand" (p. 12)] appraisals in a manner consistent with the latter definition. However, elsewhere, the same research group has defined threat appraisal more loosely as occurring "when the situation is goal relevant and environmental demands are perceived as *taxing or* [italics added] exceeding resources or ability to cope" (Tomaka et al., 1997, p. 63), while remaining vaguely consistent in defining challenge appraisal as occurring "when the situation is goal relevant and environmental demands are appraised as within the person's resources or ability to cope" (p. 64). More importantly, in terms of evaluating the results of the present study within the context of the existing literature, in their "free appraisal" studies, Tomaka et al.'s (1993) median splits must have resulted in threat and challenge groups that did not display appraisal ratios of greater or less than 1, respectively, because the authors state the following in a footnote: "These analyses were also carried out using a *conceptual* [italics added] split (ratios greater and less than 1) . . . [which] produced the same results as the ones reported" (p. 251). That Tomaka and his colleagues chose to use the procedure that did not result in groups with perceived threat in excess of ability versus perceived ability in excess of threat, illustrates the loosely defined nature of the two constructs. As stated earlier, the present study did not allow for the evaluation of the independent effects of perceived coping efficacy and primary appraisals of threat (and challenge). However, the findings that, relative to Threat subjects, Challenge subjects reported significantly greater perceived coping ability based on the Tomaka et al. (1997) Coping Ability item, and a

nonsignificant trend toward greater coping ability based on the SAM Controllable-by-self subscale, provide some evidence for the effectiveness of the performance feedback manipulation. It remains for future studies to sort out the relative importance of the two components of overall threat and challenge appraisals, primary threat appraisals and perceived coping ability, in terms of their effects on the impact of a potential stressor on subsequent emotional and physiological responses.

While not directly related to any of our hypotheses, data were also collected on several other measures related to stress appraisals via subscales of the SAM. With respect to the mental arithmetic tasks, Challenge and Threat groups did not differ in self-reports of perceived relevance or importance (Centrality), uncontrollability (Uncontrollable-by-anyone) or overall stressfulness (Stressfulness) of the tasks. The Centrality subscale may be particularly important here given Lazarus and Folkman (1984) and Tomaka et al.'s (1997) agreement that a situation must be appraised as relevant before it can be further appraised as a threat or challenge. While it is encouraging that our two groups did not differ on this measure, the mean scores for both groups were between 6 and 7, which for the 4-item subscale, averages out to a response of around 2 for each item, corresponding to a rating of "Slightly" (e.g., slightly important or relevant). Thus, the effectiveness of our Threat/Challenge manipulation, and in particular, our statement that "Performing well (poorly) on this type of task may be related to future financial success (failure)," in increasing the perceived relevance or importance of the tasks, is questionable. Future studies should explore different ways of getting subjects ego-involved in the experimental situation. With regard to perceived uncontrollability of the tasks, the lack of observed group differences provides evidence that our manipulation was successful in manipulating secondary appraisals of perceived coping efficacy independently of the closely related appraisals of perceived control. The lack of group differences in appraisals of the overall stressfulness of the task is consistent with the notion that, not only threat appraisals, but also challenge appraisals, are associated with perceived stress or demand. This finding, however, contradicts the association of threat appraisals with greater subjective stress than challenge appraisals, reported by Tomaka et al. (1993). Lastly, there was an inexplicable,

marginally significant group difference in appraisals of the math tasks as being controllable by others, with Threat subjects reporting more help available than Challenge subjects. This finding was completely unexpected, and possibly due to chance.

Despite clear differences in task-appraisals, the Threat and Challenge groups did not differ in task levels of positive or negative affect. However, it should be noted that, for the most part, while not statistically significant, the state affect findings were in the expected direction (see Table 4). We speculate that significant group differences may have emerged with a larger sample, but nevertheless, we must conclude that our data do not provide support for the notion that threat appraisals are associated with increases in negative emotions and/or decreases in positive emotions or that challenge appraisals are accompanied by increases in positive emotions and/or decreases in negative emotions. It is possible that this lack of group differences may be related to the aforementioned issue regarding the magnitude of cognitive appraisal ratios. Specifically, had we been able to induce primary appraisals of threat that not only taxed, but exceeded perceived coping resources, for the Threat group, perhaps we would have been able to demonstrate Threat/Challenge differences in state affect, as well.

In contrast to the state affect findings, data pertaining to self-reported task-involvement, perceived effort and perceived performance strongly support our hypotheses and the effectiveness of our Threat/Challenge manipulation and performance feedback. Specifically, as expected, Challenge subjects reported greater task-involvement and perceived effort and performance than Threat subjects, for both tasks. In addition, both groups reported greater task-involvement and perceived performance for the second math task, relative to the first task, possibly reflecting a practice effect, with subjects being better able to focus on the task and believing that they performed better, with experience.

Similarly, although less robust, findings regarding actual effort and performance on the math tasks also provided some evidence in support of our hypotheses. Specifically, there were marginally significant group differences in measures of effort (number of subtraction attempts and number of attempts per minute) and performance (number of correct subtractions and number of correct subtractions per minute), with Challenge

subjects tending to exhibit greater effort and performance, for both tasks, relative to the Threat group. However, the Challenge group did not differ from the Threat group in percentage of correct subtractions. Thus, despite attempting more problems than Threat subjects, Challenge subjects did not sacrifice accuracy. These findings should be interpreted with caution, given that the overall multivariate effect of Group for effort and performance measures approached, but did not reach, significance. Lastly, there was also further evidence for a practice and/or secondary instructions (feedback) effect, with both groups displaying significantly greater effort and performance, on all measures, for the second task.

The mean absolute levels of SBP, DBP, HR, CO and TPR generally followed a pattern over the experimental session that is consistent with the typical response elicited by a standard laboratory protocol involving mental arithmetic preceded and followed by rest periods, with no Threat/Challenge group differences in baseline, task or recovery levels. Specifically, consistent with the notion that mental arithmetic is an active coping, primarily beta-adrenergic task, both math tasks significantly increased CO and HR, as well as SBP (although not with BMI covaried) and DBP, above baseline and recovery levels, while task levels of TPR did not differ from baseline and only Math 2 levels differed from recovery levels (1 and 2). Furthermore, for TPR only, the recovery periods were successful in allowing for return to (below) baseline levels.

While no Threat/Challenge group differences were predicted for absolute levels of physiological variables, the primary hypotheses of this study were based on expected group differences in CO, TPR and HR task-reactivity. No significant group differences were observed for CO, TPR or HR percent change scores, with baseline levels covaried.

As for the cardiovascular recovery data, the few findings that emerged were mixed in terms of supporting or contradicting our *a priori* predictions. Specifically, with previous task levels covaried, Challenge subjects showed a marginally significant trend toward poorer CO recovery from both tasks than Threat subjects, as indicated by greater percent change scores, while displaying a trend toward better TPR recovery from the second task. One way to interpret the findings for the first recovery period is that, while not exhibiting

the expected pattern of greater myocardial reactivity in response to the tasks, the Challenge group may have maintained CO responses between the tasks, relative to the Threat group, as part of an overall pattern of preparatory action readiness to facilitate engagement in the upcoming second task. This notion is supported by the aforementioned finding of greater Math 2 task-involvement for Challenge subjects than for Threat subjects. Assuming for the moment that this speculation is accurate, then one could argue that, given the delayed CO recovery observed for the second recovery period, relative to Threat subjects, Challenge subjects also must have maintained a state of readiness following the last math task, a response that would seem to be of no adaptive value. However, unlike the first recovery period, for Recovery 2, Challenge subjects also displayed evidence of a compensatory decrease in vascular resistance, an added component which may make the overall hemodynamic pattern adaptive after all. It should, however, be pointed out that all findings pertaining to recovery data should be interpreted with caution because, in each case, the multivariate Group effects failed to reach significance, while univariate effects were marginally significant for certain variables, as discussed above.

Summary of major findings

In the present study, the cognitive appraisal data provide clear evidence of experimental group differences in primary threat and challenge appraisals of the mental arithmetic tasks, as well as relative proportions of primary threat appraisals to secondary appraisals of perceived coping ability. Furthermore, consistent with previous work, relative to Threat subjects, Challenge subjects exhibited such seemingly positive or adaptive characteristics as greater self-reported task-involvement and perceived effort and performance, as well as tendencies toward greater actual effort and performance. Despite displaying two distinct cognitive-behavioral patterns of responding, the Threat and Challenge groups exhibited no differences in affective or physiological responses (defined in terms of absolute levels or task-reactivity). There was, however, a tendency for Challenge subjects to display poorer CO recovery to both tasks, but better TPR recovery to the second task, relative to Threat subjects.

Conclusions

Considered together, the major findings from this study support a stress-response model consistent with Selye's (e.g., Selye, 1978) notions of "nonspecific" responses and the "General Adaptation Syndrome" (GAS). On the basis of numerous observations of physiological responses to a variety of noxious stimuli, Selye (1978) defined stress as "*the nonspecific response of the body to any demand*" (p. 55) and the GAS as encompassing "all nonspecific changes [all manifestations of the stress response] as they develop throughout time during continued exposure to a stressor" (p. 79). While Selye's concept of the GAS was originally intended to apply only to changes in the hypothalamic-pituitary-adrenocortical system, as pointed out by Schneiderman and McCabe (1985), "it has also become a useful concept in terms of SNS function" (p.18). Consistent with Selye's notions of nonspecificity and the GAS, Threat and Challenge subjects in the present experiment generally displayed the same basic pattern of cardiovascular response to our mental arithmetic stressors, despite appraising these stimuli in quite different ways (thus, arguably, creating different "stimuli" for the two groups), not to mention exhibiting diverging patterns of additional cognitive, as well as behavioral, responses.

Given the lack of group differences in state affect observed in this study, our findings may be even more in line with the work of Mason (e.g., Mason, 1972), who argued that "most if not all of the situations described by Selye very likely involve some degree of *emotional reaction, discomfort, or pain as well as the designated 'noxious' stimuli . . .*" (Mason, 1972, p. 71) and that, hence, the response pattern observed by Selye did not represent a nonspecific or general adaptive response to different stimuli; rather it reflected " . . . a *specific* response to a *single* type of stimulus (psychological) that these various unpleasant situations share in common" (p. 71). In other words, for Mason, it is a common undercurrent of emotional arousal shared by different stimuli that accounts for what, at face value, appears to be the same nonspecific physiological response to different stimuli. Thus, although the Threat and Challenge conditions in the present study seem to be creating very different situations (stimuli) for the two groups, given the absence of group differences in state affect, perhaps there is some common underlying emotion(s),

such as anxiety or novelty/uncertainty (as suggested by Mason et al., 1976), that is resulting in the same basic pattern of physiological response for the two groups.

A final, alternative, explanation for the primary findings in the present study is that, while our Threat/Challenge manipulation induced different patterns of appraisals and other cognitive-behavioral responses, in terms of physiological responses, the manipulation may not have been powerful enough to overcome the specific response-eliciting properties of the mental arithmetic stressor. Earlier we noted that while there are naturally-occurring individual differences in hemodynamic responses to standard laboratory stressors, such as mental arithmetic, there are also stereotypical responses that different tasks tend to elicit, across individuals, and over time. This phenomenon is sometimes referred to as stimulus response specificity or stereotypy (e.g., Lacey et al., 1963; Stern and Sison, 1990). Furthermore, the magnitude of the physiological response to mental arithmetic may be enhanced when responses to math problems are delivered vocally, as opposed to written. For example, Linden (1991) has demonstrated that vocal delivery of responses to a math task similar to the one used in the present study is associated with heightened SBP and DBP responses and greater subjective stress, relative to written responses. However, contradictory to this interpretation, as noted earlier, Tomaka et al. (1993; 1997) were able to demonstrate Threat/Challenge group differences in hemodynamic responses to a vocal-response mental arithmetic task, although these findings were not as robust when appraisals were manipulated, rather than free.

We view the lack of an association between experimentally-manipulated threat versus challenge appraisals and different patterns of cardiovascular response, obtained in this study, as an important finding, because it provides evidence that viewing the same potentially stressful event in substantially different ways makes no difference in terms of the impact on the cardiovascular system. Specifically, appraising the math task as a positive challenge, associated with greater task-involvement and perceived and actual effort and performance, was apparently of no cardiovascular benefit, relative to appraising the task as a negative threat, associated with less task-involvement, effort and performance (perceived and actual). However, it should be noted that threat and challenge appraisals

may have been associated with differences in the activity of some other unmeasured stress response system (i.e., immune or neuroendocrine). Getting back to the responses of the cardiovascular system assessed in the present study, because, on the average, subjects exhibited an active-coping, beta-adrenergic response pattern, regardless of how they perceived the task, this finding provides support for the notion that such a pattern may be maladaptive.

While null findings can often be discouraging, in terms of the progression of science, and in this case, more specifically, the field of behavioral medicine, they are every bit as important as positive findings. In a 1964 article, John R. Platt addresses this very issue in promoting the use of what he refers to as "strong inference" in science. According to Platt (1964), strong inference becomes possible when one consistently applies the following steps in approaching every question in science:

- 1) Devising alternative hypotheses; 2) Devising a crucial experiment (or several of them), with alternative possible outcomes, each of which will, as nearly as possible, exclude one or more of the hypotheses; 3) Carrying out the experiment so as to get a clean result; 4) Recycling the procedure, making subhypotheses or sequential hypotheses to refine the possibilities that remain; and so on. (p. 347)

In light of these ideas, the present study has provided evidence for the exclusion of several hypotheses pertaining to the relationships among cognitive appraisals and emotional and cardiovascular responses. Specifically, threat and challenge appraisals, as manipulated using our theoretically-grounded instructional sets and performance feedback, were not associated with different patterns of affective or hemodynamic responses. According to Platt, however, exclusion does not occur after one null finding, but rather after several. Thus, one possible first step for future research endeavors of this kind, would be to try to replicate the same findings observed here, with the same manipulation, but perhaps with a larger sample. If replication is successful, this would be a strong indication that threat and challenge appraisals induced by this manipulation do not lead to differential emotional or hemodynamic response patterns. Furthermore, if the mean ratio of perceived threat to perceived coping ability for the Threat group is again found to be less than 1 (i.e., ability >

threat), then based on our earlier discussion regarding the issue of whether inducing appraisals of threat in excess of coping ability is necessary to demonstrate physiological and/or emotional differences, the next logical step would be to in some way enhance the threat manipulation so as to achieve ratios greater than 1 (i.e., threat > ability). Thus, we have, in effect, created a second alternative hypothesis that threat and challenge appraisals are differentially related to emotional and hemodynamic responses, only when defined strictly as appraisals of threat in excess of coping ability and coping ability in excess of threat, respectively. Consequently, if strengthening the Threat manipulation used in the present study induces higher ratios of threat to coping ability for the Threat group, but fails to produce group differences in emotional or hemodynamic responses, then this would be evidence in favor of exclusion of this alternative hypothesis. On the other hand, if group differences are observed, then the hypothesis would be supported, and in need of replication. Likewise, the existing findings of Tomaka and his colleagues (1997), described earlier, which provide evidence of associations of experimentally-manipulated threat and challenge appraisals with different hemodynamic response patterns, also need to be replicated using their threat/challenge manipulation, because as Platt puts it, "Any conclusion that is not an exclusion is insecure and must be rechecked." (p. 347). In this way, a number of alternative hypotheses and subhypotheses, pertaining to the general question of how different cognitive appraisals of the same situation are related to cardiovascular and emotional (and also behavioral) responses to that situation, could be tested sequentially, with replication, eventually resulting in affirmation or exclusion of those hypotheses. With regard to subhypotheses, two research questions that immediately come to mind, for future research efforts to address are: (1) Are there gender differences in relationships of threat and challenge appraisals to hemodynamic, emotional and behavioral response patterns?; and (2) How do relationships among cognitive appraisals and cardiovascular, emotional and behavioral responses vary for different stressors, including tasks that tend to be associated with more of a mixed myocardial/vascular hemodynamic pattern and less of a preexisting set of beliefs regarding ability, than mental arithmetic?

While the steps leading to strong inference, as applied to the present study above,

may simply seem to illustrate “. . . *the* method of science . . . “ (Platt, 1964, p. 347), according to Platt, “. . . many of us have almost forgotten it” (p. 347 - 348). For instance, Platt goes on to say, “How many of us write down our alternatives and crucial experiments every day, focusing on the *exclusion* of a hypothesis?” (p. 348). Platt emphasizes not only the need to have multiple alternative hypotheses, but also the importance of not becoming too “attached” to any one hypothesis. In doing so, Platt says, “It becomes much easier then for each of us to aim every day at conclusive disproofs--at *strong* inference--without either reluctance or combativeness.” (p. 350).

REFERENCES

REFERENCES

Allen, M. T., Obrist, P. A., Sherwood, A., & Crowell, M. D. (1987). Evaluation of myocardial and peripheral vascular responses during reaction time, mental arithmetic, and cold pressor tasks. Psychophysiology, 24(6), 648-656.

Allen, M. T., Stoney, C. M., Owens, J. F., & Matthews, K. A. (1993). Hemodynamic adjustments to laboratory stress: The influence of gender and personality. Psychosomatic Medicine, 55, 505-517.

Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioral change. Psychological Review, 84(2), 191-215.

Beck, A. T. (1967). Depression: Clinical, experimental, and theoretical aspects. New York: Hoeber.

Beck, A. T., Steer, R. A., & Garbin, M. G. (1988). Psychometric properties of the Beck Depression Inventory: Twenty-five years of evaluation. Clinical Psychology Review, 8, 77-100.

Blascovich, J., & Katkin, E. S. (1993). Cardiovascular reactivity to psychological stress and disease: Conclusions. In J. Blascovich & E. S. Katkin (Eds.), Cardiovascular reactivity to psychological stress & disease (pp. 225-237). Washington, DC: American Psychological Association.

Blascovich, J., & Tomaka, J. (1996). The biopsychosocial model of arousal regulation. In M. P. Zanna (Ed.), Advances in experimental social psychology (Vol. 28, pp. 1-51). New York: Academic Press.

Booth-Kewley, S., & Friedman, H. S. (1987). Psychological predictors of heart disease: A quantitative review. Psychological Bulletin, 101(3), 343-362.

Braden, D. S., Leatherbury, L., Treiber, F. A., & Strong, W. B. (1990). Noninvasive assessment of cardiac output in children using impedance cardiography. American Heart Journal, 120, 1166-1172.

Cohen, S., & Hoberman, H. M. (1983). Positive events and social supports as buffers of life change stress. Journal of Applied Social Psychology, 13(2), 99-125.

Cohen, S., Kamarck, T., & Mermelstein, R. (1983). A global measure of perceived stress. Journal of Health and Social Behavior, 24, 385-396.

Dienstbier, R. A. (1989). Arousal and physiological toughness: Implications for mental and physical health. Psychological Review, 96(1), 84-100.

Elliot, A. J., & Harackiewicz, J. M. (1996). Approach and avoidance achievement goals and intrinsic motivation: A mediational analysis. Journal of Personality and Social Psychology, 70(3), 461-475.

Folkman, S. (1984). Personal control and stress and coping processes: A theoretical analysis. Journal of Personality and Social Psychology, 46(4), 839-852.

Fredrikson, M., & Matthews, K. A. (1990). Cardiovascular responses to behavioral stress and hypertension: A meta-analytic review. Annals of Behavioral Medicine, 12(1), 30-39.

Gerin, W., Litt, M. D., Deich, J., & Pickering, T. G. (1996). Self-efficacy as a component of active coping: Effects on cardiovascular reactivity. Journal of Psychosomatic Research, 40(5), 485-493.

Girdler, S. S., Turner, J. R., Sherwood, A., & Light, K. C. (1990). Gender differences in blood pressure control during a variety of behavioral stressors. Psychosomatic Medicine, 52, 571-591.

Greenhouse, S. W., & Geisser, S. (1959). On methods in the analysis of profile data. Psychometrika, 24, 95-112.

Julius, S. (1992). Relationship between the sympathetic tone and cardiovascular responsiveness in the course of hypertension. In E. H. Johnson, W. D. Gentry, & S. Julius (Eds.), Personality, elevated blood pressure, and essential hypertension (pp. 219-230). Washington, DC: Hemisphere.

Julius, S., & Cottier, C. (1983). Behavior and hypertension. In T. M. Dombroski, T. H. Schmidt, & G. Blumchen (Eds.), Biobehavioral bases of coronary heart disease (pp. 271-289). New York: Karger.

Julius, S., & Esler, M. (1975). Autonomic nervous cardiovascular regulation in borderline hypertension. The American Journal of Cardiology, 36, 685-696.

Julius, S., & Hansson, L. (1983). Borderline hypertension: Epidemiologic and clinical implications. In J. Genest, O. Kuchel, P. Hamet, & M. Cantin (Eds.), Hypertension: Physiopathology and treatment (2nd ed., pp. 753-764). New York: McGraw-Hill.

Kaplan, N. M., Lieberman, E., & Neal, W. W. (1994). Clinical hypertension (6th ed.). Baltimore: Williams & Wilkins.

Kelsey, R. M. (1993). Habituation of cardiovascular reactivity to psychological stress: Evidence and implications. In J. Blascovich & E. S. Katkin (Eds.), Cardiovascular reactivity to psychological stress & disease (pp. 135-153). Washington, DC: American Psychological Association.

Krantz, D. S., & Manuck, S. B. (1984). Acute psychophysiologic reactivity and risk of cardiovascular disease: A review and methodologic critique. Psychological Bulletin, 96(3), 435-464.

Lacey, J. I., Kagan, J., Lacey, B. C., & Moss, H. A. (1963). The visceral level: Situational determinants and behavioral correlates of autonomic response patterns. In P. H. Knapp (Ed.), Expression of the emotions in man (pp. 161-196). New York: International Universities Press.

Lawler, K. A., & Kline, K. A. (1998, March). Hemodynamic reactivity patterns: Will the real "hot reactor" please stand up? Poster session presented at the annual meeting of the Society of Behavioral Medicine, New Orleans, LA.

Lawler, K. A., Wilcox, Z. C., & Anderson, S. F. (1995). Gender differences in patterns of dynamic cardiovascular regulation. Psychosomatic Medicine, 57, 357-365.

Lazarus, R. S. (1991). Emotion and adaptation. New York: Oxford University Press.

Lazarus, R. S., & Folkman, S. (1984). Stress, appraisal, and coping. New York: Springer.

Light, K. C., Dolan, C. A., Davis, M. R., & Sherwood, A. (1992). Cardiovascular responses to an active coping challenge as predictors of blood pressure patterns 10 to 15 years later. Psychosomatic Medicine, 54, 217-230.

Linden, W. (1991). What do arithmetic stress tests measure?: Protocol variations and cardiovascular responses. Psychophysiology, 28(1), 91-102.

Manuck, S. B. (1994). Cardiovascular reactivity in cardiovascular disease: "Once more unto the breach." International Journal of Behavioral Medicine, 1(1), 4-31.

Marrero, A. F., al'Absi, M., Pincomb, G. A., & Lovallo, W. R. (1997). Men at risk for hypertension show elevated vascular resistance at rest and during mental stress. International Journal of Psychophysiology, 25, 185-192.

Mason, J. W. (1972). Organization of psychoendocrine mechanisms: A review and reconsideration of research. In N. S. Greenfield & R.A. Sternbach (Eds.), Handbook of psychophysiology (pp. 3-91). New York: Holt, Rinehart and Winston.

Mason, J. W., Maher, J. T., Hartley, L. H., Mougey, E. H., Perlow, M. J., & Jones, L. G. (1976). Selectivity of corticosteroid and catecholamine responses to various natural stimuli. In G. Serban (Ed.), Psychopathology of human adaptation (pp. 147-171). New York: Plenum Press.

Monroe, S. M., & Kelley, J. M. (1995). Measurement of stress appraisal. In S. Cohen, R. C. Kessler, & L. U. Gordon (Eds.), Measuring stress: A guide for health and social scientists (pp. 122-147). New York: Oxford University Press.

Obrist, P. A. (1976). The cardiovascular-behavioral interaction--as it appears today. Psychophysiology, 13(2), 95-107.

Obrist, P. A. (1981). Cardiovascular psychophysiology: A perspective. New York: Plenum Press.

Peacock, E. J., & Wong, P. T. P. (1990). The Stress Appraisal Measure (SAM): A multidimensional approach to cognitive appraisal. Stress Medicine, 6, 227-236.

Pickering, T. (1996). Why study blood pressure reactivity to stress? American Journal of Hypertension, 9, 941-942.

Pickering, T. G., & Gerin, W. (1990). Cardiovascular reactivity in the laboratory and the role of behavioral factors in hypertension: A critical review. Annals of Behavioral Medicine, 12(1), 3-16.

Platt, J. R. (1964). Strong inference. Science, 146, 347-353.

Rosenberg, M. (1965). Society and the adolescent self-image. Princeton, NJ: Princeton University Press.

Rotter, J. B. (1966). Generalized expectancies for internal versus external control of reinforcement. Psychological Monographs, 80 (1, Whole No. 609).

Saab, P. G., Llabre, M. M., Hurwitz, B. E., Frame, C. A., Reineke, L. J., Fins, A. I., McCalla, J., Cieply, L. K., & Schneiderman, N. (1992). Myocardial and peripheral vascular responses to behavioral challenges and their stability in black and white Americans. Psychophysiology, 29(4), 384-397.

Saab, P. G., & Schneiderman, N. (1993). Biobehavioral stressors, laboratory investigation, and the risk of hypertension. In J. Blascovich & E. S. Katkin (Eds.), Cardiovascular reactivity to psychological stress and disease (pp. 49-82). Washington, DC: American Psychological Association.

Scheier, M. F., Carver, C. S., & Bridges, M. W. (1994). Distinguishing optimism from neuroticism (and trait anxiety, self-mastery, and self-esteem): A reevaluation of the Life Orientation Test. Journal of Personality and Social Psychology, 67(6), 1063-1078.

Schneiderman, N., & McCabe, P. M. (1985). Biobehavioral responses to stressors. In T. M. Field, P. M. McCabe, & N. Schneiderman (Eds.), Stress and coping (pp. 13-61). Hillsdale, NJ: Erlbaum.

Selye, H. (1978). The stress of life. New York: McGraw-Hill.

Sherwood, A. (1993). Use of impedance cardiography in cardiovascular reactivity research. In J. Blascovich & E. S. Katkin (Eds.), Cardiovascular reactivity to psychological stress and disease (pp. 157-199). Washington, DC: American Psychological Association.

Sherwood, A., Allen, M. T., Obrist, P. A., & Langer, A. W. (1986). Evaluation of beta-adrenergic influences on cardiovascular and metabolic adjustments to physical and psychological stress. Psychophysiology, 23(1), 89-104.

Sherwood, A., Royal, S. A., & Light, K. C. (1993). Laboratory reactivity assessment: Effects of casual blood pressure status and choice of task difficulty. International Journal of Psychophysiology, 14, 81-95.

Stern, R. M., & Sison, C. E. E. (1990). Response patterning. In J. T. Cacioppo & L. G. Tassinary (Eds.) Principles of psychophysiology: Physical, social, and inferential elements (3rd ed., pp. 193-215). New York: Cambridge University Press.

Stone, A. A. (1995). Measurement of affective response. In S. Cohen, R. C. Kessler, & L. U. Gordon (Eds.), Measuring stress: A guide for health and social scientists (pp. 148-171). New York: Oxford University Press.

Tomaka, J., Blascovich, J., Kelsey, R. M., & Leitten, C. L. (1993). Subjective, physiological, and behavioral effects of threat and challenge appraisal. Journal of Personality and Social Psychology, 65(2), 248-260.

Tomaka, J., Blascovich, J., Kibler, J., & Ernst, J. M. (1997). Cognitive and physiological antecedents of threat and challenge appraisal. Journal of Personality and Social Psychology, 73(1), 63-72.

Treiber, F. A., Musante, L., Braden, D., Arensman, F., Strong, W. B., Levy, M., & Leverett, S. (1990). Racial differences in hemodynamic responses to the cold face stimulus in children and adults. Psychosomatic Medicine, 52, 286-296.

Turner, J. R. (1989). Individual differences in heart rate response during behavioral challenge. Psychophysiology, 26(5), 497-505.

Watson, D., Clark, L. A., & Tellegen, A. (1988). Development and validation of brief measures of positive and negative affect: The PANAS scales. Journal of Personality and Social Psychology, 54(6), 1063-1070.

Wiebe, D. J. (1991). Hardiness and stress moderation: A test of proposed mechanisms. Journal of Personality and Social Psychology, 60(1), 89-99.

Wright, R. A., & Dill, J. C. (1993). Blood pressure responses and incentive appraisals as a function of perceived ability and objective task demand. Psychophysiology, 30, 152-160.

Wright, R. A., & Dismukes, A. (1995). Cardiovascular effects of experimentally induced efficacy (ability) appraisals at low and high levels of avoidant task demand. Psychophysiology, 32, 172-176.

APPENDIX
Tables and Figures

Table 1. Experimental design.

Group	<u>Block 1</u>					<u>Block 2</u>		
	Practice (1 min)	Baseline (10 min)	Feedback	Math 1 (4 min)	Rest 1 (5 min)	Feedback	Math 2 (4 min)	Rest 2 (5 min)
Threat (n = 30)			Negative			Negative		
Challenge (n = 30)			Positive			Positive		

Table 2. Demographic characteristics and measures of physical symptoms, background stress and psychological traits for Threat and Challenge groups (n = 54).

Variable	Threat (n = 27)	Challenge (n = 27)
Age (yr)	19.7 (1.7)	20.5 (2.2)
BMI (kg/m ²)	23.1 (3.1)	24.4 (3.4)
Race (#)		
Caucasian	25	25
African American	1	2
Asian	1	0
Family history (#) ^a		
FH+	13	15
FH-	10	8
Medication (#)		
Yes	3	3
No	24	24
Smoke (#)		
Yes	6	2
No	21	25
Background stress (PSS)	23.0 (7.0)	24.4 (6.1)
Physical symptoms (CHIPS)	46.9 (10.7)	48.5 (10.2)
Depression (BDI)	6.2 (4.6)	5.2 (5.1)
Self-esteem (SE)	*32.9 (4.7)	*35.2 (4.7)
Locus of control (LOC)	11.7 (4.3)	10.0 (3.2)
Optimism (LOT-R)	15.4 (3.0)	16.6 (3.2)

Note(s): ^aFor Family history data, n's = 23 for Threat and Challenge groups; * = group difference marginally significant at $p < .10$. Values for Age, BMI, CHIPS, PSS, BDI, SE, LOC, and LOT-R are means (SD).

Table 3. Descriptive statistics for cognitive appraisal ratios, primary threat and challenge appraisals and secondary appraisals of coping ability.

Variable	<u>Math 1</u>		<u>Math 2</u>	
	Threat	Challenge	Threat	Challenge
Appraisal ratio (SAM)	0.59 (0.31) ^a **	0.47 (0.19)	0.62 (0.40) **	0.47 (0.20)
Appraisal ratio (Tomaka et al., 1997)	0.91 (0.63) **	0.68 (0.36)	0.78 (0.61) **	0.58 (0.37)
Primary threat appraisal (SAM)	8.15 (3.07) **	6.89 (2.03)	8.07 (3.49) **	6.96 (2.08)
Primary threat appraisal (Tomaka et al., 1997)	3.26 (1.68)	2.89 (1.28)	2.96 (1.56)	2.63 (1.50)
Secondary appraisal of coping ability (SAM)	14.85 (3.00)	15.52 (2.69)	14.37 (3.25)	15.52 (2.58)
Secondary appraisal of coping ability (Tomaka et al., 1997)	4.15 (1.10) **	4.52 (0.80)	4.41 (1.05) **	4.85 (0.72)
Primary challenge appraisal (SAM)	9.81 (2.91) *	11.04 (2.38)	9.44 (3.03) *	10.41 (2.53)

Note(s): ^aValues are means (SD); ** = group difference significant at $p < .05$; * = group difference marginally significant at $p < .10$. "Appraisal ratio" refers to the ratio of primary appraisal of threat to secondary appraisal of coping ability, as derived from the Threat and Controllable-by-self (i.e., coping ability) subscales of the Stress Appraisal Measure (SAM) or the Threat and Coping Ability items used by Tomaka et al. (1997). "Primary threat appraisal" was assessed via the Threat subscale of the SAM or the Threat item used by Tomaka et al. (1997). "Secondary appraisal of coping ability" was measured using the SAM Controllable-by-self subscale or the Coping Ability item used by Tomaka et al. (1997). "Primary challenge appraisal" was assessed using the Challenge subscale of the SAM.

Table 4. Descriptive statistics for the Positive (PA) and Negative (NA) Affect subscales of the Positive and Negative Affect Schedule (PANAS).

Time Period	Group	PA	NA
Baseline	Threat	23.85 (6.93) ^a	14.15 (4.00)
	Challenge	26.22 (7.74)	14.78 (5.98)
Math 1	Threat	23.93 (5.87)	18.70 (9.29)
	Challenge	26.11 (7.19)	17.74 (6.93)
Math 2	Threat	23.89 (5.44)	17.15 (8.54)
	Challenge	26.93 (8.44)	14.56 (3.95)

Note(s): ^aValues are means (SD).

Table 5. Descriptive statistics for task-involvement, perceived effort and perceived performance for the mental arithmetic tasks.

Variable	<u>Math 1</u>		<u>Math 2</u>	
	Threat	Challenge	Threat	Challenge
Task-involvement	28.63 (6.17) ^a	* 31.22 (5.37)	30.22 (5.24)	* 33.04 (5.16)
Perceived effort	5.15 (1.41)	* 5.78 (1.22)	5.33 (1.41)	* 5.93 (1.11)
Perceived performance	3.48 (1.48)	* 4.44 (1.58)	3.85 (1.59)	* 4.70 (1.23)

Note(s): ^aValues are means (SD); * = group difference significant at $p < .05$.

Table 6. Descriptive statistics for behavioral measures of actual effort and performance for the mental arithmetic tasks.

Variable	Math 1			Math 2		
	Threat		Challenge	Threat		Challenge
# attempts	41.63 (19.56) ^a	*	52.00 (28.27)	52.63 (24.79)	*	61.59 (29.97)
# attempts per min	10.41 (4.89)	*	13.00 (7.07)	13.16 (6.20)	*	15.40 (7.49)
# correct	37.52 (20.26)	*	47.89 (29.93)	49.30 (25.81)	*	57.70 (31.31)
# correct per min	9.38 (5.06)	*	11.97 (7.48)	12.32 (6.45)	*	14.43 (7.83)
% correct	87.04 (9.73)		87.49 (12.83)	90.92 (8.97)		89.92 (11.76)

Note(s): ^aValues are means (SD); * = group difference marginally significant at $p < .10$.

Table 7. Descriptive statistics for absolute baseline, task and recovery levels of physiological variables.

Variable ^a	Baseline	Math 1	Recovery 1	Math 2	Recovery 2
SBP					
Threat	107.8 (7.4) ^b	128.3 (14.9)	113.0 (9.5)	127.1 (15.6)	113.6 (9.8)
Challenge	110.6 (9.4)	130.9 (14.5)	116.2 (11.6)	131.6 (15.1)	116.0 (10.6)
DBP					
Threat	58.2 (7.8)	69.8 (9.4)	59.7 (7.0)	68.5 (9.1)	59.1 (8.6)
Challenge	60.7 (8.0)	72.5 (8.2)	62.4 (9.3)	73.2 (7.9)	61.9 (9.2)
HR					
Threat	65.1 (9.7)	82.1 (16.8)	68.5 (10.7)	78.8 (15.5)	67.8 (10.4)
Challenge	62.6 (7.8)	79.4 (10.4)	66.2 (7.8)	78.4 (10.0)	65.9 (7.7)
CO					
Threat	5.4 (1.0)	6.6 (1.3)	5.7 (1.0)	6.3 (1.1)	5.7 (1.0)
Challenge	5.1 (0.8)	6.2 (0.9)	5.6 (1.0)	6.2 (0.8)	5.6 (0.9)
TPR					
Threat	1143.5 (238.8)	1118.7 (192.4)	1110.5 (204.9)	1155.3 (203.4)	1123.8 (209.9)
Challenge	1227.6 (196.5)	1201.7 (172.7)	1172.8 (219.0)	1209.4 (176.7)	1175.9 (225.7)

Note(s): ^aUnits of measurement for the variables are as follows: SBP and DBP are in mmHg, HR is in bpm, CO is in l/min and TPR is in dyne*sec/cm⁵. ^bValues are means (SD).

Table 8. Descriptive statistics for physiological task-reactivity (percentage change scores).

Variable ^a	Math 1	Math 2
HR		
Threat	26.1 (14.7) ^b	21.0 (12.9)
Challenge	27.4 (14.0)	26.0 (14.9)
CO		
Threat	22.5 (19.4)	16.7 (16.6)
Challenge	21.6 (9.8)	22.0 (12.7)
TPR		
Threat	- 0.8 (12.7)	2.5 (13.8)
Challenge	- 1.6 (8.4)	- 0.8 (9.5)

Note(s): ^aUnits of measurement for all variables are %. ^bValues are means (SD).

Table 9. Descriptive statistics for physiological recovery from tasks (percentage change scores).

Variable ^a	Recovery 1	Recovery 2
SBP		
Threat	4.9 (6.5) ^b	5.4 (6.8)
Challenge	5.0 (4.2)	4.9 (3.4)
DBP		
Threat	2.9 (7.5)	1.5 (6.7)
Challenge	2.7 (5.7)	2.0 (6.4)
HR		
Threat	5.2 (5.1)	4.3 (5.9)
Challenge	5.9 (5.6)	5.4 (5.4)
CO		
Threat	6.6 (8.3)*	5.1 (9.0)*
Challenge	9.3 (6.4)*	8.6 (6.1)*
TPR		
Threat	-2.1 (8.8)	-0.9 (8.5)*
Challenge	-4.7 (6.4)	-4.5 (6.6)*

Note(s): ^aUnits of measurement for all variables are %. ^bValues are means (SD), with lower values indicating better recovery; * = group difference marginally significant at $p < .10$.

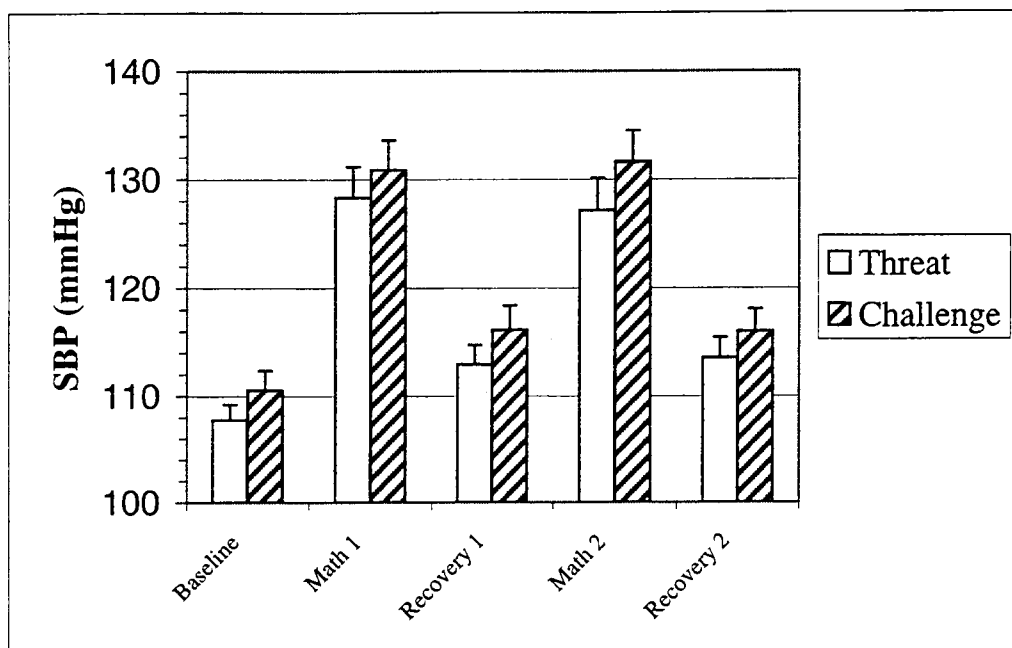


Figure 1. Mean ($\pm$ SEM) systolic blood pressure levels during rest, tasks and recovery for Threat and Challenge groups.

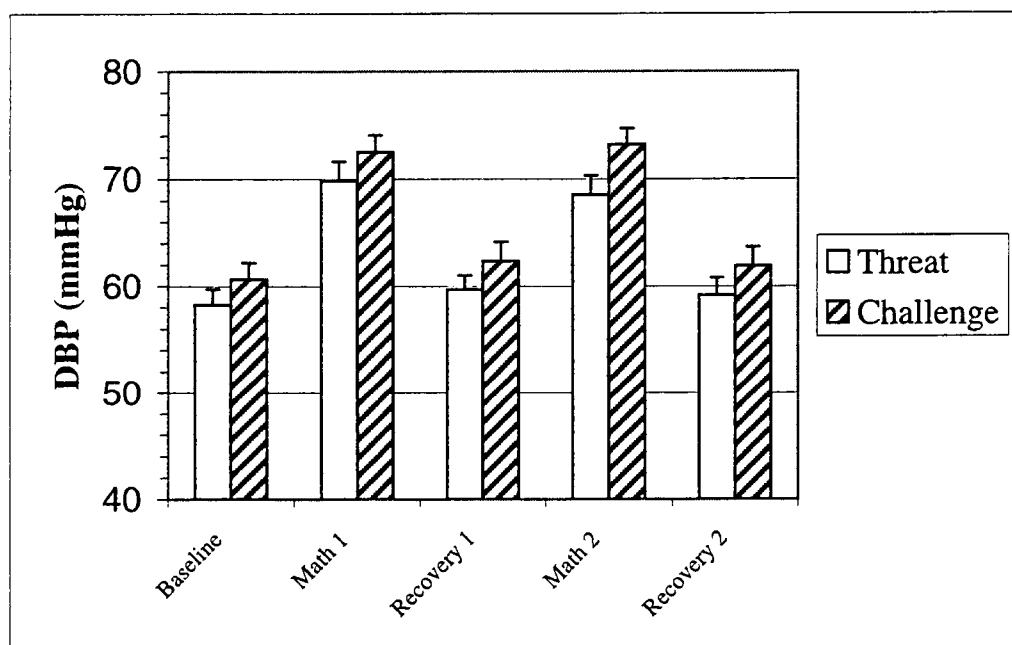


Figure 2. Mean ($\pm$ SEM) diastolic blood pressure levels during rest, tasks and recovery for Threat and Challenge groups.

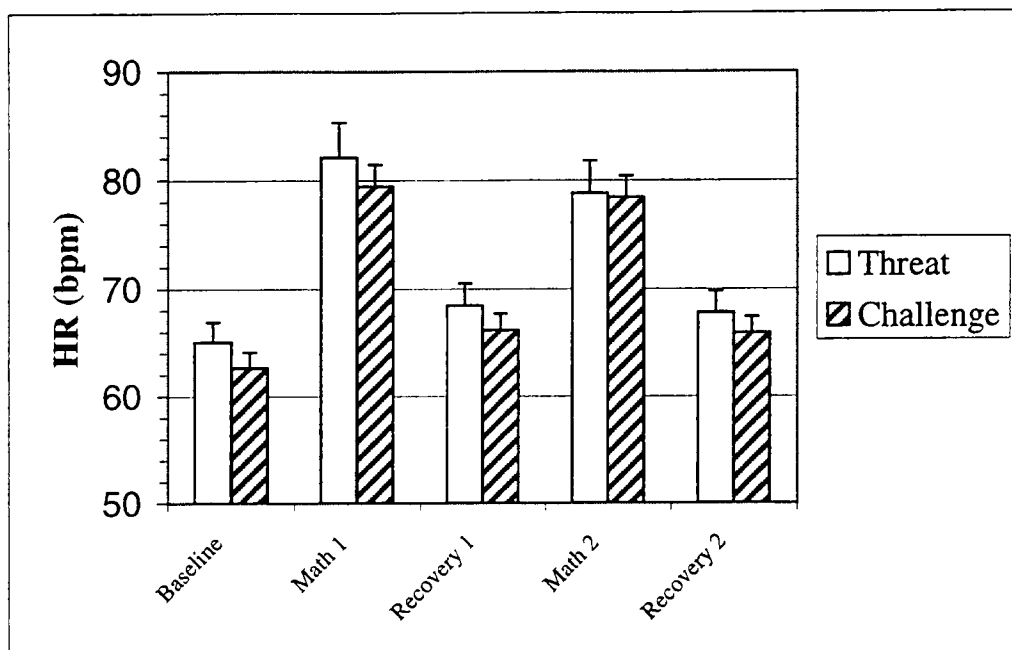


Figure 3. Mean ($\pm$ SEM) heart rate levels during rest, tasks and recovery for Threat and Challenge groups.

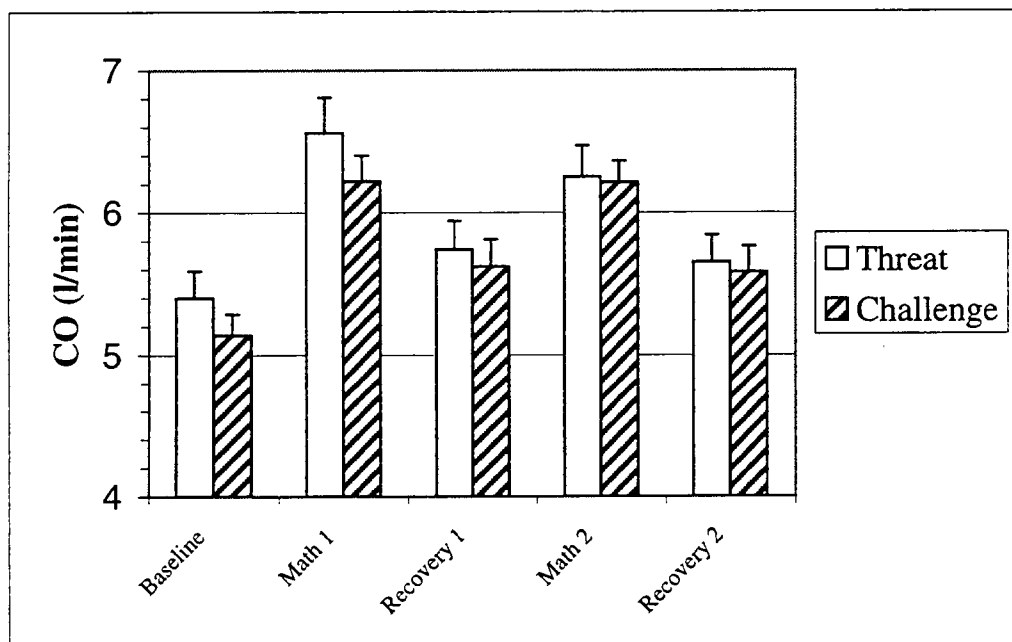


Figure 4. Mean ($\pm$ SEM) cardiac output levels during rest, tasks and recovery for Threat and Challenge groups.

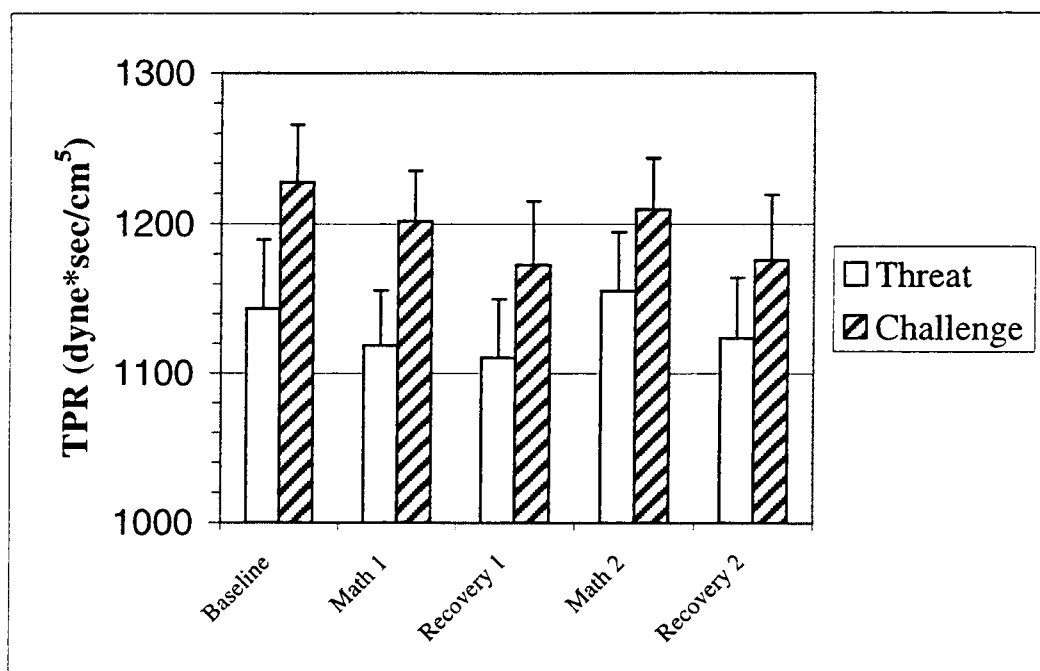


Figure 5. Mean ($\pm$ SEM) total peripheral resistance levels during rest, tasks and recovery for Threat and Challenge groups.

VITA

Keith A. Kline was born in Hagerstown, Maryland on May 5, 1971. He was raised in nearby Boonsboro, Maryland, where he attended public school, graduating from Boonsboro High School in June, 1989. The following fall, he entered Virginia Tech, in Blacksburg, Virginia, where he spent his first two years discontent with his choice of majors, before settling upon Psychology as his true calling in his junior year. In his senior year, he decided that, upon graduation, he would pursue his Doctor of Philosophy degree in Psychology. Unsure of the particular area of Psychology that most interested him, he requested information and application materials from a variety of graduate programs. By chance, as an undergraduate, he had visited the campus of The University of Tennessee, while presenting a poster at the annual meeting of the Southeastern Psychological Association in Knoxville. Based on this familiarity alone, one of the programs that he requested information from was the Ph.D. program in Experimental Psychology at The University of Tennessee. Upon receiving the description of faculty research interests for this program, he was encouraged by the number of faculty whose research fell under the heading of "Biopsychology," which was one of the areas of Psychology that he found most intriguing. In particular, the research interests of one faculty member, Dr. Kathleen Lawler, really caught his attention. Thus, he applied to this program, as well as several others. However, at the beginning of the author's last semester of college, his father unexpectedly passed away. The author contemplated whether to leave his family to return for his final semester at Virginia Tech, let alone whether to attend graduate school the following year. However, thanks to the encouragement of family and friends, he received his Bachelor of Science degree from Virginia Tech in May, 1993, and, as fate would have it, he was accepted to and chose to attend the University of Tennessee. He entered The University of Tennessee in August, 1993, received his Master of Arts degree in Psychology in August, 1996 and his Doctor of Philosophy degree in Psychology in August, 1998.

The author married the former Kelli Fowler of Seymour, Tennessee in June, 1995,

and they are expecting their first child in November, 1998. Kelli is currently the Joint Venture Coordinator for Anderson News Company, and she received her Master of Accountancy degree in August, 1998. The author has accepted a postdoctoral research position in Cardiovascular Behavioral Medicine at The University of Miami (Florida). Keith and Kelli are currently in the process of relocating to the Miami area.