1-1-2014

The interaction of feedback and reward contingency on cardiovascular reactivity during a stressful cognitive task

Alvin B. Jin
University of South Florida, albjin@gmail.com

The Interaction of Feedback and Reward Contingency on Cardiovascular Reactivity during a Stressful Cognitive Task

by

Alvin B. Jin

A dissertation submitted in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy
Department of Psychology
College of Arts & Sciences
University of South Florida

Major Professor: Kristen Salomon, Ph.D.
David M. Diamond, Ph.D.
Geoffrey F. Potts, Ph.D.
Jonathan Rottenberg, Ph.D.
Maureen E. Groer, Ph.D.

Date of Approval:
November 20, 2014

Keywords: Cardiovascular responses, Ability feedback, Reward availability, Cognitive load

Acknowledgments

I am grateful for the support and funding provided by The Charles Stark Draper Laboratory, Inc. This project would not have been possible without the financial support of the Draper Laboratory Fellowship program (IR&D #29421), as well as the various research opportunities that it has allowed me to work on and learn from. Thanks also to Dr. Andrea K. Webb who helped me become a Draper Laboratory Fellow and provided valuable input throughout all of the stages of this dissertation. Finally, thanks to my family and everyone else who has helped and supported me throughout graduate school and life.

Table of Contents

List of Tables

List of Figures

Abstract

Excessive sympathetic cardiovascular reactivity to stressful tasks is a risk factor for the development of cardiovascular disease (CVD). Many populations with a greater risk for CVD instead demonstrate blunted cardiovascular reactivity to stressful tasks. The motivational intensity theory identifies how motivation and effort influence sympathetic reactivity. Blunted reactivity may be a potential index of motivational dysregulation, which leads to poor behavioral decisions such as excess smoking or alcohol use, in turn increasing the risk for CVD. The current study sought to demonstrate how inhibited effort due to poor ability feedback with a low-contingency reward could directly increase the risk for CVD through perseverative cognition and impaired recovery. Participants (N = 89) were given either poor or good feedback on a working memory task that was purported to be related to another related working memory task. Participants were then informed that they could secure a low- or high-contingency reward opportunity by meeting a performance standard. EKG, impedance cardiography, blood pressure, and pupillometry were recorded throughout. Pre-ejection period reactivity and self-reported effort were greatest in participants given good feedback with a high-contingency reward and poor feedback with a low-contingency reward. Greater effort and sympathetic reactivity support previous findings linking these two measures. The results also suggest evaluating both internal and external rewards is important when examining motivation.

Introduction

The reactivity hypothesis identifies excessive sympathetic cardiovascular reactivity to stressful or demanding tasks as a risk factor for the development of cardiovascular disease (CVD: Krantz & Manuck, 1984). Prospective studies support this hypothesis. For example, greater pulse pressure reactivity predicts greater thickness in the intima-media lining of the carotid artery (Matthews et al., 1998), a subclinical measure of risk for atherosclerosis. Greater blood pressure reactivity also predicts left ventricular hypertrophy (Taylor, Kamarck, & Dianzumba, 2003), an increase in left ventricular mass that is related to an increased risk for mortality (Levy, Garrison, Savage, Kannel, & Castelli, 1990). While the original focus of the reactivity hypothesis was the sympathetic nervous system, both greater sympathetic and parasympathetic reactivity may predict risk for hypertension (Chida & Steptoe, 2010). In contradiction to the reactivity hypothesis, recent evidence has shown reactivity that is relatively smaller in magnitude, or "blunted," is related to increased CVD risk. Smaller sympathetic and parasympathetic cardiovascular reactivity to a mental stress predicts greater carotid intima-media thickness (IMT: Heponiemi et al., 2007) and a greater risk of becoming obese within five years (Carroll, Phillips, & Der, 2008). Additionally, populations with an increased risk for developing CVD such as smokers (Phillips, Der, Hunt, & Carroll, 2009), individuals with alcohol dependency (Panknin, Dickensheets, Nixon, & Lovallo, 2002), lower socioeconomic status (Carroll et al., 2000), and depression (Rottenberg, Clift, Bolden, & Salomon, 2007; Salomon, Bylsma, White, Panaite, & Rottenberg, 2013; Salomon, Clift, Karlsdottir, & Rottenberg, 2009) all demonstrate blunted reactivity to stress.

Carroll and colleagues have suggested that blunted reactivity may be related to an increased risk for CVD because it may indicate motivational dysregulation (Carroll, Phillips, & Lovallo, 2012). Blunted reactivity may index a failure in motivation that leads to poor behavioral decisions, such as smoking and excessive alcohol use. In turn, these actions can then lead to an increased risk for CVD. While poor behavioral decisions may increase the risk for CVD, blunted reactivity itself may also increase the risk for CVD because recovery from stress may be impaired following blunted reactivity (Heponiemi, et al., 2007; Rottenberg, et al., 2007; Salomon, et al., 2009; Salomon, et al., 2013), and impaired recovery has been identified as a risk factor for an increased risk of CVD (Chida & Steptoe, 2010; Schuler & O'Brien, 1997). The parasympathetic nervous system may be especially important because heart rate recovery in the first minute is related to parasympathetic nervous system activity following both exercise (Imai et al., 1994) and mental stress (Mezzacappa, Kelsey, Katkin, & Sloan, 2001). The current study examined how blunted reactivity may lead to impaired cardiovascular recovery of both the sympathetic and parasympathetic nervous systems.

Psychological Processes Influencing Cardiovascular Reactivity and Recovery

Effortful coping in response to stressful situations is accompanied by beta-adrenergically mediated changes in the sympathetic nervous system (Obrist et al., 1978). The motivational intensity theory examines factors that influence motivation and effort (Brehm & Self, 1989) and their influence on sympathetic reactivity to tasks. While motivation and effort may be tightly linked to sympathetic reactivity, cardiovascular recovery from stress may be just as important as reactivity in the risk for developing CVD (Linden, Earle, Gerin, & Christenfeld, 1997). The perseverative cognition hypothesis addresses the importance of recovery, positing that post-stressor thoughts lead to long-term activation of the cardiovascular system and an increased risk of CVD (Brosschot, Gerin, & Thayer, 2006). Motivation and perseverative cognition are often seen as independent factors, but motivational factors may influence acute reactivity to a stressor as well as perseverative cognition during recovery.

Motivational intensity theory. The motivational intensity theory identifies motivational arousal as a temporary state that sets the effort used to accomplish an instrumental behavior (Brehm & Self, 1989). Motivational arousal allows for a minimum amount of effort to be exerted towards the completion of a goal, conserving resources. For example, if a task is easy to complete, effort exerted would be low regardless of what is achieved by completing the task. As difficulty increases, the amount of effort necessary to complete the task increases. An increase in effort with difficulty does not continue forever and when a task becomes extremely difficult, energy expenditure is seen as wasteful and motivational arousal drops so that resources are not wasted on task completion. The mobilization of resources is often seen in the cardiovascular system as increased systolic blood pressure (SBP) and pre-ejection period (PEP), a near-pure measure of sympathetically-mediated cardiac contractile force (Berntson et al., 1994). Changes in these sympathetic measures of the cardiovascular system are thought to index effort when factors establishing motivation are manipulated.

Individuals may use the difficulty of the task, self-perceived ability, and what is obtained by successful completion of the task when deciding the maximum level of motivation and effort that is of value to complete a task. Difficulty increases effort initially, but once a threshold of impossibility is reached, effort drops off. Individuals who memorize a string of letters from two to ten report increasing difficulty and perform more poorly as the string length increases (Wright, Dill, Geen, & Anderson, 1998). The difficulty of the task steadily increases, but SBP reactivity peaks at six letters and drops at nearly impossible levels of memorization. Manipulating study time for memorizing letter strings leads to the same pattern of reactivity; as study time decreases from an easy 1000ms to an impossible 15ms, SBP and PEP reactivity increase until reaching the impossible difficulty and cardiovascular reactivity drops again (Richter, Friedrich, & Gendolla, 2008). The relationship between difficulty and cardiovascular reactivity is depicted in Figure 1. At the lowest difficulty levels, effort and cardiovascular reactivity to complete the task is minimal. As the number of letters increase or study time decreases, effort and resources need to be mobilized to a greater extent. However, there is a maximum level of effort that can be exerted to complete a task and when the task is impossible, effort is withheld leading to blunted cardiovascular reactivity.

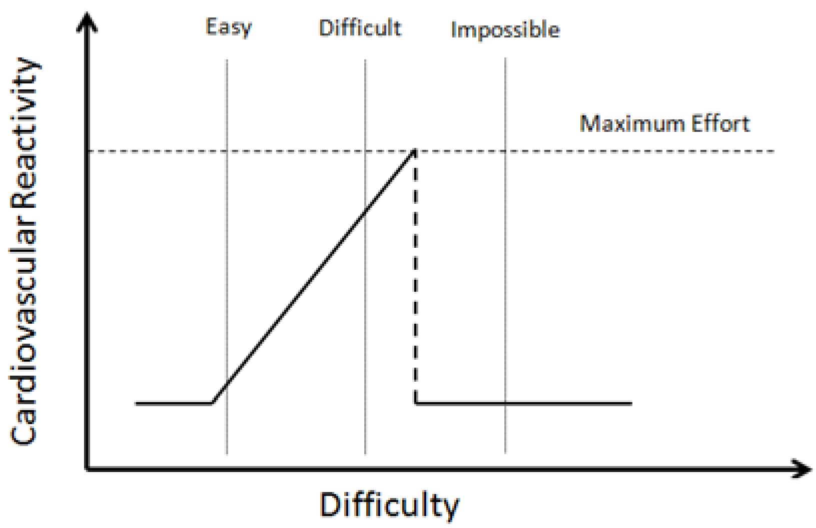

Figure 1. Relationship between difficulty and cardiovascular reactivity at a single ability level. Adapted from Wright & Dill (1993).

Self-perceived ability is the second factor in setting motivation. Ability influences effort in the opposite manner as difficulty, when self-perceived ability is higher, less effort is needed to successfully complete a task. Males and females given a task on which the opposite gender is purported to perform better respond with greater SBP reactivity compared to individuals informed those of the same gender usually perform better (Wright, Murray, Storey, & Williams, 1997). Self-perceived ability also interacts with the perceived difficulty of a task. Individuals who report lower ability at math demonstrate greater SBP increases when a task is easy, while high ability individuals have greater blood pressure reactivity when the task is difficult (Wright, Wadley, Pharr, & Butler, 1994). Also, individuals informed that they have poor ability at a task react with greater heart rate (Wright & Dismukes, 1995) and blood pressure (Wright & Dill, 1993) increases when given an easier goal, while those told they had strong ability have the greatest reactivity to a difficult goal. It is important to note the influence of ability is domain specific because poor feedback leads to greater blood pressure reactivity only when a task is identified as similar to the first, but not when the same task is identified as requiring different abilities (Wright & Hodges, 1999). Self-perceived ability shifts the difficulty in which increases in effort need to be exerted (Figure 2). Poor self-perceived ability either due to gender or math skills require individuals to begin exerting effort at a lower level. At easy difficulty levels, poor self-perceived ability leads to greater reactivity compared to individuals who believe a task will be easy and only need to exert a minimum amount of effort. However at the higher difficulty level, those with high self-perceived ability react with greater effort due to task completion still being possible, while those with poor self-perceived ability have blunted reactivity because the task is too difficult.

A third aspect that sets motivation is an evaluation of what is obtained by completing the task. Increasing rewards generally increases motivation and effort. Successful completion of the same task with increasing monetary reward results in greater heart rate (Fowles, Fisher, & Tranel, 1982), PEP (Richter & Gendolla, 2009), and blood pressure (Richter & Gendolla, 2007)

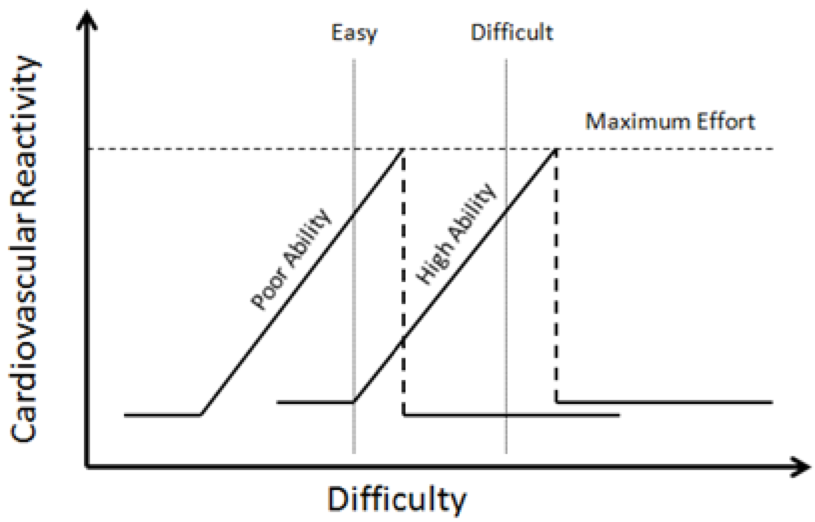

Figure 2. Relationship between difficulty and cardiovascular reactivity at multiple ability levels.

reactivity. Avoidance of performance-contingent aversive noise blasts also increases heart rate reactivity (Scher, Furedy, & Heslegrave, 1984), indicating both positive and negative outcomes are important to motivation and effort. Difficulty of the task is still important because increased PEP and blood pressure reactivity due to increased monetary reward have been shown to decrease when the task is impossible (Light & Obrist, 1983). Outcome contingency, how likely completion of a task results in a reward, also interacts with self-perceived ability. When men and women are given a task that men are purported to be better and then informed that meeting a certain performance standard yields either a low 1/15 chance of receiving a prize or a high 14/15 chance, women in the high reward chance demonstrate the greatest increase in SBP (Wright & Lockard, 2006). The influences of outcome contingency and self-perceived ability are seen in different dimensions of motivational arousal (Figure 3). While high self-perceived ability due to gender expectancy across both reward levels results in similar sympathetic reactivity as poor self-perceived ability at the lower reward level, the reasons may be different. When the self-perceived ability is high, only a minimal amount of effort to achieve a performance standard is needed. However, when self-perceived ability is poor and the chance of obtaining a reward is low, the task is not considered worthwhile to dedicate effort, leading to blunted reactivity even though the reward is desirable.

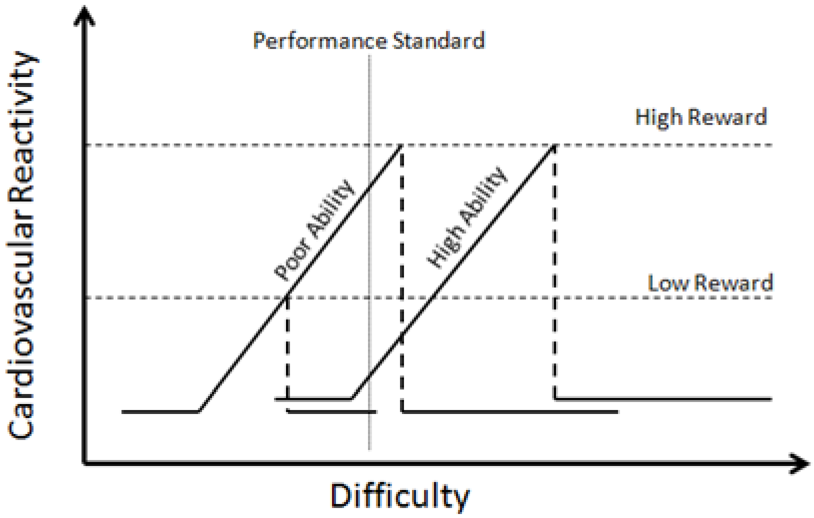

Figure 3. Relationship between difficulty and cardiovascular reactivity at multiple ability levels with a reward manipulation.

The motivational intensity theory clearly identifies how changes in difficulty, self-perceived ability, and outcome all contribute to motivational arousal. These motivational differences then influence the amount of effort exerted to complete a task. Individuals who are using only a minimum amount of effort to complete a task and those who are blunting effort due to a task being perceived as too difficult both react with similar low levels of sympathetic reactivity. While these individuals have similar levels of reactivity, the predictions are limited to the scope of task-related effort and sympathetic reactivity. The differences between using only a minimum amount of effort and those blunting effort may be observed during recovery following tasks.

Perseverative cognition hypothesis. Cardiovascular reactivity occurs in response to an acute stress, but stressful incidents may influence the cardiovascular system even when the stressor is not currently present. The perseverative cognition hypothesis identifies how repeated cognitive representations of stress, such as worry and rumination can cause continued physiological reactivity even when a stressor is not currently present (Brosschot, et al., 2006). Prolonged cardiovascular responses may increase the risk for CVD through excessive "wear-and-tear" of the system, which follows an allostatic load model of stress (McEwen, 2004). The influence of perseverative cognition on the cardiovascular system is often seen immediately following stressful cognitive tasks. For example, giving individuals distracting, non-stressful tasks following a mental arithmetic task with harassment results in better blood pressure recovery (Glynn, Christenfeld, & Gerin, 2002; Neumann, Waldstein, Sellers, Thayer, & Sorkin, 2004). The distracting tasks relate to fewer reported number of thoughts during recovery, suggesting that distractions improve recovery by preventing thoughts about the stressor. Individual differences also play a factor in perseverative cognition. Greater self-reported rumination following recovery is related to greater blood pressure during recovery (Radstaak, Geurts, Brosschot, Cillessen, & Kompier, 2011). Trait worry also predicts impaired recovery of heart rate and respiratory sinus arrhythmia (RSA), an index of parasympathetic nervous system functioning, following a purported measure of intelligence (Verkuil, Brosschot, de Beurs, & Thayer, 2009). Impaired recovery following the test of intelligence is additionally related to delayed recognition of control words compared to intelligence words on a lexical decision task, a task used to measure implicit cognitive associations. Perseverative cognition may be explicitly reported, but implicit thoughts may also be occurring.

Perseverative cognition may occur when individuals inhibit effort due to a task being too difficult but not when limited effort is due to a task being perceived as fairly easy. The emotional component that occurs when a task is perceived as too difficult may be important in eliciting perseverative cognition. During ambulatory recording, positive and negative emotions cause similar increases in heart rate, but five minutes later heart rate remains elevated only after negative events (Brosschot & Thayer, 2003). Maintained cardiovascular activity following negative events may contribute to the relationship between negative repetitive thoughts and poor health (Segerstrom, Roach, Evans, Schipper, & Darville, 2010). Negative thoughts about a previous task can result in perseverative cognition, but valence may not be the only precipitating factor. Repetitive thoughts can be focused on different targets, either internal or external. Individuals who have negative thoughts that are also introspective report the greatest level of depressive symptoms (Segerstrom et al., 2012), suggesting that the introspective nature of thoughts combined with negative valence is important in maintaining perseverative cognition and increasing the risk for disease. When individuals with poor self-perceived ability are given a high-contingency reward, a greater amount of effort is justified to complete the task. Repetitive thoughts following the task may be negative, but quickly resolved because enough effort is used so that potential failure can be attributed to the difficulty of the task. If effort is instead inhibited when a task is too difficult given a low-contingency reward, negative and introspective thoughts may occur maintaining perseverative cognition and impairing recovery of cardiovascular activity.

Parasympathetic Nervous System Reactivity and Recovery

The focus for decades of cardiovascular research has been how excessive sympathetic reactivity to stress increases the risk for CVD (Krantz & Manuck, 1984). In recent years, the parasympathetic nervous system has gained more prominence with Porges' polyvagal perspective (Porges, 1995, 2007). The polyvagal perspective identifies the evolutionary importance of the parasympathetic nervous system in social behaviors. The vagus is the 10th

cranial nerve and contains parasympathetic efferent and afferent neurons. According to Porges, during rest, the action of the vagus (specifically, the branch originating from the nucleus ambiguus) is to foster calm states and aid in social communication. During times of stress, the influence from this branch of the vagus over the heart withdraws, allowing the sympathetic nervous system to mobilize resources for action. The link between the parasympathetic nervous system and social behaviors may lead to a unique pattern of blunted reactivity and impaired recovery from stress in certain situations. Over repeated stressors, parasympathetic control over the cardiovascular system (Brosschot & Thayer, 1998) may be reduced and lead to an increased risk for CVD.

Respiratory sinus arrhythmia and self-regulation. Quantification of respiratory sinus arrhythmia (RSA) provides an index of the functioning of the parasympathetic nervous system, specifically the nucleus ambiguus. Greater tonic parasympathetic nervous system functioning as measured through resting RSA has often been linked to better emotional behaviors. In children, higher resting RSA predicts greater emotional reactivity to movies (Cole, Zahn-Waxler, Fox, Usher, & Welsh, 1996), suggesting emotional flexibility. The opposite relationship is seen in adults, where greater resting RSA predicts fewer displays of emotion to a negative film compared to those with lower resting RSA (Pu, Schmeichel, & Demaree, 2010). In adults, controlling emotions is socially acceptable suggesting RSA is related to self-regulation. Additionally, greater resting RSA predicts longer persistence at an unsolvable anagram task (Segerstrom & Nes, 2007), fewer false positives on a reaction time performance task (Hansen, Johnsen, & Thayer, 2003), and fewer anticipatory errors to cognitive reaction time tasks (Luft, Takase, & Darby, 2009). Greater resting RSA is related to better emotional self-regulation and performance on cognitive tasks that require self-regulation.

Resting RSA is important during rest and the benefits to social communication may be reflected in self-regulation. However during times of stress, parasympathetic cardiac control withdraws, eliciting a decrease in RSA, allowing the sympathetic nervous system to mobilize resources for action (Porges, 2007). In terms of reactivity, adequate RSA withdrawal may be related to greater flexibility in responding to stressful situations. Children who respond with greater RSA withdrawal to a sad film have more adaptive emotional responses and fewer depressive symptoms (Gentzler, Santucci, Kovacs, & Fox, 2009). In adults, greater RSA withdrawal to a stressful task is related to lower social anxiety (Movius & Allen, 2005). Blunted reactivity, i.e., reduced RSA withdrawal, is present in individuals with generalized anxiety disorder (Lyonfields, Borkovec, & Thayer, 1995; Thayer, Friedman, & Borkovec, 1996) and individuals with major depressive disorder (Bylsma, Salomon, Taylor-Clift, Morris, & Rottenberg, 2014; Rottenberg, et al., 2007), suggesting these individuals may have reduced flexibility to stressful events. Reduced RSA withdrawal may also be related to the use of self-regulation. Individuals asked to eat carrots instead of nearby cookies have reduced RSA withdrawal compared to those allowed to eat the cookies (Segerstrom & Nes, 2007). Eating carrots was rated as more difficult and effortful than eating cookies, suggesting self-regulation is effortful and can be seen as reduced RSA withdrawal. The link between the parasympathetic nervous system and self-regulation may be especially important in the development of CVD.

Self-regulation and cardiovascular disease. Hostility and anger, which often require self-regulation to avoid interpersonal conflict, have a strong relationship to the development of CVD (Chida & Steptoe, 2009). Brosschot and Thayer (1998) suggest that the link between hostility and CVD is not related to excessive sympathetic activity, but instead a reduction of parasympathetic control over the cardiovascular system. In daily life, hostile individuals are more likely to get angry, and social rules suggest it is more appropriate to inhibit anger instead of making overt expressions. Repeated inhibition of hostility and anger may result in sustained cardiovascular activity and be related to impaired parasympathetic control. Individuals high in trait hostility both have lower resting RSA, and respond to negative mood inductions with blunted reactivity and impaired recovery (Demaree & Everhart, 2004). Inhibition of anger may also lead to different hemodynamic patterns of blood pressure recovery compared to expression. Blood pressure is the result of two hemodynamic inputs, cardiac output (CO), the amount of blood pumped by the heart, and total peripheral resistance (TPR), a measure of how much constriction there is in the peripheral vasculature (Berntson, Quigley, & Lozano, 2007). While blood pressure may demonstrate the same level of reactivity across individuals, there may be variability in whether CO or TPR is driving the changes (Gregg, Matyas, & James, 2002). Individuals allowed to express anger towards a confederate following a debate demonstrate greater CO during recovery while those not able to express anger have greater TPR during recovery (Dorr, Brosschot, Sollers, & Thayer, 2007). Impaired TPR recovery is also seen in individuals with low socioeconomic status (Steptoe, Willemsen, Kunz-Ebrecht, & Owen, 2003), and may contribute to an increased risk for CVD in this population.

Self-regulation may be present in those inhibiting effort due to excessive difficulty compared to those exerting only a limited effort. Individuals with depression demonstrate greater sympathetic reactivity when a task is easy, but blunted reactivity when a task is difficult (Brinkmann & Gendolla, 2008). Similarly to low ability appraisals, negative mood increases the difficulty appraisal, and shifts the effort threshold to a lower level, leading to greater effort at easier difficulty and reduced effort at a lower level of difficulty. Sympathetic reactivity may be reduced, but individuals with depression may be using effortful self-regulation to prevent expending and wasting resources, identified by reduced RSA withdrawal. This may explain the blunted reactivity and delayed recovery of both the sympathetic and parasympathetic nervous system in individuals with depression (Rottenberg, et al., 2007; Salomon, et al., 2009). Individuals who inhibit effort on a possible task due to poor-self perceived ability may engage in perseverative cognition following the task, resulting in delayed recovery of the parasympathetic nervous system and blood pressure sustained through increased TPR. Differences in recovery due to self-regulation may then lead to reduced parasympathetic control over time and an increased risk for CVD.

Non-Cardiovascular Indices of Effort

The motivational intensity theory links sympathetic measurements such as SBP and PEP to effort. However, little work has been done beyond manipulating conditions to validate the relationship between effort and SBP and PEP. Additionally, other models propose that changes in PEP and SBP are not related to effort, but appraising the task as a challenge to be met and overcome (Blascovich, Mendes, Tomaka, Salomon, & Seery, 2003). Therefore, validating the relationship between PEP and SBP reactivity and effort using non-cardiovascular measures would seem prudent. Pupil diameter is controlled by the sympathetic and parasympathetic nervous systems, with the sympathetic nervous system dilating the pupils and the parasympathetic nervous system responsible for constriction (Beatty & Lucero-Wagoner, 2000). Due to the dual innervation, pupillometry (the measurement of pupil diameter) cannot be used to index the functioning of either branch, but pupil diameter reactivity often demonstrates changes in response to stressful cognitive tasks. Examining pupil diameter changes that are influenced by difficulty and ability may reveal how pupil diameter can be used to evaluate effort along with cardiovascular responses.

Pupil diameter reactivity changes with difficulty in a similar pattern as cardiovascular sympathetic measures. When individuals are given a mathematical transformation task at various difficulty levels, pupil diameter increases along with heart rate and skin conductance (Kahneman, Tursky, Shapiro, & Crider, 1969). At extremely high difficulty levels, pupil diameter reactivity also blunts when the task becomes impossible. When given either a 5, 9, or 13 digit span task, the pupil diameter increase between baseline and the recall of the first digit is greater when given 5 and 9 digits compared to 13 (Granholm, Asarnow, Sarkin, & Dykes, 1996). This pattern suggests that pupil diameter may be indexing the effort needed to remember 5 and 9 digits, but at an overload of 13 digits the task is too difficult and effort is withheld. The change in pupil diameter between the presentation of the last digit and recall of the first digit demonstrates a similar pattern, in which pupil diameter increases when individuals memorize 5 and 8 digits, but not when asked to memorize 11 (Cabestrero, Crespo, & Quiros, 2009). While both calculations may index a lack of effort, pupil diameter begins decreasing in the middle of presentation of the 13 number chain (Granholm, et al., 1996). Effort may already be reduced before the end of number presentation, so the change from baseline to number recall may be the best index of effort in overload conditions.

Self-perceived ability also influences pupil diameter responses in the opposite direction as difficulty. Individuals with higher scores on an intelligence test respond to a mental multiplication task with smaller pupil diameter increases across various difficulties, suggesting more effort in those with lower intelligence (Ahern & Beatty, 1979). However, when given two similar span tasks, individuals who have lower operational span ability have greater increases in pupil diameter when completing easier sets of a reading span task, while individuals with higher operational span have the greatest pupil diameter increase on more difficult sets of the reading span task (Heitz, Schrock, Payne, & Engle, 2008). Pupil responses demonstrate the similar difficulty and ability interaction as seen in sympathetic measures of reactivity suggesting the same link to effort.

Perseverative cognition may also affect pupil diameter recovery after tasks. Following the display of negative and personally relevant words, individuals with depression maintain greater pupil diameter during the few seconds of recovery immediately after the display of words (Siegle, Steinhauer, Carter, Ramel, & Thase, 2003). Sustained pupil diameter following the display of the negative and personally relevant words is also correlated with measures of trait rumination, reflecting the idea that negative and introspective thoughts may be important in delaying pupil diameter recovery. Using pupillometry with cardiovascular measures may be especially useful due to the different temporal aspects of pupil responses. If the immediate pupil diameter responses to a task are similar to cardiovascular measures that are recorded over a longer period, the relationships between pupillometry, cardiovascular measures, and effort and perseverative cognition can be better supported.

Current Study

The present study examined how delayed recovery may be related to blunted reactivity by examining motivation and self-regulation. The study was conducted using a 2 (ability feedback: poor, good) x 2 (reward: low-, high-contingency) factorial design. Ability feedback was manipulated by giving false feedback on a prior purported task of working memory related to a second purported task of working memory. The feedback was presented as an evaluation of performance compared to previous peers as either good or poor. Reward was manipulated by giving either a low- or high-contingency chance of winning a monetary prize if performance on the second task met a performance standard. Dependent measures included pre-ejection period

(PEP) to assess sympathetic nervous system activity and respiratory sinus arrhythmia (RSA) to assess parasympathetic nervous system activity. Heart rate and blood pressure, and the two hemodynamic components of blood pressure, cardiac output (CO) and total peripheral resistance (TPR), were also measured. Pupil diameter was collected continuously during the tasks as a non-cardiovascular index of effort and perseverative cognition during the task. The present study intended to address the following goals.

Specific Aim 1: Replicate previous findings that suggest effort and sympathetic reactivity are greatest when self-perceived ability is poor and there is a high-contingency reward.

Difficulty was held constant at a fixed overload condition. Both cardiovascular reactivity and pupil diameter may increase with cognitive load, so differences in performance with a full cognitive load may be related to changes in effort. When reward on this task is increased, the level of motivation should be raised and effort willing to be exerted increased. Further, self-perceived ability should interact with reward to influence both motivation and effort. Thus, when individuals believe they are poor at the task with a high-contingency reward, there will be large effort-based sympathetic cardiovascular reactivity. In those who believe they are poor at the task with a low-contingency reward, effort will be inhibited because completion of the task is not worthwhile. Individuals who believe the task is easy due to high self-perceived ability will also have smaller sympathetic cardiovascular reactivity because only a minimal effort will be necessary to successfully complete the task, giving the following hypotheses:

- PEP reactivity will be greater in individuals given poor feedback with a high-contingency reward compared to all other conditions.
- SBP reactivity will be greater in individuals given poor feedback with a high-contingency reward compared to all other conditions.

Specific Aim 2a: Identify how inhibited effort due to high task difficulty is different from a lack of effort due to an easy task. Self-regulation and perseverative cognition may lead to different patterns of parasympathetic reactivity and recovery.

While sympathetic reactivity is closely linked with effort, parasympathetic reactivity may be related to self-regulation. In individuals with good self-perceived ability as well as those with poor self-perceived ability with a high-contingency reward, greater withdrawal of the parasympathetic system should be seen to allow for engagement in the activity. Under poor self-perceived ability with a low-contingency reward, the task will be perceived as too difficult for the opportunity to gain a reward, so self-regulation will be used to avoid failure. Only in the poor-self perceived ability, low-contingency reward group, will blunted parasympathetic withdrawal be seen. This may then lead to impaired parasympathetic recovery giving the following hypotheses:

- RSA reactivity will be reduced in individuals given poor feedback with a low-contingency reward compared to all other conditions.
- RSA recovery will be impaired in individuals given poor feedback with a low-contingency reward compared to all other conditions.

Specific Aim 2b: Explore how perseverative cognition influences the hemodynamic profile of blood pressure recovery.

Inhibiting effort due to excess task difficulty may lead to perseverative cognition in those who have poor self-perceived ability with a low-contingency reward. Perseverative cognition should be greatest in these individuals because thoughts will be negative due to poor self-perceived ability and introspective due to inhibited effort. Additionally, perseverative cognition may lead to a unique pattern of hemodynamic recovery of blood pressure, giving the following hypotheses:

- Explicit and implicit perseverative cognition will be greatest in individuals given poor feedback with a low-contingency reward compared to all other conditions.
- TPR recovery will be impaired in individuals given poor feedback with a low-contingency reward compared to all other conditions.

Specific Aim 3: Use pupil diameter as a non-cardiovascular index of effort to provide additional support to the cardiovascular findings.

Task evoked pupil diameter change between baseline and recall of the first digit may be most related to the sympathetic related changes of effort. Therefore, individuals with poor self-perceived ability and a high-contingency reward will have greater increases in pupil diameter compared to all others. Pupil diameter in the recovery period following recall of numbers may be related to perseverative cognition, meaning individuals with poor self-perceived ability and a low-contingency reward may maintain greater pupil diameter compared to all other conditions, giving the following hypotheses:

- Pupil diameter reactivity will be greater in individuals given poor feedback with a high-contingency reward compared to all other conditions.
- Pupil diameter recovery will be impaired in individuals given poor feedback with a low-contingency reward compared to all other conditions.

Method

Participants

A total of 89 participants were recruited from the undergraduate pool at the University of South Florida. Age, gender, BMI, and waist to hip ratio are presented in Table 1. Data from seven participants were removed: Two participants were removed due to an excessive number of ectopic beats, two removed due to problems with the physiological collection, one due to reported hypertension, and two removed due to reports of suspicion about poor performance on the PASAT. Also, those who were taking medication that affects the cardiovascular system, had diabetes, or were pregnant were excluded, as these conditions independently affect cardiovascular reactivity and recovery. All participants were asked to avoid alcohol, caffeine, nicotine, nonprescription drugs, and physical exercise for 2 hours prior to coming to the lab. Participants were compensated with SONA credits and 20 US Dollars. The final groups consisted of 19 participants given poor feedback with the high-contingency reward, 22 poor feedback with the low-contingency reward, 20 good feedback with the high-contingency reward, and 21 good feedback with the low-contingency reward.

Measures

Health history questionnaire. A health history questionnaire was given to probe for smoking, alcohol, and medication use because all of these can influence reactivity (Appendix A). They were evaluated to ensure equal distribution of these factors across groups.

Motive to avoid failure. The six-item Motive to Avoid Failure (MaF: Hagtvet & Benson, 1997) instrument has been related to motivation under uncertain situations and measures test anxiety (Appendix B). The scale includes statements such as, "I am afraid of failing when I am given a task which I am uncertain that I can solve." In previous work in the lab, this scale predicted blunted reactivity and impaired recovery from a purported task of intelligence, so was used to ensure random assignment in those given poor and good feedback. No difference was found between participants who were assigned to receive poor (M = 12.80, SD = 4.48) and good (M = 14.05, SD = 4.15) feedback, $F(1,78) = 1.80$, *ns*. Participants assigned to receive the low-contingency reward (M = 14.42, SD = 4.89) had greater motive to avoid failure than participant assigned to receive the high-contingency reward (M = 12.33, SD = 3.37), $F(1,78) = 5.17$, $p < .05$, $\eta_p^2 = .06$. No interaction was found, $F(1,78) = 1.17$, *ns*.

Behavioral activation system drive. The four-item behavioral activation system (BAS) drive subscale (Carver & White, 1994) contains items related to the pursuit of a desired goal (Appendix C). This subscale includes statements such as, "When I want something, I usually go all-out to get it." This scale was used to ensure random assignment in those given the low- and high-contingency rewards. No difference was found between participants who were assigned to receive low-contingency (M = 7.74, SD = 2.47) and high-contingency (M = 7.87, SD = 2.81) reward, $F(1,78) = 0.05$, *ns*. No difference was found between participants who were assigned to receive poor (M = 7.71, SD = 2.54) and good (M = 7.90, SD = 2.73) feedback, $F(1,78) = 0.08$, *ns*, and no interaction was found, $F(1,78) = 1.11$, *ns*.

State emotion. State emotion was assessed before and after the two tasks (Appendix D). Participants scored a variety of emotions (e.g. anxiety, fear, pride) on a 9-point Likert scale ranging from "none" to "an extreme amount" (Rottenberg, Ray, & Gross, 2007).

Perseverative Cognition Measures

Pre- and post-task appraisals. Before each task, participants were asked to report their perceived ability on the task, difficulty of the task, and how hard they will try to complete the task, also on a 9-point Likert Scale (Appendix E). Additionally, before the second task, participants were asked to report the likelihood of winning money if the performance standard was met. Ability, difficulty, and effort ratings before both tasks and likelihood of obtaining the reward if the second task was performed successfully was used to evaluate the effectiveness of the ability and reward manipulations. Following a recovery period after each task, participants were asked to report difficulty and self-reported effort during the task. The participant also rated how much thinking about the previous task occurred during the recovery period, which was used as the measure of explicit perseverative cognition.

Lexical decision task. Implicit perseverative cognition was also measured using a lexical decision task (LDT: Verkuil, et al., 2009). Participants were shown a string of letters and were asked to decide if the string is a word or not a word. Each word was preceded by a fixation cross presented for 2000 ms. Participants had a maximum of 1000 ms to answer these questions. There were a total of 64 items presented, 8 words related to positive performance (e.g., triumph, dominant), 8 positive words not related to performance (e.g., brave, tolerant), and 16 neutral distracter words (table, piano). The remaining 32 items were non-words. Implicit perseverative cognition was calculated as the difference in reaction time between the performance-related words and positive control words.

Cardiovascular Reactivity Tasks

Paced auditory serial addition test (PASAT). The PASAT is a computerized task in which individuals are presented a string of numbers, and they are required to add the previous two numbers that were presented. The numbers were presented with interstimulus intervals between 750ms and 2500ms. This type of task has been used to elicit sympathetic reactivity characterized by mixed alpha- and beta- adrenergic response (Willemsen et al., 1998).

Digit span task. The digit span task used was a 13 digit overload task as used in previous studies (Granholm, et al., 1996). There were 5 trials each taking 36 seconds. The trial started with 3 seconds of preparation, 13 seconds of stimulus presentation, a 2 second delay, and 13 seconds of free recall, followed by a 5 second recovery before the next trial.

Physiological Recording Apparatus

A Biopac MP150 system was used to measure electrocardiogram (ECG), impedance cardiography and respiration signals. An ECG100 amplifier was recorded using Cleartrace LT disposable Ag/AgCl electrodes (Conmed Andover Medical, Haverhill, MA), placed in a modified Lead II configuration on the participant's chest. ECG was sampled at 1000 Hz. Respiration was measured with one TSD201 respiratory effort transducers placed around the chest and amplified using a RSP100C respiration amplifier sampling at 1000 Hz (Biopac Systems, Inc., Goleta, CA).

Impedance was measured using a Biopac NICO100C (Biopac Systems, Inc., Goleta CA). A small current measuring 0.4mA, 100kHz signal was transmitted through disposable aluminum/mylar band electrodes around the neck and chest according to published guidelines (Sherwood et al., 1990). Transthoracic impedance waveforms (Z_0, dZ/dt) were measured using a tetrapolar lead configuration. This signal was sampled at 1000Hz per channel by a PC. ECG, respiration, and impedance cardiography were acquired using AcqKnowledge 3.7.2 software (Biopac Systems, Inc.). Systolic (SBP) and diastolic (DBP) blood pressure were measured using a CNAP Monitor (CNSystems, Austria) to collect non-invasive blood pressure according to published guidelines (Shapiro et al., 1996).

Pupil diameter was measured with a head-mounted eyetracker collecting at 60Hz. Two pairs of infrared lights and cameras sensitive to infrared light were affixed to the set of lensless glasses and positioned several centimeters from the eye. The signals were collected from a computer using ViewPoint EyeTracker (Arrington Research, Scottsdale, AZ). The room had a fixed luminance (18 lx at location off the participant's eye during the digit span task) and the screen displayed a constant gray background with a black fixation cross during the task and recovery periods. Pupil diameter was calculated by fitting a circle over the pupil and calculating the major- and minor-axes of the circle. A ratio of major- to minor-axis was calculated and a ratio below 0.6 was used to classify a blink. Pupil diameter during blinks was linearly interpolated.

Procedure

Upon arrival, the participant was asked to read the consent form. Following consent, participants completed several questionnaires assessing food, caffeine, and nicotine consumption, as well as medication use, as these are known to affect cardiovascular responses. Participants also responded to the psychosocial measures at this time. After the questionnaires, the experimenter attached two bands of Mylar tape to the participant's neck and two bands around the torso according to published guidelines for impedance cardiography (Sherwood, et al., 1990). The experimenter then used alcohol to clean the skin beneath the right collarbone and beneath the left ribcage before placement of the two Ag-AgCl electrodes in a modified lead II configuration.

Participants were then seated in a comfortable chair, where the experimenter attached leads to the Mylar bands for impedance cardiography. A blood pressure cuff was then attached to the participant's non-dominant arm and several measurements were taken to ensure the equipment was working properly. Additionally, the eyetracker was placed on the head and a short calibration was conducted to establish gaze location. After the calibration, the distance from the camera to the pupil was measured for the calculation of pupil diameter in millimeters. The experimenter then left the room and instructed the participant to watch a neutral movie about Alaska for the ten-minute resting baseline period. This task was chosen because prior research indicated that a minimally demanding task (i.e., vanilla baseline) produces a more stable estimate of physiological function than a baseline with no task (Jennings, Kamarck, Stewart, Eddy, & Johnson, 1992). State emotion was measured immediately following conclusion of the movie.

Participants then had the instructions for the PASAT explained to them as a measure of working memory, in which parts of the task were almost impossible, and then given a small practice period. A pre-task questionnaire was given following practice that assessed believed ability on the task, difficulty of the task, and intended effort on the task. The PASAT was a recording lasting three minutes and was immediately followed by a five-minute recovery period. Following recovery, false feedback was given in which half the participants were told they performed in the 35th percentile of all others who had completed the task and half the participants were told they performed at the 76th percentile. A post-task questionnaire was used to ensure participants understood the feedback and was given with the performance ranking displayed. After the post-task questionnaire was completed, an additional five minutes of footage from the Alaska movie was played to allow for a return to baseline physiological levels. State emotion was measured again following the movie.

After the state emotion questionnaire, participants received instructions for the digit span task. The digit span task was phrased as an additional test of working memory that was also almost impossible to perform perfectly. Individuals were also told that if performance was better than 50% of all other individuals who had participated, they would earn a chance at winning 20 US dollars. In the low-contingency reward condition, this was a 1/15 chance to win the money while in the high-contingency reward condition, this was a 14/15 chance of winning. Participants then rated ability, difficulty, and effort as before the previous task, and were also asked to rate likelihood of winning the reward if successful. The digit span task was an audio file lasting three-minutes followed immediately by a ten-minute recovery period.

After the recovery period, individuals were given a five-button response box. Participants were then given instructions for the lexical decision task. Participants were told to place the index finger of the dominant hand on the middle button and return it there after each trial. The two adjacent buttons were labeled “Yes” and “No” and the participant was instructed to press either button with the index finger. The lexical decision task was presented and the timing was recorded using E-prime 2.0. A 10-item practice of 5 words and 5 non-words was presented, followed by the set of 64 words and non-words. After the lexical decision task, the second post-task questionnaire was given, followed by a final state emotion questionnaire, and debriefing.

Cardiovascular Data Reduction

RSA was calculated using MindWare HRV 2.51 Software module (MindWare Technologies, Ltd., Gahanna, OH). R-wave markers in the ECG signal were evaluated for artifacts by visual inspection and by the MAD/MED artifact detection algorithm (Berntson, Quigley, Jang, & Boysen, 1990) implemented in the MindWare software. Suspected artifacts were corrected manually (<1% of all R-waves needed correction). This approach accords with current guidelines for frequency domain methods to determine heart rate variability (Berntson et al., 1997). To arrive at minute-by-minute estimates of heart rate and RSA during baselines and tasks, a 60-second time series of inter-beat intervals (IBIs: the time in milliseconds between sequential ECG R spikes) was created from an interpolation algorithm that has a 250-ms sample time. This 60-second IBI time series was linearly-detrended, mean-centered, and tapered using a Hamming window. Spectral-power values were determined (in ms^2/Hz) with fast Fourier transformations, and the power values in the 0.15–0.50 Hz spectral bandwidth were integrated (ms^2). These spectral-power values were then natural-log transformed prior to statistical analyses because of distributional violations. The natural-logged spectral-power value in the 0.15–0.50 Hz bandwidth is the indicator of RSA for each minute.

Impedance-derived measures of pre-ejection period (PEP) and cardiac output (CO) were obtained using MindWare. The ECG and dZ/dt signals were ensemble-averaged over 60-s epochs. The data were screened for artifact by visual inspection. Mean arterial pressure (MAP) was calculated as (SBP + (2 * DBP)) / 3. Total peripheral resistance (TPR) was estimated using the formula TPR = (MAP/CO) * 80. MindWare was also used to calculate respiration rate from spectral analysis of thoracic impedance. The value of respiration obtained by analysis of thoracic impedance is highly related to that obtained by traditional strain-gauge measurement (Ernst et al., 1999).

Baseline, task, and recovery values for each measure were computed by averaging the values for each phase. Reactivity scores were calculated as the arithmetic difference between task and baseline averages (Llabre, Spitzer, Saab, Ironson, & Schneiderman, 1991). Recovery scores were also calculated as the arithmetic difference between recovery and baseline values.

RSA recovery will be calculated using only the first minute following each task, as RSA quickly changes and often rebounds above baseline in the first minute following a cognitive task (Mezzacappa, et al., 2001).

Eyetracking Data Reduction

Pupil diameter was calculated using CPSLab 11 (Scientific Assessment Technologies, Salt Lake City, UT). A Savitzky-Golay (Savitzky & Golay, 1964) filter was used to smooth the data using a 2^{nd} order polynomial over a 3000 ms window. Filtered data were visually inspected and remaining noise was linearly interpolated. Data were then averaged and second by second values were obtained. The distance from the pupil to the camera was then used to calculate pupil diameter in millimeters. Baseline values were calculated as the average of the 3 second baseline period. The change score from baseline to the first second of recall was used as pupil diameter reactivity, and the change from baseline to the average of the 5 seconds of recovery was used as the recovery measure.

Table 1

Baseline Demographics

Age

	Reward Availiability	Low		High			
		M	(SD)	M	(SD)	M	(SD)
Performance Feedback	Poor	20.14	(2.98)	19.79	(2.04)	19.98	(2.56)
	Good	20.43	(2.48)	20.35	(2.56)	20.39	(2.49)
		20.28	(2.72)	20.08	(2.31)		

Gender

	Reward Availiability	Low		High			
		Females	(%)	Females	(%)	Females	(%)
Performance Feedback	Poor	16	(72.7%)	14	(78.9%)	30	(73.2%)
	Good	19	(90.5%)	12	(60.0%)	31	(75.6%)
		35	(81.4%)	26	(66.6%)		

Body Mass Index

	Reward Availiability	Low		High			
		M	(SD)	M	(SD)	M	(SD)
Performance Feedback	Poor	25.23	(4.03)	23.24	(3.24)	24.31	(3.77)
	Good	24.23	(5.62)	23.29	(2.79)	23.76	(4.41)
		24.75	(4.82)	23.27	(2.98)		

Waist to Hip Ratio

	Reward Availiability	Low		High			
		M	(SD)	M	(SD)	M	(SD)
Performance Feedback	Poor	0.82	(0.13)	0.81	(0.07)	0.82	(0.11)
	Good	0.79	(0.06)	0.79	(0.08)	0.79	(0.07)
		0.81	(0.10)	0.80	(0.07)		

Results

Demographics

Age, gender, BMI, and waist to hip ratio are presented in Table 1. Two (feedback) x 2 (reward) ANOVAs were conducted on these demographic variables. Age was not different in participants assigned to receive either poor or good feedback, $F(1, 78) = 0.57$, *ns*, the low- and high-contingency rewards, $F(1, 78) = 0.14$, *ns*, or interaction between feedback and reward, $F(1, 78) = 0.06$, *ns*. BMI was also not different in those assigned to receive the different feedback, $F(1, 77) = 0.27$, *ns*, reward conditions, $F(1, 77) = 2.61$, *ns*, or interaction, $F(1, 77) = 0.09$, *ns*. Finally, no differences in waist to hip ratio were found in the different feedback, $F(1, 78) = 1.54$, *ns*, or different reward conditions, $F(1, 78) = 0.30$, *ns*, or interaction, $F(1, 78) = 0.02$, *ns*.

Random Assignment Checks

Baseline cardiovascular data. Two x 2 ANOVAs were used to identify differences in physiology before either manipulation. Baseline cardiovascular physiology is presented in Table 2. Participants assigned to receive poor feedback had significantly greater respiratory sinus arrhythmia (RSA), $F(1, 78) = 4.06$, $p < .05$, $\eta_p^2 = .05$, with marginally lower heart rate (HR), $F(1, 78) = 3.77$, $p = .056$, $\eta_p^2 = .05$, and total peripheral resistance (TPR), $F(1, 78) = 3.94$, $p = .051$, $\eta_p^2 = .05$, than those assigned to receive good feedback. No differences were found for pre-ejection period (PEP), $F(1, 78) = 0.004$, *ns*, systolic blood pressure (SBP), $F(1, 78) = 0.09$, *ns*, diastolic blood pressure (DBP), $F(1, 78) = 1.83$, *ns*, or cardiac output (CO), $F(1, 78) = 1.80$, *ns*.

Table 2

Baseline Cardiovascular Physiology

Heart Rate (beats/minute)

	Reward Availiability	Low M	Low (SD)	High M	High (SD)	M	(SD)
Performance Feedback	Poor	69.82	(7.62)	71.18	(9.74)	70.45	(8.58)
	Good	77.40	(10.10)	71.45	(9.01)	74.50	(9.93)
		73.52	(9.61)	71.32	(9.25)		

Pre-Ejection Period (ms)

	Reward Availiability	Low M	Low (SD)	High M	High (SD)	M	(SD)
Performance Feedback	Poor	120.67	(11.31)	115.17	(11.81)	118.12	(11.73)
	Good	119.70	(19.26)	115.73	(13.19)	117.77	(16.50)
		120.20	(15.52)	115.46	(12.37)		

Respiratory Sinus Arrhythmia (ln ms^2)

	Reward Availiability	Low M	Low (SD)	High M	High (SD)	M	(SD)
Performance Feedback	Poor	6.92	(0.92)	6.96	(0.93)	6.94	(0.91)
	Good	6.32	(1.12)	6.55	(1.47)	6.43	(1.29)
		6.63	(1.05)	6.75	(1.24)		

Systolic Blood Pressure (mmHg)

	Reward Availiability	Low M	Low (SD)	High M	High (SD)	M	(SD)
Performance Feedback	Poor	104.65	(7.13)	101.11	(13.44)	103.01	(10.55)
	Good	104.62	(9.52)	102.45	(7.77)	103.56	(8.67)
		104.64	(8.28)	101.79	(10.78)		

Diastolic Blood Pressure (mmHg)

	Reward Availiability	Low M	Low (SD)	High M	High (SD)	M	(SD)
Performance Feedback	Poor	66.94	(5.78)	64.04	(7.69)	65.59	(6.80)
	Good	70.46	(6.38)	64.47	(6.55)	67.54	(7.07)
		68.66	(6.27)	64.26	(7.04)		

Table 2 (Continued)

Total Peripheral Resistance ($dyn*s/cm^5$)

	Reward Availiability	Low		High			
		M	(SD)	M	(SD)	M	(SD)
Performance Feedback	Poor	846.60	(243.27)	869.02	(184.70)	856.99	(215.75)
	Good	998.14	(189.62)	902.97	(217.87)	951.71	(206.99)
		920.61	(229.32)	886.43	(200.47)		

Cardiac Output (L/minute)

	Reward Availiability	Low		High			
		M	(SD)	M	(SD)	M	(SD)
Performance Feedback	Poor	7.57	(1.61)	7.25	(1.30)	7.42	(1.45)
	Good	6.74	(1.16)	7.20	(1.73)	6.97	(1.47)
		7.15	(1.44)	7.23	(1.51)		

DBP was greater in those assigned to receive the low-contingency reward compared to those assigned to the high contingency condition, $F(1, 78) = 9.29$, $p < .05$, $\eta_p^2 = .11$. No HR, $F(1, 78) = 1.29$, *ns*, PEP, $F(1, 78) = 2.25$, *ns*, RSA, $F(1, 78) = 0.30$, *ns*, SBP, $F(1, 78) = 1.79$, *ns*, TPR, $F(1, 78) = 0.61$, *ns*, or CO, $F(1, 78) = 0.05$, *ns*, differences were found due to reward. A marginal interaction was also found in resting heart rate, participants assigned to receive poor feedback with the low-contingency reward had the lowest heart rate while those assigned to receive good feedback with the high-contingency reward had the greatest heart rate, $F(1, 78) = 3.28$, $p = .074$, $\eta_p^2 = .04$. No other interactions were found for PEP, $F(1, 78) = 0.06$, *ns*, RSA, $F(1, 78) = 0.14$, *ns*, SBP, $F(1, 78) = 0.10$, *ns*, DBP, $F(1, 78) = 1.12$, *ns*, TPR, $F(1, 78) = 1.58$, *ns*, or CO, $F(1, 78) = 1.39$, *ns*.

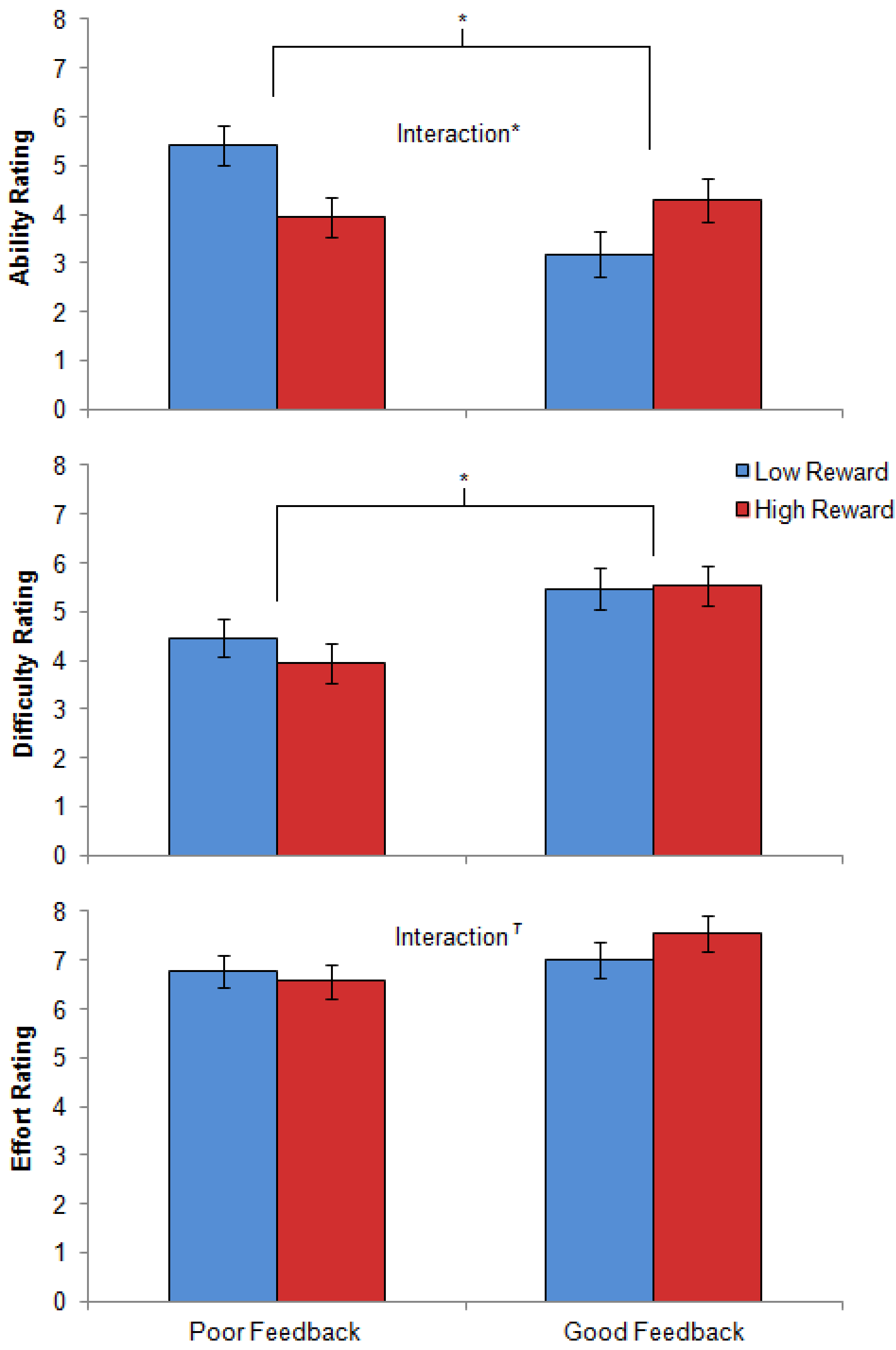

Figure 4. Self-reported ratings of ability, difficulty, and intended effort before the PASAT. All scales from 0-8. Error bars presented as ± *SEM*. $*p < .05$ $^{\dagger}p < .10$

PASAT task appraisal. Self-reported questionnaires of believed ability, task difficulty, and intended effort were given before each task. All questions were given on a 9-point Likert scale (0-8) and are presented in Figure 4. Two x 2 ANOVAs were used to evaluate differences between appraisals. An issue with random assignment was found before either manipulation; participants assigned to receive poor feedback after the PASAT rated themselves as having higher ability before the task, $F(1, 78) = 4.69$, $p < .05$, $\eta_p^2 = .06$. No difference between the reward conditions was found, $F(1, 78) = 0.17$, *ns*, but a significant interaction was found, $F(1, 78) = 8.91$, $p < .05$, $\eta_p^2 = .10$. The greatest ability at the PASAT was reported in those assigned to receive poor feedback with the low-contingency reward and reported ability was lowest in those assigned to receive good feedback with the low-contingency reward.

Self-reported difference in ability may have also influenced how participants perceived difficulty before the PASAT. Participants assigned to receive poor feedback rated the PASAT as easier than those who were assigned to receive good feedback, $F(1,78) = 10.87$, $p < .05$, $\eta_p^2 = .12$. No difference was found on difficulty between those assigned to receive the different reward contingencies, $F(1, 78) = 0.30$, *ns*, and no interaction, $F(1, 78) = 0.53$, *ns*.

Greater ability and lower difficulty in participants assigned to receive poor feedback was also related to marginally lower effort in those assigned to receive poor feedback, $F(1, 78) = 2.84$, $p = .096$, $\eta_p^2 = .04$. No differences in self-reported effort were found between those assigned to receive the different reward contingencies, $F(1, 78) = 0.34$, *ns*, nor interaction between the feedback and reward, $F(1, 78) = 1.19$, *ns*.

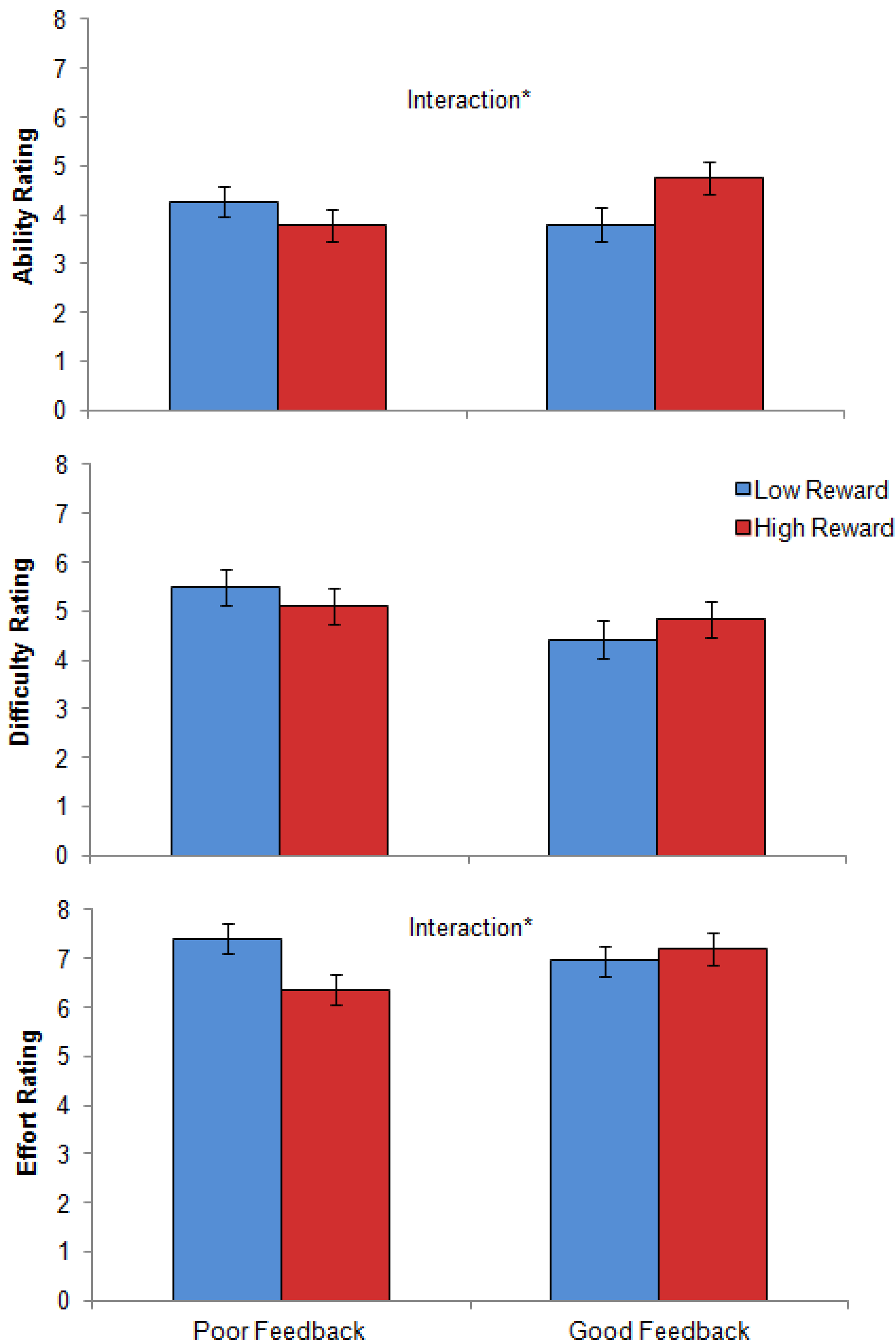

Figure 5. Self-reported ratings of ability, difficulty, and intended effort before the digit span task. Error bars presented as ± *SEM*. *p < .05

Specific Aim 1: Effort and Sympathetic Reactivity

Span task appraisal. The same appraisal of ability, difficulty, and intended effort were also given before the digit span task (Figure 5). Self-reported ability before the digit span task was not different between those who received poor and good feedback, $F(1, 78) = 0.60$, *ns*, or the low- and high-contingency rewards, $F(1, 78) = 0.51$, *ns*. A similar significant interaction was found as before the PASAT, $F(1, 78) = 4.91$, $p < .05$, $\eta_p^2 = .06$. Participants who received good feedback with the high-contingency reward reported the greatest ability, and ability was also high in those who received poor feedback with the low-contingency reward. Due to the random assignment issue of self-reported ability before the PASAT, multiple regression was conducted to determine the influence of initial self-reported PASAT ability, and feedback and reward conditions on ability rating before the digit span task. Greater reported ability before the PASAT predicted greater self-reported ability on the digit span task ($b = 0.37$, $\beta = 0.52$, $t(78) = 5.17$, $p < .05$). Participants who received good feedback following the PASAT also reported higher ability before the digit span task compared to those who received poor feedback ($b = 0.58$, $\beta = 0.20$, $t(78) = 1.97$, $p = .052$). Participants given the low-contingency reward did not rate ability differently than those given the high-contingency reward ($b = -0.29$, $\beta = -0.10$, $t(78) = -1.03$, *ns*).

Participants who received poor feedback during the PASAT reported that the digit span task was marginally more difficult than those who received good feedback, $F(1, 78) = 3.29$, $p = .073$, $\eta_p^2 = .04$. Difficulty was not influenced by the different reward contingencies, $F(1, 78) = 0.001$, *ns*, nor was there an interaction between feedback and reward, $F(1, 78) = 1.25$, *ns*. Another multiple regression was conducted to identify how the difficulty rating of the PASAT, and feedback and reward conditions influenced self-reported ratings of difficulty on the digit span task. Self-reported difficulty on the PASAT marginally predicted reported difficulty on the digit span task (*b* = 0.18, *β* = 0.21, *t*(78) = 1.80, *p* = .075). Participants given good feedback following the PASAT reported that the digit span task was easier compared to participants given poor feedback (*b* = -0.92, *β* = -0.28, *t*(78) = -2.40, *p* < .05). As with ability, low-contingency reward did not relate to different difficulty ratings from the high-contingency reward (*b* = -0.05, *β* = -0.02, *t*(78) = -0.15, *ns*).

Effort on the digit span task did not differ due to feedback, *F*(1, 78) = 0.34, *ns*, nor reward contingency, *F*(1, 78) = 1.19, *ns*. A significant interaction was found in which reported effort was greatest in those who received poor feedback with the low-contingency reward and good feedback with the high-contingency reward, *F*(1, 78) = 4.24, *p* < .05, η_p^2 = .05.

Likelihood of winning the reward if the performance standard was met was also measured. Participants given the high-contingency reward rated the chance of winning as more likely (*M* = 5.77, *SD* = 2.38) than those who received the low-contingency reward (*M* = 1.86, *SD* = 1.67), *F*(1,78) = 75.45, *p* < .05, η_p^2 = .49. No difference was found between those given the poor feedback (*M* = 3.37, *SD* = 2.90) and good feedback (*M* = 4.07, *SD* = 2.72), *F*(1,78) = 2.01, *ns*. No interaction was found between feedback and reward, *F*(1,78) = 1.03, *ns*.

Sympathetic reactivity to the digit span task. To test the hypothesis that sympathetic reactivity and effort would be greatest in participants who had poorer ability with a high likelihood reward, planned comparisons were used to evaluate SBP and PEP in those given poor feedback with the high-contingency reward compared to all others. SBP reactivity was not different in participants given poor feedback with the high-contingency reward (*M* = 10.74, *SD* = 7.02) and all other conditions (*M* = 10.00, *SD* = 7.53), *F*(1, 78) = 0.15, *ns*. PEP reactivity also did not differ between participants given poor feedback with the high-contingency reward (*M* = -6.39, *SD* = 7.62) and all other conditions (*M* = -8.72, *SD* = 5.93), *F*(1, 77) = 2.12, *ns*. Due to the

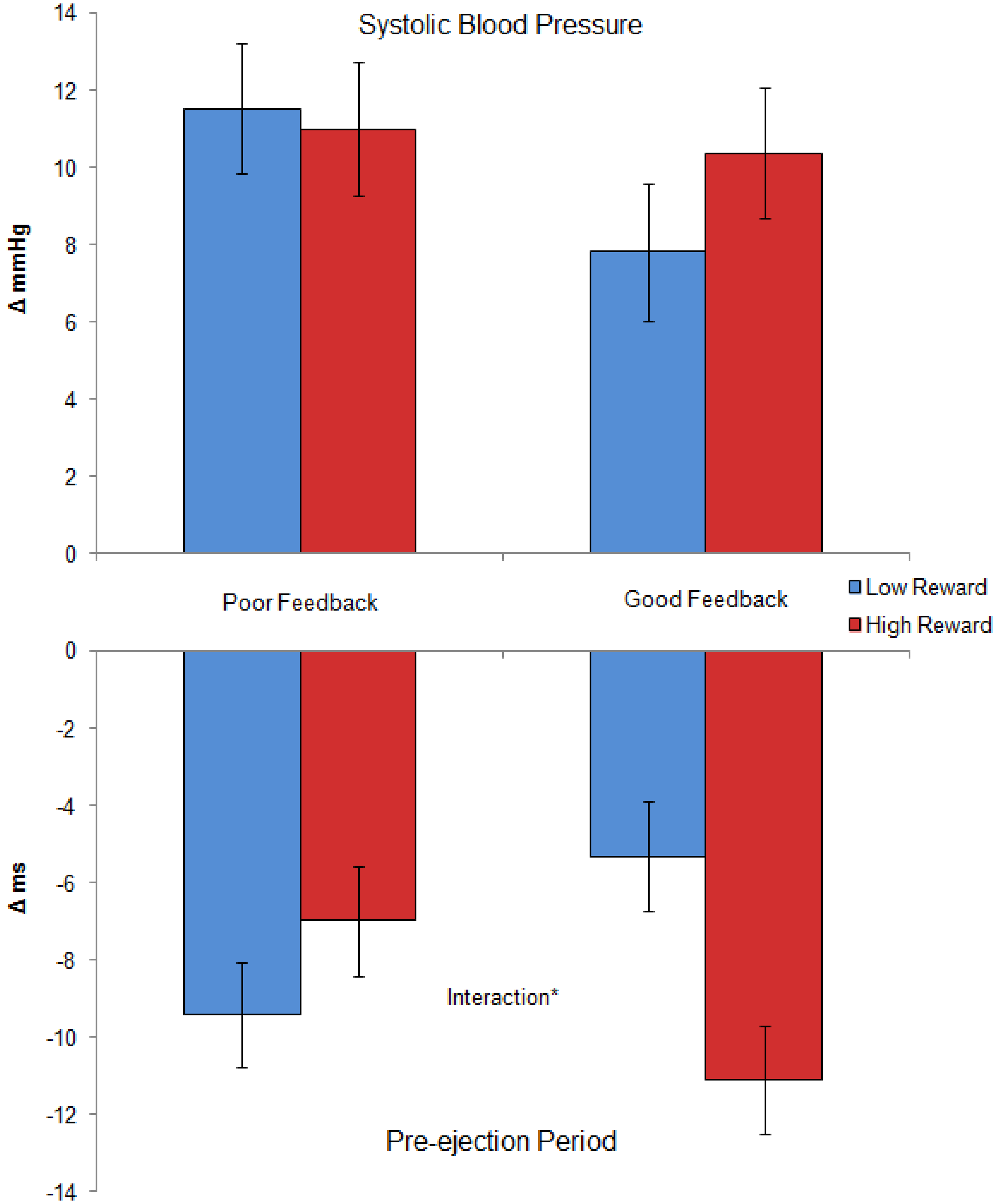

Figure 6. Sympathetic reactivity to the digit span task as change scores from resting. Data presented are adjusted for covariates. Note that greater decreases in PEP indicate greater increases in sympathetic reactivity. Error bars presented as ± *SEM*. **p* < .05

issues with random assignment, follow-up 2 x 2 ANCOVAs were run with initial working memory ability (self-reported PASAT ability), level of test anxiety (motive to avoid failure), and resting SBP or PEP included as covariates (Figure 6). SBP did not differ due to feedback, $F(1, 75) = 1.61$, *ns*, reward, $F(1, 75) = 0.34$, *ns*, nor was an interaction found between the two, $F(1, 75) = 0.78$, *ns*. No difference in PEP was found due to feedback, $F(1, 74) = 0.00$, *ns*, or reward, $F(1, 74) = 1.41$, *ns*, but a significant interaction between ability feedback and reward was found on PEP, $F(1, 74) = 8.14$, $p < .05$, $\eta_p^2 = .10$. PEP reactivity was greatest in those given poor feedback with the low-contingency reward and good feedback with the high-contingency reward.

Specific Aim 2a: Effort and Parasympathetic Reactivity and Recovery

Another goal was to identify how blunted effort due to excessive task difficulty and low effort due to task ease could result in different patterns of parasympathetic reactivity and recovery. Planned comparison ANOVAs were conducted comparing the poor feedback with low-contingency reward condition against the other three conditions. The planned comparison for RSA reactivity found no difference between poor feedback with the low-contingency reward ($M = -0.61$, $SD = 0.65$) and all other conditions ($M = -0.35$, $SD = 0.63$), $F(1, 78) = 2.61$, *ns*. Another exploratory 2 x 2 ANCOVA was conducted on RSA reactivity, covarying baseline self-reported ability, test anxiety, and resting RSA (Figure 7). RSA reactivity was not different due to feedback, $F(1, 75) = 0.59$, *ns*. reward, $F(1, 75) = 1.27$, *ns*, or interaction between feedback and reward, $F(1, 75) = 0.05$, *ns*.

Along with blunted RSA reactivity, participants given poor feedback with the low-contingency reward were also predicted to differ in RSA recovery. The planned comparison of RSA recovery found no difference between participants given poor feedback with the

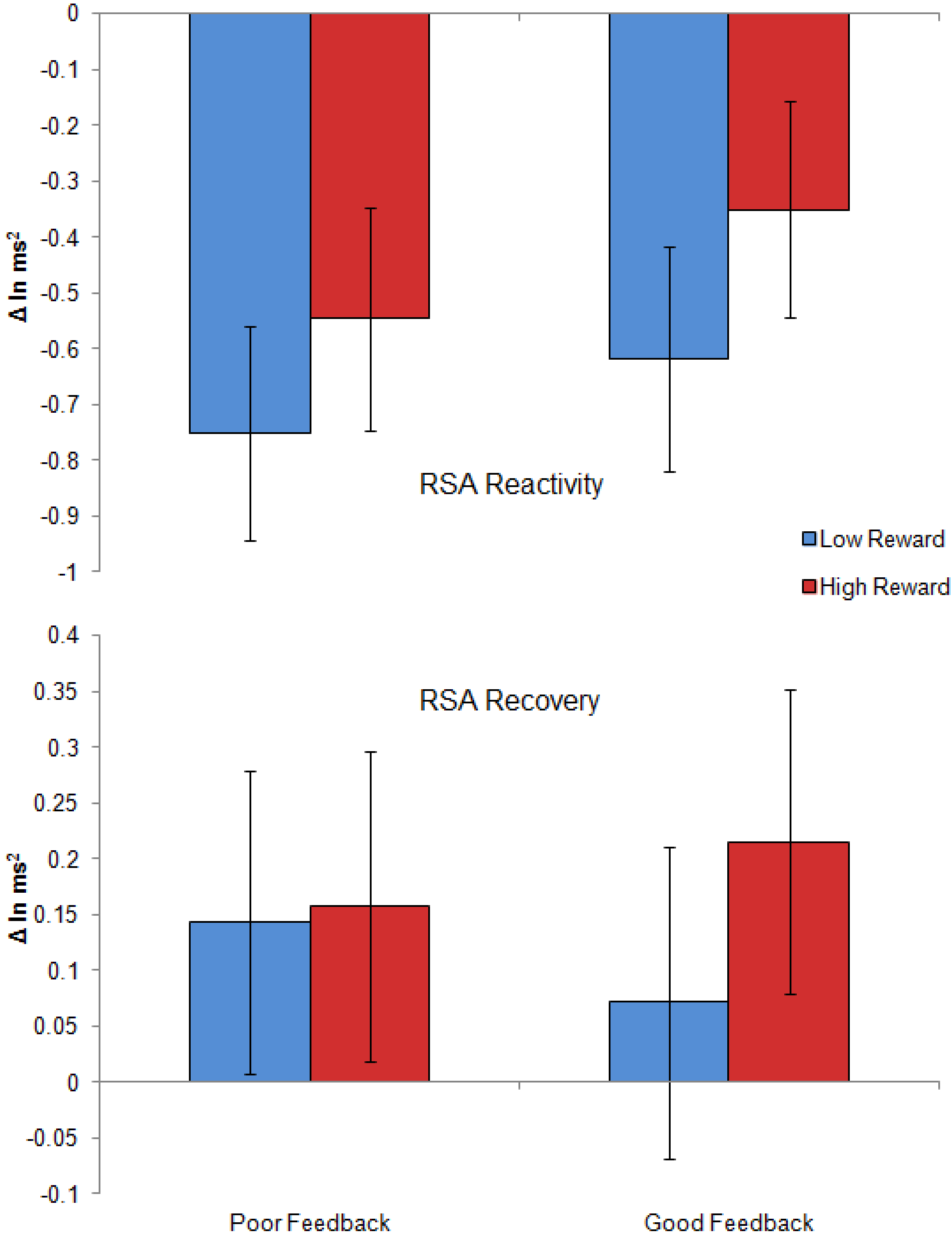

Figure 7. Parasympathetic reactivity and recovery to the digit span task as change scores from resting. Note that larger decreases in RSA indicate greater reactivity. Data presented are adjusted for covariates. Error bars presented as <u>+</u> *SEM*.

low-contingency reward (*M* = 0.07, *SD* = 0.60) and all other conditions (*M* = 0.17, *SD* = 0.61), *F*(1, 78) = 0.47, *ns*. The exploratory ANCOVA of RSA recovery using the same covariates as reactivity plus RSA reactivity found no effect of feedback, *F*(1, 74) = 0.003, *ns*, reward, *F*(1, 74) = 0.32, *ns*, or interaction between the two, *F*(1, 74) = 0.22, *ns*.

Specific Aim 2b: Perseverative Cognition and Hemodynamic Recovery

Explicit and implicit persevertive cognition. Following the digit span task, participants were asked to report how much they thought about the task during the recovery period on a scale from 0-8. The planned comparison of those given poor feedback with the low-contingency reward (*M* = 4.14, *SD* = 2.51) and all other groups (*M* = 4.10, *SD* = 2.50) found no difference, *F*(1,78) = 0.01, *ns*. An exploratory 2 x 2 ANCOVA was conducted controlling for baseline self-reported ability and task anxiety. No differences were found due to feedback, *F*(1,76) = 1.31, *ns*, reward, *F*(1,76) = 0.10, *ns*, or interaction between feedback and reward, *F*(1,76) = 0.55, *ns*. Implicit perseverative cognition was obtained by subtracting the time needed to identify performance related words from positive control words. All of the groups identified the performance related words slightly faster than the control words, but there was no differences between participants given poor feedback with the low-contingency reward (*M* = -21.58, *SD* = 49.38) and the other groups combined (*M* = -17.46, *SD* = 67.17), *F*(1,78) = 0.06, *ns*. The exploratory 2 x 2 ANCOVA controlling for the same baseline factors as explicit perseverative cognition found no differences due to feedback, *F*(1,73) = 0.05, *ns*, reward, *F*(1,73) = 0.15, *ns*, or interaction between feedback and reward, *F*(1,78) = 0.42, *ns*. Explicit and implicit measures of perseverative cognition are presented in Figure 8.

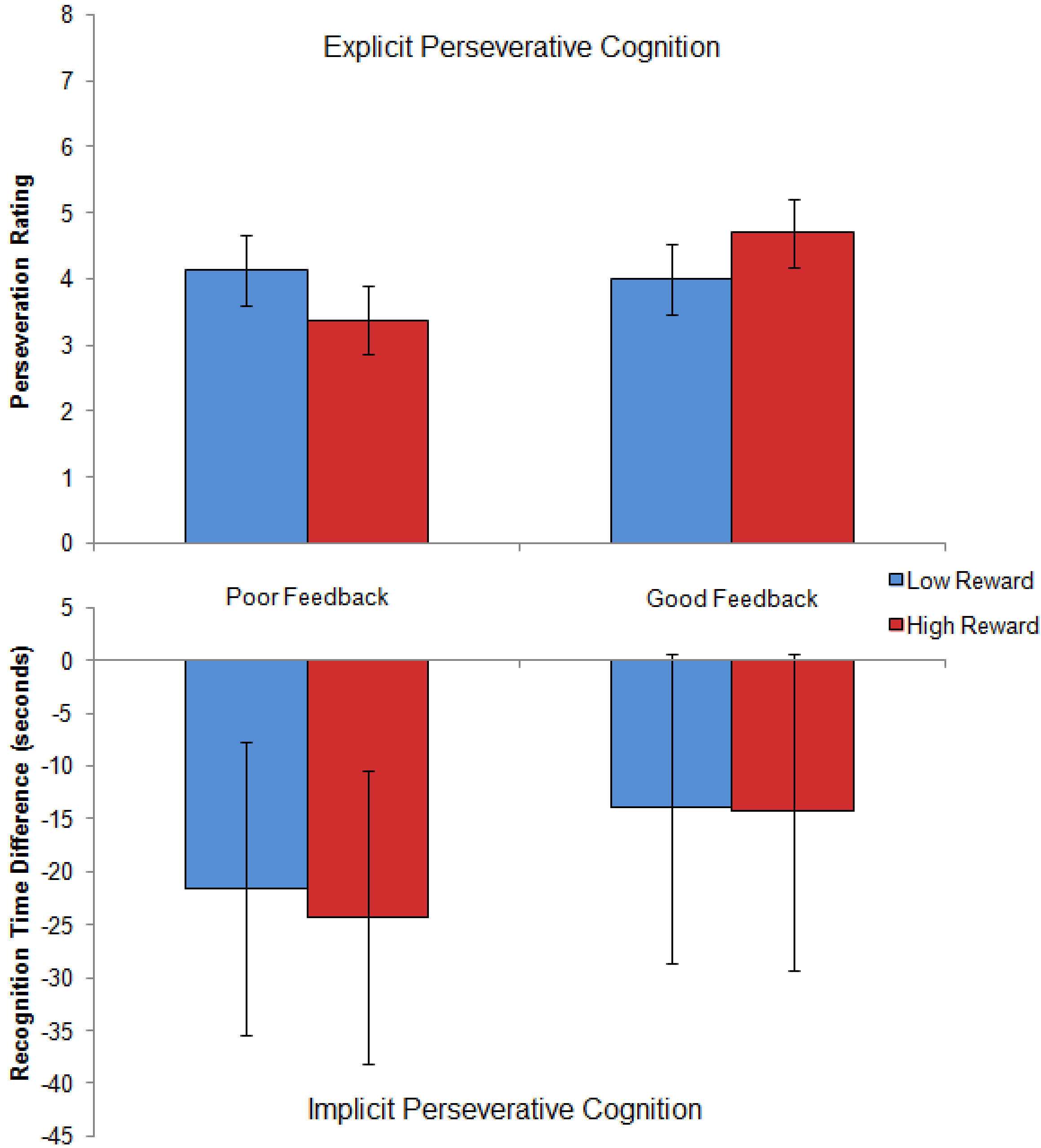

Figure 8. Explicit perseverative cognition from self reported scale (0-8) and implicit perseverative cognition (the difference between recognition time of performance related words to positive control words). Data presented are adjusted for covariates.

Hemodynamics of blood pressure recovery following the digit span task. Participants given poor feedback with the low-contingency reward were predicted to have impaired recovery of TPR following the digit span task. To identify if overall blood pressure recovery was different, a series of 2 x 2 ANCOVAs were conducted with baseline ability, test anxiety, and resting and reactivity measures of SBP or DBP (Figure 9). No difference in SBP recovery was found due to feedback, $F(1,73) = 0.04$, *ns*, reward, $F(1,73) = 1.29$, *ns*, or interaction between feedback and reward, $F(1,73) = 0.58$, *ns*. DBP recovery also did not differ due to feedback, $F(1,73) = 0.84$, *ns*, reward, $F(1,73) = 2.48$, *ns*, or interaction between feedback and reward, $F(1,73) = 0.26$, *ns*.

A planned comparison was used to identify if TPR recovery was impaired in those given poor feedback with the low-contingency reward compared to all other groups. TPR recovery was not different between participants given poor feedback with the low-contingency reward ($M = -18.71$, $SD = 34.56$) and all other conditions ($M = -27.11$, $SD = 51.57$), $F(1, 75) = 0.48$, *ns*. A follow-up 2 x 2 ANCOVA using the same covariates as blood pressure recovery found no effect of feedback, $F(1, 71) = 0.02$, *ns*, reward, $F(1, 71) = 0.05$, *ns*, or interaction between the two, $F(1, 71) = 0.07$, *ns*. The 2 x 2 ANCOVA evaluating the other hemodynamic component of blood pressure recovery found no difference in cardiac output (CO) recovery due to feedback, $F(1, 72) = 0.09$, *ns*, reward, $F(1, 72) = 1.14$, *ns*, or interaction between the two, $F(1, 72) = 1.27$, *ns*.

Specific Aim 3: Effort and pupil diameter

The hypotheses about pupil diameter were evaluated using two planned comparisons. The increase in pupil diameter from baseline of the span task to the first second of recall was not greater in participants given poor feedback with the high-contingency reward ($M = 0.24$, $SD = 0.17$) compared to all others ($M = 0.24$, $SD = 0.25$), $F(1, 71) = 0.002$, *ns*.

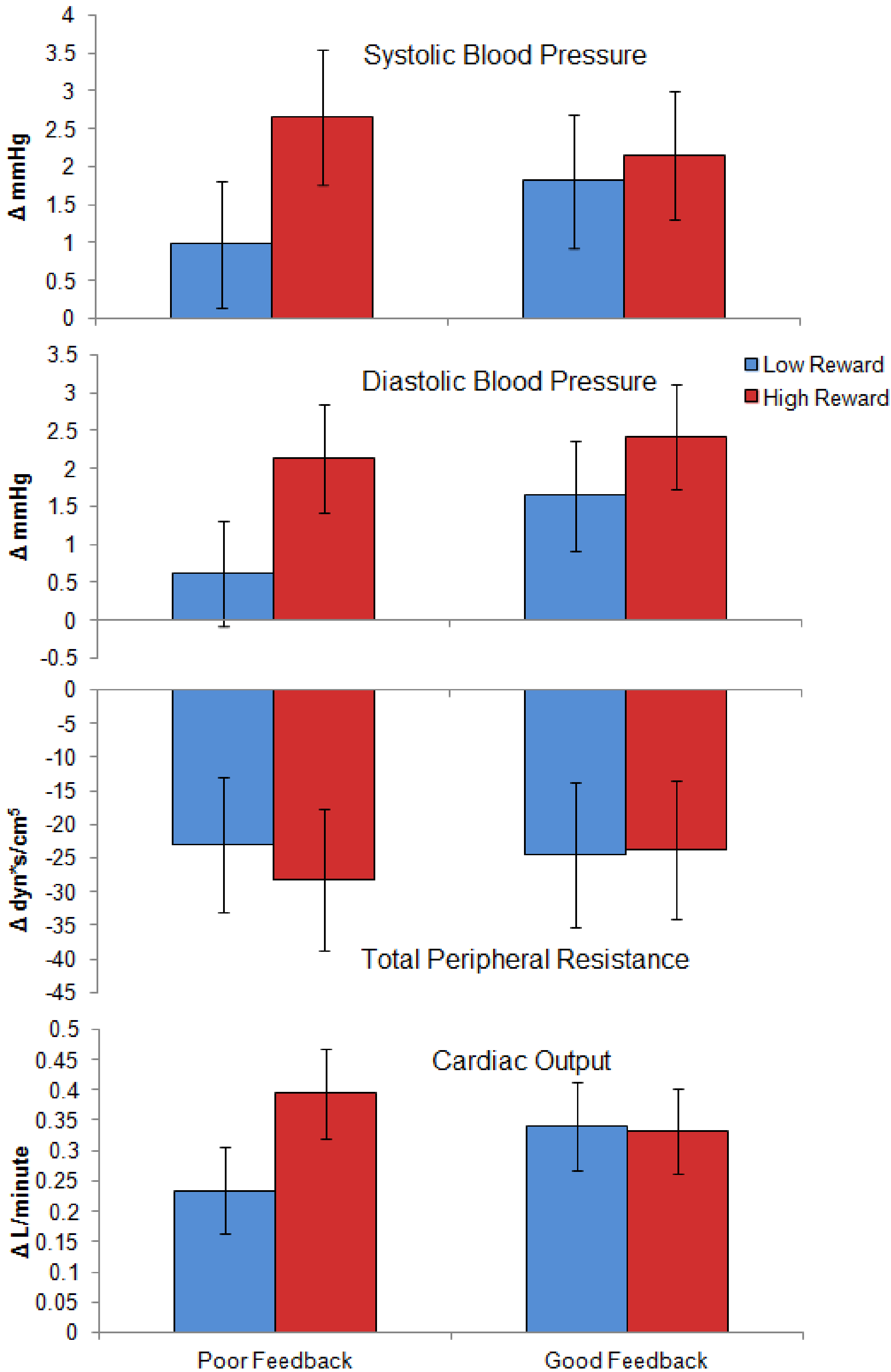

Figure 9. Blood pressure and hemodynamic recovery following the digit span task as change scores from resting. Note that larger values indicate more impaired recovery. Data presented are adjusted for covariates. Error bars presented as ± *SEM*.

Follow-up 2 x 2 ANCOVA of pupil diameter reactivity found no effect of feedback, $F(1, 68) = 0.00$, *ns*, reward, $F(1, 68) = 0.31$, *ns*, or interaction between the two, $F(1, 68) = 0.09$, *ns*. Pupil diameter recovery also was not impaired in participants given poor feedback with the low-contingency reward ($M = 0.04$, $SD = 0.18$) compared to all others ($M = 0.002$, $SD = 0.20$), $F(1, 72) = 0.48$, *ns*.

Follow-up 2 x 2 ANCOVA of pupil diameter recovery found no effect of feedback, $F(1, 67) = 0.49$, *ns*, reward, $F(1, 67) = 0.19$, *ns*, or interaction between the two, $F(1, 67) = 2.04$, *ns*.

Pupil diameter was included in the current study to provide additional validation for the relationship between sympathetic cardiovascular reactivity and effort. To understand if pupil diameter reactivity was related to a similar aspect of effort as sympathetic cardiovascular responses, we conducted correlations between, SBP, PEP, pupil diameter reactivity and effort (Table 3). Greater PEP and SBP reactivity, the two sympathetic measures, were correlated with each other ($r = -.45$, $N = 81$, $p < .05$). Unfortunately pupil diameter was not correlated to either sympathetic measure and self-reported effort was not related to any physiological measure.

Table 3

Correlations Between Physiological Reactivity and Effort on the Digit Span Task

Variable	1	2	3	4
1. Systolic Blood Pressure	-			
2. Pre-Ejection Period	-.45*	-		
3. Pupil Diameter	-.06	.02	-	
4. Self-Reported Effort	-.14	-.06	-.15	-

Note. *p < .05

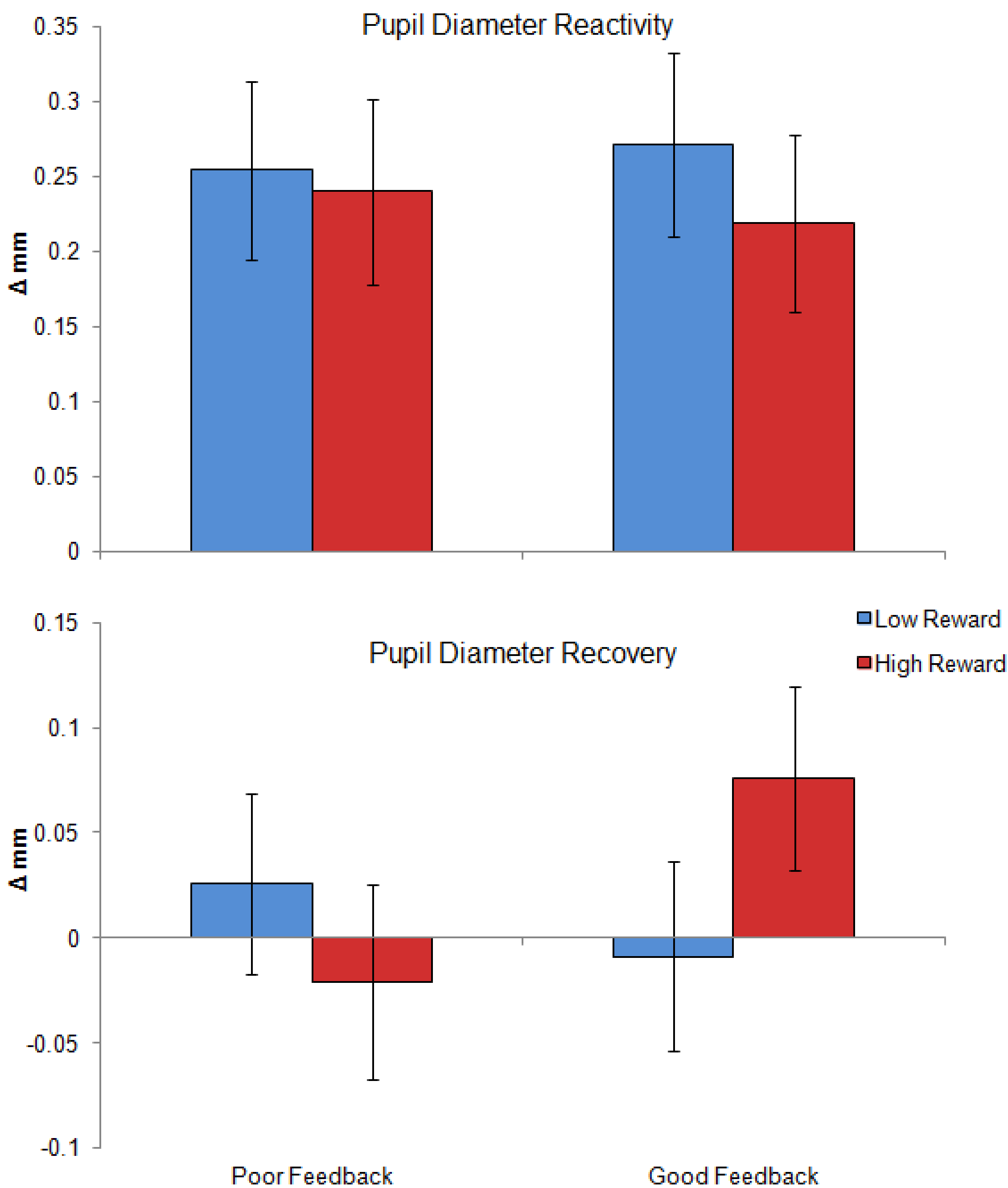

Figure 10. Pupil diameter reactivity calculated as change in diameter from baseline to the recall of the first digit. Pupil diameter recovery calculated as the change of the average of recovery from the average of baseline. Data presented are adjusted for covariates. Error bars presented as ± *SEM*.

Task Performance

Given the self-reported differences in perceived ability and difficulty of the PASAT, difference in the performance of the PASAT was tested. No difference in performance as measured by correct responses was found between those assigned to receive poor feedback (*M* = 31.95, *SD* = 10.75) and good feedback (*M* = 31.66, *SD* = 8.37), $F(1, 78) = 0.002$, *ns*. Nor was there a difference between those assigned to the low-contingency reward (*M* = 32.81, *SD* = 9.31) and high-contingency reward (*M* = 30.69, *SD* = 9.87), $F(1, 78) = 1.00$, *ns*. No interaction between feedback and reward was found, $F(1, 78) = 1.85$, *ns*. Performance on the digit span was scored giving one point for numbers recalled in the correct order and subtracting one point for any omissions or insertions of incorrect numbers. Additionally two numbers recalled in reverse order were given a single point. During the digit span task, no difference was found between those given poor feedback (*M* = -0.06, *SD* = 1.79) and good feedback (*M* = -0.23, *SD* = 1.89), $F(1, 78) = 0.19$, *ns*. No difference was found between those given the low-contingency reward (*M* = -0.005, *SD* = 1.84) and high-contingency reward (*M* = -0.30, *SD* = 1.84), $F(1, 78) = 0.51$, *ns*. No interaction was found on the performance of the digit span task, $F(1, 78) = 0.30$, *ns*.

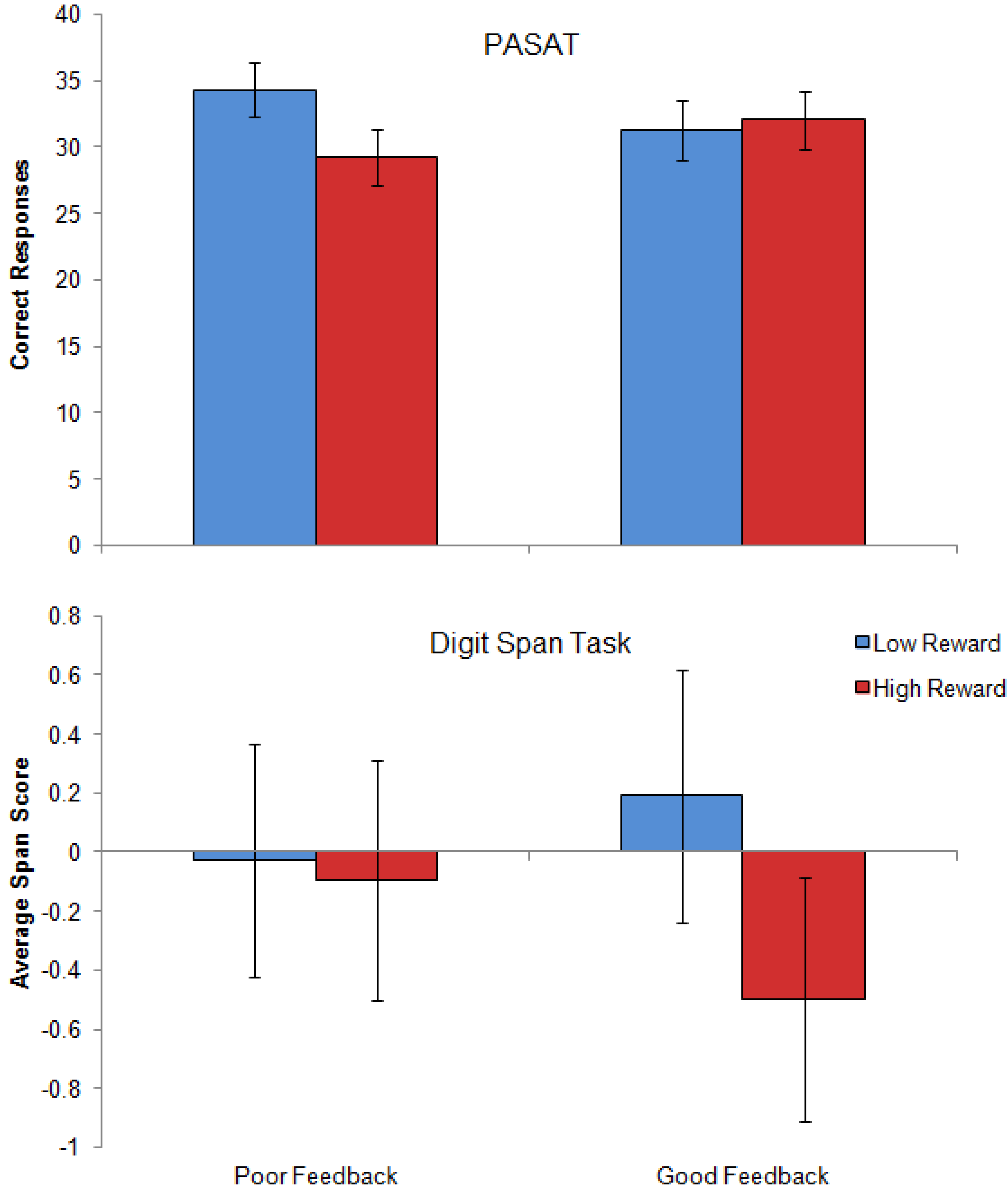

Figure 11. Performance on the PASAT scored as correct number of responses. Performance on the digit span task scored using the same system as previous studies (Peavler, 1974). Error bars presented as ± *SEM*.

Discussion

The primary hypothesis that sympathetic reactivity during the digit span task, measured through PEP and SBP, would be greatest in those given poor feedback with the high-contingency reward was not supported by the data. Instead, PEP reactivity was greatest in those given poor feedback with the low-contingency reward and good feedback with the high-contingency reward. Although the primary hypothesis was not supported, one aim of this study was to examine how sympathetic reactivity and effort may be related as proposed in the motivational intensity theory (Brehm & Self, 1989). Before the digit span task, the same interaction was found in self-reported effort; participants given poor feedback with the low-contingency reward and good feedback with the high-contingency reward reported the greatest level of effort. The greater PEP reactivity and effort ratings found in these groups provides some support for a link between sympathetic reactivity and effort.

The interaction found in the present study may be due to the problem with random assignment of self-reported ability. Before the manipulation of feedback and contingency, an interaction in self-reported ability was found in which those to be assigned to receive poor feedback with the low-contingency reward and those assigned to receive good feedback with the high-contingency reward reported having the greatest ability. The same interaction of self-reported ability was maintained before the digit span task. Reported ability may have influenced reactivity because of the designed difficulty of the cognitive task. The digit span task was designed to maximize cognitive load in order to identify sympathetic changes of effort that are beyond cognitive load. Even though the groups were given different performance feedback on the PASAT as compared to others and achievement was based on relative performance compared to peers, all participants may have identified the task as difficult due to the high cognitive load. If participants identified the task as difficult, the greater sympathetic reactivity of higher ability participants is similar to what is generally found when ability is crossed with difficulty (Wright & Dill, 1993; Wright & Dismukes, 1995; Wright et al, 1994). The random assignment problems combined with the high cognitive load of the task may be the reason for the PEP interaction.

The inability for the false feedback manipulation to overcome pre-existing differences suggests that the feedback manipulation was not influential enough to achieve the intended effect. The false feedback manipulation slightly influenced reported ability during the digit span task, but reported ability before either manipulation was more important. The current study may not have designed a strong enough manipulation to cause the desired change of ability appraisal. In a previous study crossing ability with reward contingency (Lockard & Wright, 2006), ability appraisal was manipulated by telling participants they would be good or bad at a task because of gender. Participants were then given a preliminary task that confirmed pre-existing group membership. Individuals receive daily confirmation in terms of gender differences making any manipulations based on gender more robust than feedback on a single task. In addition to false feedback, the reward manipulation may have also failed to achieve the desired effect. Participants in the current study understood the reward manipulation correctly as either a high- or low-contingency chance of winning the reward; however the inherent uncertainty of the reward manipulation may have made the reward less tangible. The participants could have understood that the reward was either highly likely or unlikely but did not find the reward important enough to influence effort and reactivity on task performance.

Another possibility is that the feedback and reward manipulations influenced the groups and the interaction was a result of the manipulations, outside of the random assignment issue. Due to the high cognitive load necessary for the task, participants given good feedback with the high-contingency reward may have judged the task as difficult but attainable, and increased the amount of effort to achieve the goal in order to obtain a chance at winning the reward. The remaining three groups may have decided that increasing effort to achieve the target goal of the monetary reward was not necessary. For the participants who were given good feedback with the low-contingency reward, the goal may have been perceived as possible but not worth the increased effort because of the low-contingency chance of winning the reward. All of the participants given poor feedback may have thought the task was too difficult to achieve the goal, leading to lower effort. However, for participants given poor feedback with the low-contingency reward, the small chance of winning the reward may have made the monetary reward completely unimportant. With the low chance of winning the externally based reward, these participants may have maintained effort by shifting the goal to restoring the self-perceived working memory ability that was lost following poor ability feedback. Performing better than peers on the second task to achieve personal success could have acted as an alternate ceiling for effort that was higher than what was set by the monetary reward.

Instead of either random assignment or experimental design problems, sympathetic reactivity and effort may not be closely associated with one another. PEP reactivity and reported effort were greater in similar groups, but no correlation was found between the measures of sympathetic reactivity and effort. To this date, no study has found a direct correlation between these two measures, previous studies evaluating how effort and sympathetic reactivity are related have manipulated group membership and the changes in sympathetic reactivity that follow suggest changes in effort (Brehm & Self, 1989). One reason no correlation was found between effort and sympathetic measures may be because participants are unable to accurately identify their own cognitive states (Nisbett & Wilson, 1977). Individuals are poor at understanding how specific stimuli influence appraisals and focus instead on pre-existing beliefs when making judgments. The current participants might not be accurately appraising their emotional state, leading to an inability to find a correlation between sympathetic reactivity and self-reported effort. On the other hand, sympathetic reactivity and effort may not be related to each other and sympathetic reactivity may be a result of another cognitive process, like appraisals of challenge and threat (Blascovich et al., 2003). Correlations between self-reported beliefs and cardiovascular measures should be reported in future studies so that the relationship between self-reported effort and cardiovascular reactivity can be better understood.

A secondary hypothesis was that participants given poor feedback with the low-contingency reward would have blunted parasympathetic reactivity because of self-regulation. This hypothesis was also not supported; blunted RSA reactivity was not found in participants given poor feedback with the low-contingency reward. The high cognitive load necessary to complete this task may have again contributed to these findings. The average self-reported rating of effort before the digit span task was 7 on a scale ranging from 0 to 8. Even though a significant interaction was found, overall engagement in the task was very high suggesting that none of the groups were regulating or inhibiting effort to the task. Self-regulation in other studies is manipulated by asking people to eat either displayed carrots or cookies (Segerstrom & Nes, 2007) or through instructions to express or inhibit anger (Brosschot & Thayer, 1998). The present study sought to elicit self-regulation by reducing self-perceived ability through poor feedback and lowering the reward contingency. As previously mentioned in the context of effort, the combination of the false feedback and reward manipulation may not have had the intended consequence. Without a specific self-regulating task, individuals who should be inhibiting effort on the basis of ability and reward availability may identify different reasons for engaging in the task, preventing any self-regulation. The parasympathetic reactivity findings provide further support for the idea that participants may flexibly shift between reasons for effort allocation.

Another set of hypotheses stated that perseverative cognition would also be increased in participants given poor feedback with the low-contingency reward. These hypotheses were not supported; no differences in implicit or explicit perseverative cognition were found, and RSA and TPR recovery were not impaired in participants given poor feedback with the low-contingency reward. Even though cardiovascular and self-reported measures indicated effort was necessary to complete the digit span task, poor performance on a memory task may not be important enough for an individual to ruminate about. Usually perseverative cognition is induced by hostile behavior of a confederate (Dorr et al., 2007) or harassing a participant during a cognitive task (Glynn, Christenfeld, & Gerin, 2007), so the current ability feedback may not have been strong enough to elicit group differences in perseverative cognition. Additionally, the reward manipulation could have been inadequate to cause rumination about the task. The reward may be appealing but because the reward is an additional bonus, nothing is lost by failing so there is no reason to think about the task after it is over. If achieving the performance standard instead led to the loss of something valuable, perseverative cognition differences between groups could be elicited.

Pupillometry did not support the hypotheses or the cardiovascular findings. Overall, pupil diameter reactivity was similar to what is generally observed when 13-digits are memorized (Granholm et al., 1996; Peavler, 1974); pupil diameter reactivity peaked with presentation of the 10th digit, and dropped before the end of the recorded string (Figure 12).

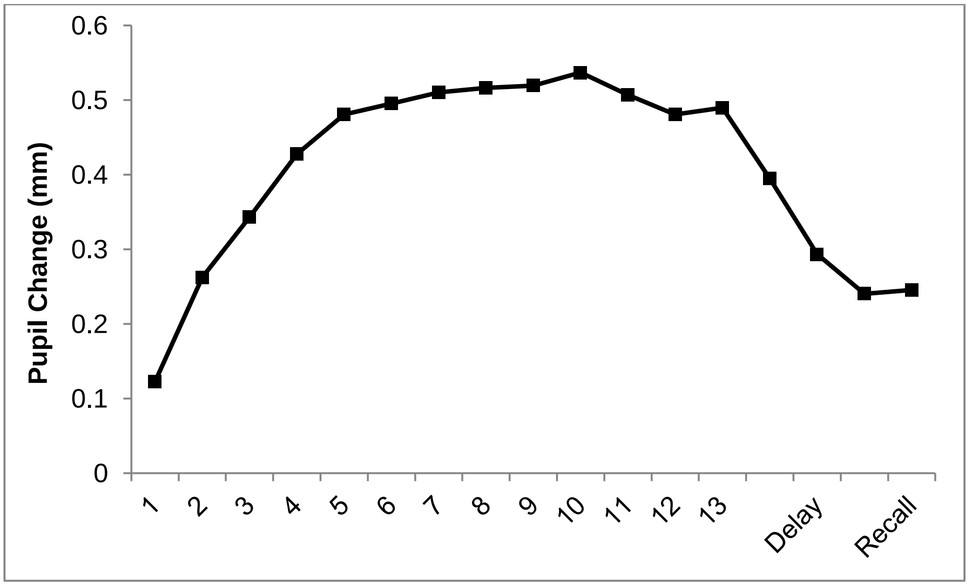

Figure 12. Pupil diameter change from baseline. Digits were presented at a rate of 1 per second, followed by a 3-second delay and recall.

The instructions that were given to participants in the present study may have influenced the pupillometry measures. Participants were prompted to recall as many numbers as possible and that performance would be compared to others in terms of the accuracy of digits recalled. In previous studies, no performance related rewards were offered and the participant was simply instructed to recall as many digits as possible. Comparing performance in the current study to previous findings, the present sample performed better at a score of -0.15 opposed to a previously reported score of -0.91 (Granholm et al., 1996). The better performance in the current study could be explained by a potential shift in strategy. Identifying accuracy as important along with the entire length of the string may have made participants try to focus on remembering a shorter string well. If all of the groups were trying to recall a similar sized subset of the entire digit span, cognitive load may have been more influential on pupil diameter than effort. Sympathetic reactivity of PEP and SBP may be more related to effort, but pupil diameter may be a better tool when cognitive load needs to be either examined or controlled.

Implications and Conclusions

The current study sought to identify how cardiovascular reactivity and recovery could be used to identify differences between inhibition of effort due to excess task difficulty and low effort due to limited motivational necessity. The inability to support the hypotheses in the current study may have been due to various issues with the two manipulations of ability and reward. When evaluating ability, random assignment may have caused some issues. The difference in self-perceived ability before the manipulations and how much the ratings contributed to ability rating before the digit span task suggests how important pre-existing beliefs are in task appraisal. While pre-existing beliefs may be more important, temporary feedback can potentially lead to long-term changes. For example, following an anger recall task in the laboratory, individuals had greater heart rate and blood pressure in the 24-hour ambulatory period immediately following the task (Ottaviani, Shapiro, & Fitzgerald, 2011). The influence of the ability manipulation may not have had immediate consequences during the task and recovery, but monitoring 24-hour ambulatory cardiovascular functioning after the laboratory session may provide additional information on how ability feedback is integrated with future appraisals.

The reward manipulation may have also failed to achieve the desired effect. Reward manipulations increase sympathetic reactivity when performance is linked to obtaining positive rewards (Richter & Gendolla, 2007; Richter & Gendolla, 2009) or avoiding an aversive punishment (Scher, Furedy, & Heslegrave, 1984); the present study offered a positive reward if individuals met a certain performance standard. The greater PEP found in participants who received poor feedback with the low-contingency reward conflicts with the idea that the external reward should not be important given the lack of ability and low reward possibility. Instead this group may have focused on performing well for personal reasons. In a previous study, individuals with depression demonstrated blunted cardiovascular reactivity to a task when presented with a monetary reward compared to control participants (Brinkmann, Schupbach, Joye, & Gendolla, 2009). Individuals with depression may have decided the task was not worth the effort and inhibited the response to the task. The current study attempted to identify how blunted cardiovascular reactivity and impaired recovery to a task could occur outside of psychopathology; achieving that goal may have been unrealistic because the relatively healthy sample may be able to adjust appraisals in order to avoid the poor pattern of blunted reactivity and impaired recovery. The ability to flexibly adjust appraisals of reward when confronting uncertain tasks could be a protective skill. Sensitivity to a specific reward may not be the only important factor in evaluating motivation in individuals with depression; adaptability when placed in a negative situation may be just as important to cardiovascular health.

The reactivity hypothesis (Krantz & Manuck, 1984) identifies greater sympathetic reactivity as a risk factor for the development of cardiovascular disease (CVD). The reactivity hypothesis is unable to explain the greater risk for CVD in individuals who react with smaller reactivity, leading to the development of the idea that smaller, or "blunted," reactivity indexes motivational dysregulation (Carroll, Phillips, & Lovallo, 2012). Low ability to control behaviors leads to poor decision making, which in turn increases the risk for CVD. The current study sought to demonstrate how poor self-perceived ability could interact with low-reward availability and result in blunted cardiovascular reactivity and impaired recovery, also increasing the risk for

CVD. While the current study was unable to find the anticipated patterns, it reinforces the importance of examining sympathetic and parasympathetic reactivity and recovery. Ability and reward may influence motivation and sympathetic reactivity, but survival is also dependent on interaction with other individuals. The late evolutionary development of specific parasympathetic influence over the cardiovascular system (Porges, 2007) suggests that living in a society requires nuanced control in certain situations. Gaining greater knowledge of the relationship between cardiovascular responses and cognitive processes will allow better understanding of the development of CVD.

References

Ahern, S., & Beatty, J. (1979). Pupillary responses during information processing vary with Scholastic Aptitude Test scores. *Science, 205*(4412), 1289-1292.

Beatty, J., & Lucero-Wagoner, B. (2000). The pupillary system. In J. T. Cacioppo, L. G. Tassinary & G. G. Berntson (Eds.), *Handbook of psychophysiology (2nd ed.).* (pp. 142-162). New York, NY US: Cambridge University Press.

Berntson, G. G., Bigger, J. T., Jr., Eckberg, D. L., Grossman, P., Kaufmann, P. G., Malik, M., . . . van der Molen, M. W. (1997). Heart rate variability: origins, methods, and interpretive caveats. *Psychophysiology, 34*(6), 623-648.

Berntson, G. G., Cacioppo, J. T., Binkley, P. F., Uchino, B. N., Quigley, K. S., & Fieldstone, A. (1994). Autonomic cardiac control. III. Psychological stress and cardiac response in autonomic space as revealed by pharmacological blockades. *Psychophysiology, 31*(6), 599-608.

Berntson, G. G., Quigley, K. S., Jang, J. F., & Boysen, S. T. (1990). An approach to artifact identification: application to heart period data. *Psychophysiology, 27*(5), 586-598.

Berntson, G. G., Quigley, K. S., & Lozano, D. (2007). Cardiovascular psychophysiology. In J. T. Cacioppo, L. G. Tassinary & G. G. Berntson (Eds.), *Handbook of psychophysiology (3rd ed.).* (pp. 182-210). New York, NY US: Cambridge University Press.

Blascovich, J., Mendes, W. B., Tomaka, J., Salomon, K., & Seery, M. (2003). The robust nature of the biopsychosocial model challenge and threat: A reply to Wright and Kirby. *Personality and Social Psychology Review, 7*(3), 234-243. doi: 10.1207/s15327957pspr0703_03

Brehm, J. W., & Self, E. A. (1989). The intensity of motivation. *Annual Review of Psychology, 40*, 109-131. doi: 10.1146/annurev.ps.40.020189.000545

Brinkmann, K., & Gendolla, G. H. (2008). Does depression interfere with effort mobilization? Effects of dysphoria and task difficulty on cardiovascular response. *Journal of Personality and Social Psychology, 94*(1), 146-157. doi: 10.1037/0022-3514.94.1.146

Brinkmann, K., Schupbach, L., Joye, I. A., & Gendolla, G. H. E. (2009). Anhedonia and effort mobilization in dysphoria: Reduced cardiovascular response to reward and punishment. *International Journal of Psychophysiology, 74*(3), 250-258. doi: 10.1016/j.ijpsycho.2009.09.009

Brosschot, J. F., Gerin, W., & Thayer, J. F. (2006). The perseverative cognition hypothesis: a review of worry, prolonged stress-related physiological activation, and health. *Journal of Psychosomatic Research, 60*(2), 113-124. doi: 10.1016/j.jpsychores.2005.06.074

Brosschot, J. F., & Thayer, J. F. (1998). Anger inhibition, cardiovascular recovery, and vagal function: a model of the link between hostility and cardiovascular disease. *Annals of Behavioral Medicine, 20*(4), 326-332.

Brosschot, J. F., & Thayer, J. F. (2003). Heart rate response is longer after negative emotions than after positive emotions. *International Journal of Psychophysiology, 50*(3), 181-187. doi: 10.1016/s0167-8760(03)00146-6

Bylsma, L. M., Salomon, K., Taylor-Clift, A., Morris, B. H. & Rottenberg, J. (2014). Blunted respiratory sinus arrhythmia reactivity in Major Depressive Disorder is mood-state dependent. *Psychosomatic Medicine, 76*(1), 66-77. doi: 0033-3174/14/7601-0066

Cabestrero, R., Crespo, A., & Quiros, P. (2009). Pupillary dilation as an index of task demands. *Perceptual and Motor Skills*, *109*(3), 664-678.

Carroll, D., Harrison, L. K., Johnston, D. W., Ford, G., Hunt, K., Der, G., & West, P. (2000). Cardiovascular reactions to psychological stress: the influence of demographic variables. *Journal of Epidemiology and Community Health*, *54*(11), 876-877.

Carroll, D., Phillips, A. C., & Der, G. (2008). Body mass index, abdominal adiposity, obesity, and cardiovascular reactions to psychological stress in a large community sample. *Psychosomatic Medicine, 70*(6), 653-660. doi: 10.1097/PSY.0b013e31817b9382

Carroll, D., Phillips, A. C., & Lovallo, W. R. (2012). The behavioral and health corollaries of blunted physiological reactions to acute psychological stress: Revising the reactivity hypothesis. In R. A. Wright & G. H. E. Gendolla (Eds.), *How motivation affects cardiovascular response: Mechanisms and applications.* (pp. 243-263). Washington, DC US: American Psychological Association.

Carver, C. S., & White, T. L. (1994). Behavioral inhibition, behavioral activation, and affective responses to impending reward and punishment: The BIS/BAS Scales. *Journal of Personality and Social Psychology, 67*(2), 319-333. doi: 10.1037/0022-3514.67.2.319

Chida, Y., & Steptoe, A. (2009). The Association of Anger and Hostility With Future Coronary Heart Disease A Meta-Analytic Review of Prospective Evidence. *Journal of the American College of Cardiolology, 53*(11), 936-946. doi: 10.1016/j.jacc.2008.11.044

Chida, Y., & Steptoe, A. (2010). Greater cardiovascular responses to laboratory mental stress are associated with poor subsequent cardiovascular risk status: a meta-analysis of prospective evidence. *Hypertension, 55*(4), 1026-1032. doi: 10.1161/HYPERTENSIONAHA.109.146621

Cole, P. M., Zahn-Waxler, C., Fox, N. A., Usher, B. A., & Welsh, J. D. (1996). Individual differences in emotion regulation and behavior problems in preschool children. *Journal of Abnormal Psychology, 105*(4), 518-529.

Demaree, H. A., & Everhart, D. E. (2004). Healthy high-hostiles: Reduced parasympathetic activity and decreased sympathovagal flexibility during negative emotional processing. *Personality and Individual Differences, 36*(2), 457-469. doi: 10.1016/s0191-8869(03)00109-0

Dorr, N., Brosschot, J. F., Sollers, J. J., 3rd, & Thayer, J. F. (2007). Damned if you do, damned if you don't: the differential effect of expression and inhibition of anger on cardiovascular recovery in black and white males. *International Journal of Psychophysiology, 66*(2), 125-134. doi: 10.1016/j.ijpsycho.2007.03.022

Fowles, D. C., Fisher, A. E., & Tranel, D. T. (1982). The heart beats to reward: the effect of monetary incentive on heart rate. *Psychophysiology, 19*(5), 506-513.

Gentzler, A. L., Santucci, A. K., Kovacs, M., & Fox, N. A. (2009). Respiratory sinus arrhythmia reactivity predicts emotion regulation and depressive symptoms in at-risk and control children. *Biological Psychology, 82*(2), 156-163. doi: 10.1016/j.biopsycho.2009.07.002

Glynn, L. M., Christenfeld, N., & Gerin, W. (2002). The role of rumination in recovery from reactivity: cardiovascular consequences of emotional states. *Psychosomatic Medicine, 64*(5), 714-726.

Glynn, L. M., Christenfeld, N., & Gerin, W. (2007). Recreating cardiovascular responses with rumination: The effects of a delay between harassment and its recall. *International Journal of Psychophysiology, 66*, 135-140. doi: 10.1016/j.ijpsycho.2007.03.018

Granholm, E., Asarnow, R. F., Sarkin, A. J., & Dykes, K. L. (1996). Pupillary responses index cognitive resource limitations. *Psychophysiology, 33*(4), 457-461.

Gregg, M. E., Matyas, T. A., & James, J. E. (2002). A new model of individual differences in hemodynamic profile and blood pressure reactivity. *Psychophysiology*, *39*(1), 64-72. doi: 10.1017/S0048577202001154

Hagtvet, K. A., & Benson, J. (1997). The motive to avoid failure and test anxiety responses: Empirical support for integration of two research traditions. *Anxiety, Stress & Coping: An International Journal*, *10*(1), 35-57. doi: 10.1080/10615809708249294

Hansen, A. L., Johnsen, B. H., & Thayer, J. F. (2003). Vagal influence on working memory and attention. *International Journal of Psychophysiology, 48*(3), 263-274. doi: 10.1016/s0167-8760(03)00073-4

Heitz, R. P., Schrock, J. C., Payne, T. W., & Engle, R. W. (2008). Effects of incentive on working memory capacity: behavioral and pupillometric data. *Psychophysiology*, *45*(1), 119-129. doi: 10.1111/j.1469-8986.2007.00605.x

Heponiemi, T., Elovainio, M., Pulkki, L., Puttonen, S., Raitakari, O., & Keltikangas-Jarvinen, L. (2007). Cardiac autonomic reactivity and recovery in predicting carotid atherosclerosis: the cardiovascular risk in young Finns study. *Health Psychology*, *26*(1), 13-21. doi: 10.1037/0278-6133.26.1.13

Imai, K., Sato, H., Hori, M., Kusuoka, H., Ozaki, H., Yokoyama, H., . . . Kamada, T. (1994). Vagally mediated heart rate recovery after exercise is accelerated in athletes but blunted in patients with chronic heart failure. *Journal of the American College of Cardiology, 24*(6), 1529-1535.

Jennings, J. R., Kamarck, T., Stewart, C., Eddy, M., & Johnson, P. (1992). Alternate cardiovascular baseline assessment techniques: vanilla or resting baseline. *Psychophysiology, 29*(6), 742-750.

Kahneman, D., Tursky, B., Shapiro, D., & Crider, A.. (1969). Pupillary, heart rate, and skin resistance changes during a mental task. *Journal of Experimental Psychology, 79*(1), 164-167.

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.

Levy, D., Garrison, R. J., Savage, D. D., Kannel, W. B., & Castelli, W. P. (1990). Prognostic implications of echocardiographically determined left ventricular mass in the Framingham Heart Study. *New England Journal of Medicine, 322*(22), 1561-1566. doi: 10.1056/NEJM199005313222203

Light, K. C., & Obrist, P. A. (1983). Task difficulty, heart rate reactivity, and cardiovascular responses to an appetitive reaction time task. *Psychophysiology, 20*(3), 301-312.

Linden, W., Earle, T. L., Gerin, W., & Christenfeld, N. (1997). Physiological stress reactivity and recovery: Conceptual siblings separated at birth? *Journal of Psychosomatic Research, 42*(2), 117-135. doi: 10.1016/s0022-3999(96)00240-1

Llabre, M. M., Spitzer, S. B., Saab, P. G., Ironson, G. H., & Schneiderman, N. (1991). The reliability and specificity of delta versus residualized change as measures of cardiovascular reactivity to behavioral challenges. *Psychophysiology, 28*(6), 701-711. doi: 10.1111/j.1469-8986.1991.tb01017.x

Luft, C. D. B., Takase, E., & Darby, D. (2009). Heart rate variability and cognitive function: Effects of physical effort. *Biological Psychology*, *82*(2), 196-201. doi: 10.1016/j.biopsycho.2009.07.007

Lyonfields, J. D., Borkovec, T. D., & Thayer, J. F. (1995). Vagal tone in generalized anxiety disorder and the effects of aversive imagery and worrisome thinking. *Behavior Therapy, 26*(3), 457-466. doi: 10.1016/s0005-7894(05)80094-2

Matthews, K. A., Owens, J. F., Kuller, L. H., Sutton-Tyrrell, K., Lassila, H. C., & Wolfson, S. K. (1998). Stress-induced pulse pressure change predicts women's carotid atherosclerosis. *Stroke*, *29*(8), 1525-1530.

McEwen, B. S. (2004). Protection and damage from acute and chronic stress: allostasis and allostatic overload and relevance to the pathophysiology of psychiatric disorders. *Annals of the New York Academy of Sciences*, *1032*, 1-7. doi: 10.1196/annals.1314.001

Mezzacappa, E. S., Kelsey, R. M., Katkin, E. S., & Sloan, R. P. (2001). Vagal rebound and recovery from psychological stress. *Psychosomatic Medicine*, *63*(4), 650-657.

Movius, H. L., & Allen, J. J. (2005). Cardiac Vagal Tone, defensiveness, and motivational style. *Biological Psychology, 68*(2), 147-162. doi: 10.1016/j.biopsycho.2004.03.019

Neumann, S. A., Waldstein, S. R., Sellers, J. J., 3rd, Thayer, J. F., & Sorkin, J. D. (2004). Hostility and distraction have differential influences on cardiovascular recovery from anger recall in women. *Health Psychology, 23*(6), 631-640. doi: 10.1037/0278-6133.23.6.631

Nisbett R. E. & Wilson, T. D. (1977). Telling more than we can know: Verbal reports on mental processes. *Psychological Review, 84*(3), 231-259. doi: 10.1037/0033-295X.84.3.231

Obrist, P. A., Gaebelein, C. J., Teller, E. S., Langer, A. W., Grignolo, A., Light, K. C., & McCubbin, J. A. (1978). The relationship among heart rate, caratid dP/dt, and blood pressure in humans as a function of the type of stress. *Psychophysiology, 15*(2), 102-115.

Panknin, T. L., Dickensheets, S. L., Nixon, S. J., & Lovallo, W. R. (2002). Attenuated heart rate responses to public speaking in individuals with alcohol dependence. *Alcoholism: Clinical and Experimental Research, 26*(6), 841-847.

Peavler, W. S. (1974). Pupil size, information overlad, and performance differences. *Psychophysiology, 11*(5), 559-566.

Phillips, A. C., Der, G., Hunt, K., & Carroll, D. (2009). Haemodynamic reactions to acute psychological stress and smoking status in a large community sample. *International Journal of Psychophysiology, 73*(3), 273-278. doi: 10.1016/j.ijpsycho.2009.04.005

Porges, S. W. (1995). Orienting in a defensive world: mammalian modifications of our evolutionary heritage. A Polyvagal Theory. *Psychophysiology, 32*(4), 301-318.

Porges, S. W. (2007). The polyvagal perspective. *Biological Psychology, 74*(2), 116-143. doi: 10.1016/j.biopsycho.2006.06.009

Pu, J., Schmeichel, B. J., & Demaree, H. A. (2010). Cardiac vagal control predicts spontaneous regulation of negative emotional expression and subsequent cognitive performance. *Biological Psychology, 84*(3), 531-540. doi: 10.1016/j.biopsycho.2009.07.006

Radstaak, M., Geurts, S. A., Brosschot, J. F., Cillessen, A. H., & Kompier, M. A. (2011). The role of affect and rumination in cardiovascular recovery from stress. *International Journal of Psychophysiology, 81*(3), 237-244. doi: 10.1016/j.ijpsycho.2011.06.017

Richter, M., Friedrich, A., & Gendolla, G. H. (2008). Task difficulty effects on cardiac activity. *Psychophysiology, 45*(5), 869-875. doi: 10.1111/j.1469-8986.2008.00688.x

Richter, M., & Gendolla, G. H. (2007). Incentive value, unclear task difficulty, and cardiovascular reactivity in active coping. *International Journal of Psychophysiology, 63*(3), 294-301. doi: 10.1016/j.ijpsycho.2006.12.002

Richter, M., & Gendolla, G. H. (2009). The heart contracts to reward: monetary incentives and preejection period. *Psychophysiology, 46*(3), 451-457. doi: 10.1111/j.1469-8986.2009.00795.x

Rottenberg, J., Clift, A., Bolden, S., & Salomon, K. (2007). RSA fluctuation in major depressive disorder. *Psychophysiology, 44*(3), 450-458. doi: 10.1111/j.1469-8986.2007.00509.x

Rottenberg, J., Ray, R. D., & Gross, J. J. (2007). Emotion elicitation using films. In J. A. Coan & J. J. B. Allen (Eds.), *Handbook of emotion elicitation and assessment*. (pp. 9-28). New York: Oxford University Press.

Salomon, K., Bylsma, L. M., White, K. E., Panaite, V., & Rottenberg, J. (2013). Is blunted cardiovascular reactivity in depression mood-state dependent? A comparison of major depressive disorder remitted depression and healthy controls. *International Journal of Psychophysiology*. doi: 10.1016/j.ijpsycho.2013.05.018

Salomon, K., Clift, A., Karlsdottir, M., & Rottenberg, J. (2009). Major depressive disorder is associated with attenuated cardiovascular reactivity and impaired recovery among those free of cardiovascular disease. *Health Psychology, 28*(2), 157-165. doi: 10.1037/a0013001

Savitzky, A. & Golay, M. J. E. (1964). Smoothing and differentiation of data by simplified least squares procedures. *Analytical Chemistry, 36*(8), 1627-1639. Doi: 10.1021/ac60214a047

Scher, H., Furedy, J. J., & Heslegrave, R. J. (1984). Phasic T-wave amplitude and heart rate changes as indices of mental effort and task incentive. *Psychophysiology, 21*(3), 326-333.

Schuler, J. L., & O'Brien, W. H. (1997). Cardiovascular recovery from stress and hypertension risk factors: a meta-analytic review. *Psychophysiology, 34*(6), 649-659.

Segerstrom, S. C., & Nes, L. S. (2007). Heart rate variability reflects self-regulatory strength, effort, and fatigue. *Psychological Science, 18*(3), 275-281. doi: 10.1111/j.1467-9280.2007.01888.x

Segerstrom, S. C., Roach, A. R., Evans, D. R., Schipper, L. J., & Darville, A. K. (2010). The structure and health correlates of trait repetitive thought in older adults. *Psychology and Aging, 25*(3), 505-515. doi: 10.1037/a0019456

Segerstrom, S. C., Stanton, A. L., Flynn, S. M., Roach, A. R., Testa, J. J., & Hardy, J. K. (2012). Episodic repetitive thought: Dimensions, correlates, and consequences. *Anxiety, Stress & Coping: An International Journal, 25*(1), 3-21. doi: 10.1080/10615806.2011.608126

Shapiro, D., Jamner, L. D., Lane, J. D., Light, K. C., Myrtek, M., Sawada, Y., & Steptoe, A. (1996). Blood pressure publication guidelines. Society for Psychophysical Research. *Psychophysiology, 33*(1), 1-12.

Sherwood, A., Allen, M. T., Fahrenberg, J., Kelsey, R. M., Lovallo, W. R., & van Doornen, L. J. (1990). Methodological guidelines for impedance cardiography. *Psychophysiology, 27*(1), 1-23.

Siegle, G. J., Steinhauer, S. R., Carter, C. S., Ramel, W., & Thase, M. E. (2003). Do the seconds turn into hours? Relationships between sustained pupil dilation in response to emotional information and self-reported rumination. *Cognitive Therapy and Research, 27*(3), 365-382. doi: 10.1023/a:1023974602357

Steptoe, A., Willemsen, G., Kunz-Ebrecht, S. R., & Owen, N. (2003). Socioeconomic status and hemodynamic recovery from mental stress. *Psychophysiology, 40*(2), 184-191.

Taylor, T. R., Kamarck, T. W., & Dianzumba, S. (2003). Cardiovascular reactivity and left ventricular mass: an integrative review. *Annals of Behavioral Medicine, 26*(3), 182-193.

Thayer, J. F., Friedman, B. H., & Borkovec, T. D. (1996). Autonomic characteristics of generalized anxiety disorder and worry. *Biological Psychiatry, 39*(4), 255-266. doi: 10.1016/0006-3223(95)00136-0

Verkuil, B., Brosschot, J. F., de Beurs, D. P., & Thayer, J. F. (2009). Effects of explicit and implicit perseverative cognition on cardiac recovery after cognitive stress. *International Journal of Psychophysiology, 74*(3), 220-228. doi: 10.1016/j.ijpsycho.2009.09.003

Willemsen, G., Ring, C., Carroll, D., Evans, P., Clow, A., & Hucklebridge, F. (1998). Secretory immunoglobulin A and cardiovascular reactions to mental arithmetic and cold pressor. *Psychophysiology, 35*(3), 252-259.

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*(2), 152-160.

Wright, R. A., Dill, J. C., Geen, R. G., & Anderson, C. A. (1998). Social evaluation influence on cardiovascular response to a fixed behavioral challenge: effects across a range of difficulty levels. *Annals of Behavioral Medicine*, *20*(4), 277-285.

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*(2), 172-176.

Wright, R. A., & Hodges, D. (1999). The domain specificity of cardiovascular ability (efficacy) effects. *Basic and Applied Social Psychology, 21*(4), 291-300. doi: 10.1207/15324839951036317

Wright, R. A., & Lockard, S. (2006). Sex, outcome expectancy, and cardiovascular response to a masculine challenge. *Psychophysiology*, *43*(2), 190-196. doi: 10.1111/j.1469-8986.2006.00384.x

Wright, R. A., Murray, J. B., Storey, P. L., & Williams, B. J. (1997). Ability analysis of gender relevance and sex differences in cardiovascular response to behavioral challenge. *Journal of Personality and Social Psychology*, *73*(2), 405-417.

Wright, R. A., Wadley, V. G., Pharr, R. P., & Butler, M. (1994). Interactive influence of self-reported ability and avoidant task demand on anticipatory cardiovascular responsivity. *Journal of Research in Personality, 28*(1), 68-86. doi: 10.1006/jrpe.1994.1007

Appendix A

Questionnaires

Appendix A1: Demographics & Health History

1. Age: ____
2. Gender (please circle one): Male Female
3. How would you describe your race or ethnicity?
   a) American Indian or Alaska Native
   b) Arab or Middle Eastern
   c) Asian or Asian-American
   d) Black or African American
   e) Hispanic or Latino
   f) Other/Not Listed
   g) White or Caucasian

4. College GPA: ________
5. Please list all prescription and non-prescription medications that you are currently taking. Be sure to also include any medications you have taken in the last 48 hours, even if it is something you do not regularly take (such as aspirin or cold medicine).

____

____

____

____

6. When did you last eat? ______________ am / pm (circle one)
   a. What did you eat? ____
7. Do you drink beverages containing caffeine? ☐Yes ☐No (check one)
   a. If yes, when did you last drink a caffeinated beverage?

      Time: ____________ am / pm (circle one)

   b. How many caffeinated drinks have you had today? ____________
8. Do you smoke nicotine cigarettes? ☐Yes ☐ No (check one)

Appendix A1 (Continued)

a. If yes, when did you last smoke? Time: ___________ am / pm (circle one)

b. How many nicotine cigarettes have you smoked today? ___________

c. How many nicotine cigarettes do you normally smoke in a day? ___________

9. When did you last exercise? Please consider any activity that elevated your heart rate for 30 or more minutes.

   Date: ____________ Time: _____________ Activity: ______________

Appendix A2: Motive to Avoid Failure

Please answer how you feel about the following statements using the following scale:

(1) Almost never
(2) Sometimes
(3) Often
(4) Almost Always

1. _____ I am afraid of failing in situations where the outcome is uncertain.
2. _____ Just thinking about working on new, somewhat difficult tasks makes me feel uneasy.
3. _____ I dislike work that I am not sure I can manage.
4. _____ I am afraid of failing when I am given a task which I am uncertain that I can solve.
5. _____ I dislike doing things which seem somewhat difficult.
6. _____ I dislike working in situations if I am uncertain how well I will do.

Appendix A3: BAS Drive

Please answer how you feel about the following statements using the following scale:

(1) very true for me
(2) somewhat true for me
(3) somewhat false for me
(4) very false for me

1. _____ When I want something, I usually go all-out to get it.
2. _____ I go out of my way to get things I want.
3. _____ If I see a chance to get something I want, I move on it right away.
4. _____ When I go after something I use a “no holds barred” approach.

Appendix A4: State Emotion Questionnaire

Instructions: For each of the following items, please mark the circle corresponding to the number on the scale that best describes how you are feeling right now.
On this scale, 0 means *you did not feel even the slightest bit of the emotion* and 8 means you feel *an extreme amount*.

	none						an extreme amount		
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1. How much **fear** do you feel?................................	O	O	O	O	O	O	O	O	O
2. How much **guilt** do you feel?...............................	O	O	O	O	O	O	O	O	O
3. How **happy** do you feel?.....................................	O	O	O	O	O	O	O	O	O
4. How **annoyed** do you feel?..................................	O	O	O	O	O	O	O	O	O
5. How **anxious** do you feel?...................................	O	O	O	O	O	O	O	O	O
6. How **sad** do you feel?..	O	O	O	O	O	O	O	O	O
7. How much **shame** do you feel?...........................	O	O	O	O	O	O	O	O	O
8. How **distressed** do you feel?................................	O	O	O	O	O	O	O	O	O
9. How **disgusted** do you feel?.................................	O	O	O	O	O	O	O	O	O
10. How much **love** do you feel?................................	O	O	O	O	O	O	O	O	O
11. How **nervous** do you feel?..................................	O	O	O	O	O	O	O	O	O
12. How **elated** do you feel?..	O	O	O	O	O	O	O	O	O
13. How **enthusiastic** do you feel?............................	O	O	O	O	O	O	O	O	O
14. How **hostile** do you feel?.......................................	O	O	O	O	O	O	O	O	O
15. How **interested** do you feel?................................	O	O	O	O	O	O	O	O	O
16. How **angry** do you feel?...	O	O	O	O	O	O	O	O	O
17. How **amused** do you feel?.....................................	O	O	O	O	O	O	O	O	O
18. How much **pride** do you feel?...............................	O	O	O	O	O	O	O	O	O
19. How **lively** do you feel?..	O	O	O	O	O	O	O	O	O
20. How **jittery** do you feel?...	O	O	O	O	O	O	O	O	O

Appendix A5: Pre- and Post-Task Questionnaires

Pre-Task #1

Instructions: For each of the following items, please mark the circle corresponding to the number on the scale that best describes how you are feeling about the following task.

	0	1	2	3	4	5	6	7	8
	very low								very high
1. How strong is your ability at this task?	O	O	O	O	O	O	O	O	O
	not at all								extremely
2. How difficult will the task be?	O	O	O	O	O	O	O	O	O
	not at all stressful								very stressful
3. How stressful do you expect the upcoming task to be?	O	O	O	O	O	O	O	O	O
	not at all								very much
4. How hard will you try at this task?	O	O	O	O	O	O	O	O	O
	not at all able								very able
5. How able are you to cope with this task?	O	O	O	O	O	O	O	O	O

Appendix A5 (Continued)

Post-Task #1

Please write down your percentile rank on the task: ________________

Instructions: For each of the following items, please mark the circle corresponding to the number on the scale that best describes how you are feeling about the following task.

	not at all								extremely
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1. How difficult was the task?................	O	O	O	O	O	O	O	O	O
	not at all								very much
2. How hard did you try at this task?................	O	O	O	O	O	O	O	O	O
	not at all stressful								very stressful
3. How stressful was the task?.........	O	O	O	O	O	O	O	O	O
	not at all								very much
4. How much did you think about the task during the blank screen?................	O	O	O	O	O	O	O	O	O
	not at all able								very able
5. How able were you to cope with the task?............	O	O	O	O	O	O	O	O	O
	little improvement								great improvement
6. How much do you think you could improve if you did this task again?................	O	O	O	O	O	O	O	O	O

Appendix A5 (Continued)

Pre-Task #2

Instructions: For each of the following items, please mark the circle corresponding to the number on the scale that best describes how you are feeling about the following task.

	very low								very high	
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	
1. How strong is your ability at this task?................	O	O	O	O	O	O	O	O	O	
	not at all								extremely	
2. How difficult will it be to attain performance in the 50^{th} percentile?..	O	O	O	O	O	O	O	O	O	
	not at all stressful								very stressful	
3. How stressful do you expect the upcoming task to be?...	O	O	O	O	O	O	O	O	O	
	not at all								very much	
4. How hard will you try to achieve the 50^{th} percentile goal?...	O	O	O	O	O	O	O	O	O	
	not at all able								very able	
5. How able are you to cope with this task?.............	O	O	O	O	O	O	O	O	O	
	little improvement								great improvement	
6. If successful, what chance do you think you have at winning the money?..............	O	O	O	O	O	O	O	O	O	

Appendix A5 (Continued)

Post-Task #2

Please write what you believe your percentile rank is: ________________

Instructions: For each of the following items, please mark the circle corresponding to the number on the scale that best describes how you are feeling about the following task.

	not at all								extremely
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1. How difficult was the task?................	O	O	O	O	O	O	O	O	O
	not at all								very much
2. How hard did you try at this task?................	O	O	O	O	O	O	O	O	O
	not at all stressful								very stressful
4. How stressful was the task?.........	O	O	O	O	O	O	O	O	O
	not at all								very much
5. How much did you think about the task during the blank screen?................	O	O	O	O	O	O	O	O	O
	not at all able								very able
6. How able were you to cope with the task?............	O	O	O	O	O	O	O	O	O
	little improvement								great improvement
7. How much do you think you could improve if you did this task again?................	O	O	O	O	O	O	O	O	O

Appendix B

Additional Tables

Appendix B1

Cardiovascular Reactivity to the Digit Span Task

Heart Rate (beats/minute)

	Reward Availiability	Low		High			
		M	(SD)	M	(SD)	M	(SD)
Performance Feedback	Poor	11.23	(7.76)	8.57	(5.33)	10.00	(6.79)
	Good	6.98	(6.91)	9.18	(6.52)	8.05	(6.73)
		9.15	(7.58)	8.88	(5.90)		

Pre-Ejection Period (ms)

	Reward Availiability	Low		High			
		M	(SD)	M	(SD)	M	(SD)
Performance Feedback	Poor	-9.26	(5.37)	-6.39	(7.62)	-7.93	(6.59)
	Good	-6.44	(4.62)	-10.62	(7.19)	-8.43	(6.27)
		-7.88	(5.16)	-8.50	(7.62)		

Resipratory Sinus Arrhythmia (ln ms^2)

	Reward Availiability	Low		High			
		M	(SD)	M	(SD)	M	(SD)
Performance Feedback	Poor	-0.73	(1.00)	-0.58	(0.68)	-0.66	(0.86)
	Good	-0.58	(0.85)	-0.36	(0.89)	-0.47	(0.87)
		-0.66	(0.92)	-0.46	(0.79)		

Appendix B1 (Continued)

Systolic Blood Pressure (mmHg)

	Reward Availiability	Low		High			
		M	(SD)	M	(SD)	M	(SD)
Performance Feedback	Poor	11.25	(6.87)	10.74	(7.02)	11.01	(6.86)
	Good	8.61	(7.98)	10.08	(7.87)	9.33	(7.86)
		9.96	(7.47)	10.40	(7.37)		

Diastolic Blood Pressure (mmHg)

	Reward Availiability	Low		High			
		M	(SD)	M	(SD)	M	(SD)
Performance Feedback	Poor	8.08	(5.02)	6.91	(5.06)	7.54	(5.01)
	Good	6.73	(6.42)	7.21	(3.71)	6.96	(5.22)
		7.42	(5.72)	7.06	(4.37)		

Total Peripheral Resistance (dyn*s/cm^5)

	Reward Availiability	Low		High			
		M	(SD)	M	(SD)	M	(SD)
Performance Feedback	Poor	19.71	(75.95)	30.52	(84.40)	24.72	(79.15)
	Good	35.36	(74.98)	2.65	(79.58)	19.82	(77.97)
		27.35	(74.99)	16.58	(82.13)		

Cardiac Output (L/minute)

	Reward Availiability	Low		High			
		M	(SD)	M	(SD)	M	(SD)
Performance Feedback	Poor	0.76	(0.77)	0.45	(0.68)	0.62	(0.73)
	Good	0.39	(0.51)	0.69	(0.73)	0.53	(0.63)
		0.58	(0.67)	0.57	(0.71)		

Appendix B2

Cardiovascular Recovery After the Digit Span Task

Heart Rate (beats/minute)

	Reward Availiability	Low		High			
		M	(SD)	M	(SD)	M	(SD)
Performance Feedback	Poor	1.92	(1.84)	2.53	(2.10)	2.21	(1.96)
	Good	1.77	(2.65)	2.14	(2.92)	1.96	(2.76)
		1.85	(2.24)	2.33	(2.53)		

Pre-Ejection Period (ms)

	Reward Availiability	Low		High			
		M	(SD)	M	(SD)	M	(SD)
Performance Feedback	Poor	-2.87	(2.42)	-4.29	(3.71)	-3.51	(3.11)
	Good	-3.38	(2.83)	-5.09	(4.59)	-4.22	(3.84)
		-3.11	(2.61)	-4.71	(4.15)		

Resipratory Sinus Arrhythmia (ln ms^2)

	Reward Availiability	Low		High			
		M	(SD)	M	(SD)	M	(SD)
Performance Feedback	Poor	0.07	(0.60)	0.15	(0.49)	0.11	(0.55)
	Good	0.13	(0.56)	0.24	(0.77)	0.18	(0.67)
		0.10	(0.58)	0.19	(0.64)		

Systolic Blood Pressure (mmHg)

	Reward Availiability	Low		High			
		M	(SD)	M	(SD)	M	(SD)
Performance Feedback	Poor	1.54	(2.55)	2.96	(5.33)	2.20	(4.09)
	Good	0.82	(3.80)	2.25	(5.01)	1.53	(4.45)
		1.19	(3.18)	2.59	(5.11)		

Appendix B2 (Continued)

Diastolic Blood Pressure (mmHg)

	Reward Availiability	Low		High			
		M	(SD)	M	(SD)	M	(SD)
Performance Feedback	Poor	0.85	(3.75)	2.20	(3.59)	1.48	(3.69)
	Good	1.23	(2.89)	2.53	(3.73)	1.87	(3.35)
		1.04	(3.32)	2.37	(3.62)		

Total Peripheral Resistance ($dyn*s/cm^5$)

	Reward Availiability	Low		High			
		M	(SD)	M	(SD)	M	(SD)
Performance Feedback	Poor	-18.71	(34.59)	-26.54	(44.18)	-22.23	(38.87)
	Good	-26.56	(51.20)	-28.24	(60.51)	-27.38	(55.19)
		-22.45	(42.93)	-27.41	(52.47)		

Cardiac Output (L/minute)

	Reward Availiability	Low		High			
		M	(SD)	M	(SD)	M	(SD)
Performance Feedback	Poor	0.28	(0.33)	0.35	(0.34)	0.31	(0.33)
	Good	0.29	(0.36)	0.37	(0.45)	0.33	(0.40)
		0.29	(0.34)	0.36	(0.39)		

Appendix B3

Self-Reported Ratings Before PASAT and Digit Span Task

Ability

	Reward Availiability	PASAT Low M	(SD)	PASAT High M	(SD)	M	(SD)		Digit Span Low M	(SD)	Digit Span High M	(SD)	M	(SD)
Performance Feedback	Poor	5.41	(1.74)	3.95	(1.78)	4.73	(1.88)	Poor	4.27	(1.16)	3.79	(1.58)	4.05	(1.38)
	Good	3.19	(2.18)	4.30	(2.05)	3.73	(2.17)	Good	3.81	(1.43)	4.75	(1.62)	4.27	(1.58)
		4.33	(2.24)	4.13	(1.91)				4.05	(1.31)	4.28	(1.65)		

Difficulty

	Reward Availiability	PASAT Low M	(SD)	PASAT High M	(SD)	M	(SD)		Digit Span Low M	(SD)	Digit Span High M	(SD)	M	(SD)
Performance Feedback	Poor	4.46	(2.13)	3.95	(1.96)	4.22	(2.04)	Poor	5.50	(1.44)	5.11	(2.16)	5.32	(1.80)
	Good	5.48	(1.60)	5.55	(1.39)	5.51	(1.49)	Good	4.85	(1.39)	4.43	(1.57)	4.63	(1.48)
		4.95	(1.94)	4.77	(1.86)				4.98	(1.58)	4.97	(1.78)		

Effort

	Reward Availiability	PASAT Low M	(SD)	PASAT High M	(SD)	M	(SD)		Digit Span Low M	(SD)	Digit Span High M	(SD)	M	(SD)
Performance Feedback	Poor	6.77	(1.90)	6.58	(1.64)	6.68	(1.72)	Poor	7.41	(0.96)	6.37	(2.14)	6.93	(1.68)
	Good	7.00	(1.90)	7.55	(0.76)	7.27	(1.47)	Good	6.95	(1.28)	7.20	(1.06)	7.07	(1.17)
		6.88	(1.84)	7.08	(1.35)				7.19	(1.14)	6.80	(1.70)		

Note. Scales presented scored on a scale of 0-8.

Appendix B4

Perseverative Cognition Following the Digit Span Task

Self-Reported Rumination

	Reward Availiability	Low		High			
		M	(SD)	M	(SD)	M	(SD)
Performance Feedback	Poor	4.14	(2.51)	3.47	(2.67)	3.83	(2.58)
	Good	4.14	(2.39)	4.65	(2.43)	4.39	(2.39)
		4.14	(2.43)	4.08	(2.59)		

Recognition Time Differences (sec)

	Reward Availiability	Low		High			
		M	(SD)	M	(SD)	M	(SD)
Performance Feedback	Poor	-21.58	(49.38)	-24.31	(66.52)	22.88	(57.40)
	Good	-13.93	(71.79)	-14.33	(65.58)	14.11	(68.09)
		-17.76	(60.98)	-19.45	(65.34)		

Note. Explicit perseverative cognition from self reported scale (0-8) and implicit perseverative cognition (the difference between recognition time of performance related words to positive control words).

Appendix B5

Task Performance

PASAT Correct Responses

	Reward Availiability	Low		High			
		M	(SD)	M	(SD)	M	(SD)
Performance Feedback	Poor	34.27	(10.30)	29.26	(10.91)	31.95	(10.75)
	Good	31.29	(8.12)	32.05	(8.82)	31.66	(8.37)
		32.81	(9.31)	30.69	(9.87)		

Span Score

	Reward Availiability	Low		High			
		M	(SD)	M	(SD)	M	(SD)
Performance Feedback	Poor	-0.03	(1.86)	-0.09	(1.77)	-0.06	(1.80)
	Good	0.02	(1.87)	-0.50	(1.92)	-0.23	(1.89)
		-0.005	(1.84)	-0.30	(1.84)		

Note. Performance on the PASAT scored as correct number of responses. Performance on the digit span task scored using the same system as previous studies (Peavler, 1974).

Appendix C

IRB Approval Letter

USF UNIVERSITY OF SOUTH FLORIDA

RESEARCH INTEGRITY AND COMPLIANCE
Institutional Review Boards, FWA No. 00001669
12901 Bruce B. Downs Blvd., MDC035 • Tampa, FL 33612-4799
(813) 974-5638 • FAX (813) 974-7091

January 6, 2014

Alvin Jin, B.S.
Psychology
4202 E Fowler Ave
PCD 4118G
Tampa, FL 33620

RE: **Expedited Approval for Initial Review**

IRB#: Pro00015596

Title: Motivation and self-regulation in blunted cardiovascular reactivity and impaired recovery from stress

Study Approval Period: 1/6/2014 to 1/6/2015

Dear Mr. Jin:

On 1/6/2014, the Institutional Review Board (IRB) reviewed and **APPROVED** the above application and all documents outlined below.

Approved Item(s):

Protocol Document(s):

Dissertation Proposal Ver1 12-5-13

Consent/Assent Document(s)*:

Informed Consent Ver 1 12-17-13.pdf

*Please use only the official IRB stamped informed consent/assent document(s) found under the "Attachments" tab. Please note, these consent/assent document(s) are only valid during the approval period indicated at the top of the form(s).

It was the determination of the IRB that your study qualified for expedited review which includes activities that (1) present no more than minimal risk to human subjects, and (2) involve only procedures listed in one or more of the categories outlined below. The IRB may review research through the expedited review procedure authorized by 45CFR46.110 and 21 CFR 56.110. The research proposed in this study is categorized under the following expedited review category:

(4) Collection of data through noninvasive procedures (not involving general anesthesia or sedation) routinely employed in clinical practice, excluding procedures involving x-rays or microwaves. Where medical devices are employed, they must be cleared/approved for marketing.

(7) Research on individual or group characteristics or behavior (including, but not limited to, research on perception, cognition, motivation, identity, language, communication, cultural beliefs or practices, and social behavior) or research employing survey, interview, oral history, focus group, program evaluation, human factors evaluation, or quality assurance methodologies.

As the principal investigator of this study, it is your responsibility to conduct this study in accordance with IRB policies and procedures and as approved by the IRB. Any changes to the approved research must be submitted to the IRB for review and approval by an amendment.

We appreciate your dedication to the ethical conduct of human subject research at the University of South Florida and your continued commitment to human research protections. If you have any questions regarding this matter, please call 813-974-5638.

Sincerely,

John A. Schinka, Ph.D.

John Schinka, Ph.D., Chairperson
USF Institutional Review Board