HOWARD UNIVERSITY

CARDIAC COMPONENTS OF ANXIETY: CORRELATES AND INTERVENTIONS

A Thesis
Submitted to the Faculty of the
Graduate School

Of

HOWARD UNIVERSITY

in partial fulfillment of
the requirements for the
degree of

Master of Science

Department of Psychology

By

Adrian Dion Thompson

Washington, DC

May 2012

HOWARD UNIVERSITY

GRADUATE SCHOOL

DEPARTMENT OF PSYCHOLOGY

THESIS COMMITTEE

Jules P. Harrell, Ph.D.

Chairperson

Alfonso Campbell, Ph. D.

Vernon Bond, Ph.D.

Jules P. Harrell, Ph. D.

Thesis Advisor

Candidate: Adrian Dion Thompson

Date of Thesis Defense: April 30, 2012

Abstract

Background: Anxious individuals exhibit significant if not distinct patterns of cardiovascular activity. Changes in heart rate variability reflect alterations in the input of the sympathetic and parasympathetic branches cardiac autonomic nervous system (ANS). The current study examined the relationship between dispositional anxiety and the parasympathetic and sympathetic control of the heart as laboratory challenges were encountered.

Method: 50 college students performed the Stroop color-word task and mental arithmetic challenge while cardiac activity was measured using an ambulatory impedance cardiograph. Measures of cardiac sympathetic and parasympathetic activity were derived based on inter-beat intervals that are the number of milliseconds between each heartbeat. Trait anxiety was assessed using the Endler multidimensional scale which measures behavioral and somatic components of anxiety in several situations.

Results: Analyses of variance revealed that sympathetic control of the heart contributed to the increased heart rate during the math stressor, ($q(5, 240) = 8.241$, $p < .05$), whereas withdrawal of parasympathetic control of the heart increased heart rate during the Stroop task ($q(5, 240) = 3.523$, $p < .05$). While performing mental arithmetic higher state anxiety was associated with a loss of sympathetic control in both the approach and physical distress modes in the physical settings. ($r = -.311$, $p < .05$; $r = -.283$, $p < .05$). During the reading portion of the Stroop task, higher behavioral trait anxiety in interpersonal settings was related to a loss of cardiac sympathetic control ($r = -.362$, $p < .050$). Lastly, in the conflict phase of the Stroop task, higher reported physiological trait anxiety in a novel settings was associated with reduced cardiac parasympathetic control ($r = -.298$, $p < .05$).

Discussion: Self-reported levels of anxious predisposition were associated with several measures of cardiac responses to laboratory stressors. This is likely due to the demands of the tasks themselves or to a sensitivity to social cues within the context of task performance. When reported anxiety by situation matched in the laboratory context associated with performing the task, the facet of anxiety correlated with cardiac activity.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1: INTRODUCTION

Anxiety disorders show a strong association with risk factors that contribute to high morbidity and mortality rates (Friedman, 2007; W. R. Lovallo, 2003; William R Lovallo, 2005). The relationship between anxiety and cardiovascular reactivity can be explained by parasympathetic and sympathetic functions which are controlled by the Autonomic Nervous System (ANS). Cardiac components of anxiety include increased heart rate and changes in heart rate variability (HRV). (Berntson, Norman, Hawkley, & Cacioppo, 2008; Porges, 2007). Hypertension, heart disease, and diabetes have been shown to share both behavioral and physiological etiologies (William R Lovallo, 2005). Symptoms of anxiety have been associated with cognitive and behavioral techniques of avoidance, increased emotionality, and abnormal physiological responding which are often maintained by environmental circumstances. Physiological manifestations of anxiety have been associated with several somatic experiences such as shallow breathing and sweating(Van Diest, Thayer, Vandeputte, Van de Woestijne, & Van den Bergh, 2006), emotional state (William R Lovallo, 2005), and other forms of physiological arousal which are usually connected to autonomic nervous system (ANS) (Appelhans & Luecken, 2006). The aim of this project is to study relationships between the behavioral and physiological domains of anxiety cardiac sympathetic and parasympathetic activity.

Cacioppo and Berntson, (1992) have found that psychological variables have complex effects on cardiac activity. The relationship between physiological and psychological states is complicated because physiological arousal and behavioral manifestations are multi-directional and include multiple domains. Emotions and physiological responses are derived from multiple processes. As each is measured they can be labeled within the domain that best describes their function. With respect to subjective psychological measurement, the emotional response to anxiety can be described as cognitive responses or behavioral responses. Cardiac activity changes as a function of parasympathetic and sympathetic input and the relative balance between these branches of the nervous system.

The integration of cognitive and behavioral responses and the activation of physiological systems allows for a mapping of the relationship between these two facets of activity (Berntson et al., 1991). As described by Cacioppo & Berntson (1992), a multilevel analysis considers the elements from two or more levels of analysis of a particular phenomenon (subjective measures of anxiety & HRV), as well as the relational features between these phenomenon. In this case the multilevel analysis will examine differing perspectives involving emotional activity. The extent of the relationship between cardiac control across situations and the subjective reporting of anxious behaviors will determined. The intention is to generate a more comprehensive account to the phenomenon of symptoms of anxiety. (Cacioppo & Berston, 1992).

Autonomic Regulation

Anxiety as measured by state, trait, and physiological manifestations have been correlated with the emotion of fear (Friedman, 2007). The body's reaction to fear includes autonomic functions. These autonomic functions both sympathetic and parasympathetic are associated with several models of conceptualizations and theoretical approaches (G.G. Berntson, Cacioppo, & Quigley, 1994; Porges, 2007). Current research examines the role of the both branches of the autonomic nervous systems (ANS) control of cardiac activity (Norris, Gollan, Berntson, & Cacioppo, 2010; Thayer & Brosschot, 2005). Until recently, most physiological research defined autonomic control by the doctrine of autonomic reciprocity (Canon, 1929). This doctrine held that increases in one branch of the ANS will result in decreases in the other branch (G G Berntson et al., 1991). Studies using pharmacological blockades in human and animal studies have revealed that although the doctrine of autonomic reciprocity holds and is efficient in explaining autonomic phenomenon in many instances, it is far from universal.

The contemporary model of bivarate control subsumes the doctrine of autonomic reciprocity, yet also accounts for other configurations of autonomic control including instances where the two branches evidence uncoupled, co-active, and co-inhibited relationships (G G Berntson et al., 1991). The bivariate model of autonomic space, which will be utilized in the present study's analysis of individual differences, constructs sympathetic and parasympathetic axis to suggest the differing multiple modes of autonomic control. As depicted in figure 1, the bivariate model represents actual autonomic space of the individual.

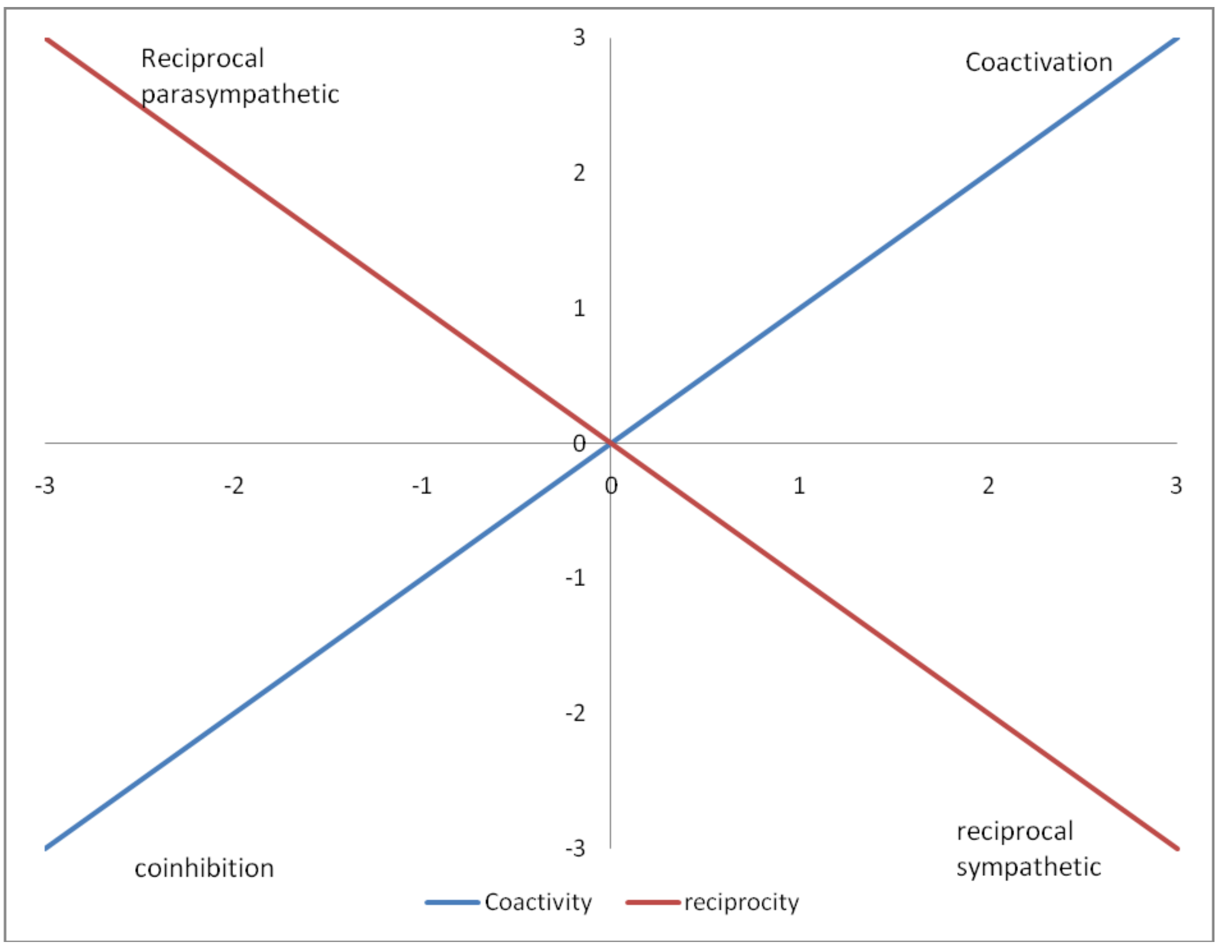


Figure 1. The bivarate Model of Autonomic Space

An individual's autonomic space is represented both parasympathetically and sympathetically. Parasympathetic coordinates on the graph, and presently were estimated by the respiratory sinus arrhythmia (RSA). The cardiac sympathetic coordinates were measured using Toichi (1997) cardiac sympathetic index (CSI). The graph will allow us to place each subject in a quadrant, based on these two measures of physiological estimates (CSI and RSA), showing ones location with respect cardiac sympathetic and parasympathetic activation.

Multidimensional Approaches to Anxiety

Endler and Okada (1975) attempted to provide a more comprehensive definition of the psychological state of anxiety by distinguishing between situational anxiety (state) and anxiety predisposition (trait). Situational anxiety is defined as a transitory state of the organism that occurs in a response to a stimulus, it can vary from moment to moment. Anxiety predisposition is seen as more of a personality trait that focuses on the individual differences and attempts to assess the likelihood of individuals experiencing state anxiety in stressful situations (Endler et al., 1991).

Endler and colleagues proposed an interactional model of anxiety which states that anxious behavior is a function of the interactions of the person and the situation (1991). Questioning the effectiveness of the global model of anxiety, with a focus solely on individual differences, the multidimensional approach evaluates personality variables of anxiety using a person-in-context method (Endler, 1991). Therefore this measurement of anxiety allows specific anxious responding to best categorized by levels of control, either by individual personality traits, specific situations, or some level of both. Differing from other models of unideminsional anxiety scales, which determine the presence of anxiety, the Endler definition combines the ability to distinguish between trait and state anxieties among individuals across several modes of response to anxiety factors (approach and physical responses) in the presence of differing situational domains.

In the multidimensional construct of anxiety, state anxiety is defined by two modes of reactions: Physiological distress and approach. The physiological distress refers to the behaviors that are initiated by the sympathetic nervous system (e.g, sweaty palms, rapid heart rate, and shortness of breath). The approach factor consists of an individual's willingness to engage in situations, which can result in avoidance behaviors. Endler and colleagues found these two modes of responding were conceptually and empirically distinct (1983,1989,1991). Also within the multidimensional construct of anxiety, trait anxiety has been found to vary across individuals, creating predispositions for anxiety in specific situations. Endler's interaction model of anxiety showed that state anxiety is a function of both specific dimensions of trait anxiety and situational threat. This was indicated by individuals with high levels of state anxiety exhibiting high levels of trait anxiety when exposed to a congruent threat, whereas individuals who exhibited low levels of state anxiety usually showed less trait anxiety (Endler 1991).

The S-R Inventory of General Trait Anxiousness assesses anxiety across a variety of situations. In conjunction with other forms of physiological measurement, the scale can be used to compare state and trait anxiety to help understand autonomic responding due to situations. The scale's trait anxiety measure (approach/physical mode) can provide a measure of behavioral flexibility across situations, indicating the individual's willingness to engage or amount of physical response. The multidimensional nature of anxiety along the bivarate plane of physiological responding allows for relationships between the two to lead to greater understanding of anxiety and autonomic regulation.

Anxiety and Autonomic Regulation

The physiological manifestations associated with anxiety responses include increased heart rate, shortness of breath, sweating, and has been associated with sympathetic influences, as defined by Canon's "flight or fight' model of stress (Canon, 1929). Subsequently, a more global approach to anxiety focused on autonomic control and anxiety was linked to excess autonomic liability and reactivity (Eysenck, 1970, Freidman, 1998). Unfortunately, these views continued Canon's tradition of ignoring the parasympathetic nervous system (Cacioppo & Berntson, 1992). Parasympathetic control is often associated with optimal functioning in the psychological and physiological domains (Cacioppo et al., 1995). Evidence suggests the parasympathetic system optimizes cardiac control, emotional responding, and attentional control. Freidman and colleagues (1998) suggested that many conceptualizations of anxiety are inadequate to because they focus solely on the control of the sympathetic system, and neglect the contribution of the parasympathetic system.

The parasympathetic system is now believed to influence more prominently the resting control of the heart, and contributes significantly to autonomic flexibility and adaptive responses to stressors (Friedman, 2007; Freidman & Thayer, 1998; Thayer & Freidman, 1993,1997). Conceptualization of anxiety models of autonomic flexibility and neurovisceral integration are closely related to theories of inhibition and perseveration. Inhibition is crucial in regulating both physiological and psychological reactions to specific stimuli in order to achieve an alternative goal or behavior. Freidman and colleagues (2007) suggest that at the evolutionary heart of anxiety is inability to block biological responses to threats. Forms of anxiety are cognitively represented through many types of internal processing (e.g., hyper-vigilance and preservative thinking). Individuals with greater vagal tone (parasympathetic control) show better inhibition over certain tasks, as well as exhibit lower levels anxious responding toward stimuli (Thayer, 2005).

Cardiac physiological responses to stress are often mediated through vagal withdrawal, which results in increased heart rate and other physiological response patterns (Porges, 1992a). Many anxiety based reactions have also been correlated with vagal withdrawal (e.g., worry, perseveration, and fear). During vagal withdrawal studies have shown that the sympathetic system is dominate in activation, which is often labeled autonomic imbalance (Thayer & Friedman, 2004). Vagal tone is explicitly referring to the understanding that the primary functions of the heart are under inhibitory control of the parasympathetic system (Thayer, 2005). Due to this phenomenon, cardiac autonomic balance is conceptualized by sympathetic dominance over sympathetic influences. In anxious individuals, as well as with other pathological states, there is a tendency for behavioral hypersensitivity and persistent vigilance to threatening situations, which is indicative of loss of physiological inhibition allowing a perpetual excitatory state common referred to as “flight or fight.” This perpetual physiological state has lead researchers to associate chronic anxiety with “trait-like” low vagal tone (Friedman, 2007).

Anxiety and physiological measures of the autonomic nervous systems have long been the topic of scientific inquiry. Heart rate variability (HRV) has been highly correlated with positive and negative effects on both emotion reactivity and negative health outcomes (Friedman, 2007; Friedman & Thayer, 1998; Lovallo, 2005). High levels of trait anxiety have a negative relationship to cardiac vagal control which has been linked to diabetes mellitus and high levels of disease (Ziegler et al., 2001; Freidman & Thayer, 1998; Friedman, 2007, Porges, 2007). Ingjaldsson and colleagues (2003) found that vagally mediated (parasympathetic dominant) HRV has an inverse relationship with negative mood and a positive correlation with positive mood. State anxiety has also been associated with HRV as seen in response to stressful tasks and stressful events, indicating that with anxious individuals vagal withdrawal is common (Porges, 2007). Looking at how both trait and state anxiety are linked with HRV is the goal of this research. Understanding the relationship between physiological responses and emotional responding is proposed to allow researcher to map individual based on both their physiological and psychological representations. Laboratory stressors will be introduced to trigger reactions in both the sympathetic and parasympathetic nervous systems of the participants. The Stroop task, which measures the ability to selectively attend to the color of word stimuli presented while ignoring the words meaning, monitors parasympathetic reaction of the individual (Boutcher & Boutcher, 2006). Mental arithmetic, found to increase HR as a result of contextual stress, will be utilized to measure the individual's sympathetic reaction (Cacioppo et al., 1995).

In an attempt to measure the individual's physiological emotional states, this study will assess physiological responses to laboratory stressors and quantify any relationships between physiological responses and behavioral flexibility (state/trait anxiety). Each individual will also have their physiological profile mapped by their autonomic space according to baseline and responding patterns. Analysis will determine if there is a relationship between subject reporting of state and trait anxiety and physiological responses across stressors. It is hypothesized laboratory stressors will elicit a physiological change, as controlled by specific branch of the autonomic nervous system. Specifically it is hypothesized that changes in heart rate during the math stressor will be medicated by the sympathetic system, whereas heart rate change during the word conflict task of the Stroop will be controlled by parasympathetic system. In regards to anxiety, it is hypothesized that individuals who exhibit high levels of trait and state anxiety will show patterns of physiological responding that corresponds to the specific autonomic branches that control the heart.

CHAPTER 2. METHODS

Participants

This study recruited 50 undergraduate students attending Howard University, a historically black university located in Northwest Washington D.C. Participants in the study received research course credit to complete their requirement of research participation for psychology courses. The participants ranged from 19 to 27 years old (M= 19.83 years). The majority of the participants self-identified as African American (98%) and the sample was majority female (n=33). Exclusion from the study included neurological, psychiatric (e.g., active psychosis), or cognitive impairment that would impair participant's ability to understand and answer questionnaires, current diagnosis of heart disease or heart condition that would interfere with HRV readings, however no persons meet criteria for exclusion.

Measures

Endler Multidimensional Anxiety Scale (EMAS): Endler's multidimensional assessment of anxiety requires respondents to rate their anxiety in terms of situational determinants and modes of responding. Endler and colleagues created the EMAS to assess distinctions between an individual's predisposition to anxious behavior in a given situation and actual physiological response patterns to anxious stimuli (Endler, et al., 1991). The state anxiety measure has been found to be comprised of two major components: cognitive and autonomic responses (Endler,et al. 1985; Endler, et al., 1989).

Measuring Heart Rate Variability (HRV): To determine HRV participants will be connected to an impedance cardiograph. Cardiovascular measures will be converted from cardiograph data into metrics of cardiac variability using the QRStool and CmetX software suite.

The QRStool provides a graphical interface to both view and extract IBI time series. Once the IBIs have been extracted by the CmetX program, a command-line utility, which calculates several metrics of cardiac chronotorpy based on provided IBI series input(Allen, 2007). Data analyzed from the CmetX program will include HR, Cardiac sympathetic Index (CSI), and Log-transformed respiratory sinus arrhythmia (LRSA), that latter two metrics have been empirically derived to represent sympathetic and parasympathetic function respectively.

Stroop Task: is a color word conflict task. The Stroop task measures the marked interference of word reading when asked to perform color naming. This task has been widely used as a mental stressor that has effects on cardiovascular reactivity. Participants are asked, in the first trial to read a set of color words, then in the next trial participants are asked to name the color of the words rather than reading the words. The Stroop task will be presented on the computer with the program Pscyscope 3.57. The Stroop task consists of three conditions color naming, word reading, then color naming of incongruent word stimuli. The Stimuli will be placed on the screen for approximately 5 seconds or until a button press is made. Each condition will consist of 30 trials and last approximately for 60 seconds. The Stroop task is seen to be a good mental stressor because it not influenced by learning effect and it demonstrates consistent autonomic reactivity (Boutcher & Boutcher, 2006). Participants will be measured for response time and amount of correct responses.

Mental arithmetic: Participants will be audibly presented a recording that will instruct them how to perform this task. The participant will hear a four digit number then asked to subtract nine from that number continually until they reached zero. The participant is asked to say the product out loud. Approximately 1 minute into the task the participant is asked to work faster. The voice of the recorder will be controlled for gender

Procedures

Participants completed a brief demographic questionnaire to collect descriptive information for the study (age, sex, race, level of education, household income, psychiatric history, medical history, and employment status). Participants were then given the EMAS to assess their current levels of anxiety across differing situations. After completion of the written portion of the study, participants were directed to the lab where a research assistant explained the process of measuring HRV to the participant before placing six electrodes on the participant. The specific placement of the electrodes was explained to the participants and visually presented on a diagram in the lab. All participants were assigned research assistants by gender, where female participants had electrodes placed on them by a female research assistants and male participants by male research assistants. Participants were also connected to an automated blood pressure monitor that recorded blood pressure readings at each level of the experiment and during the rest periods. Prior to the start of the experiment, each participant received a 5 minute rest period to obtain resting measures of blood pressure and heart rate. During the rest period the participant listened to soft music (jazz) to aid relaxation. After the rest period, the participants received two experimental tasks, the math stressor and the stroop task. The order of the two experimental tasks were randomly assigned in order to counterbalanced the effect of the tasks.

CHAPTER 3. RESULTS

Patterns of Cardiac Response

Changes in HR, CSI, and LRSA were analyzed in a two by six split plot factorial design, where the effects of gender and laboratory tasks (math/Stroop) were measured. Gender was the between-subject variable and periods (Baseline, Stroop read, color conflict, Math and Rest) constituted the within-subject variable. The Greenhouse-Geiser correction was used for repeated measures comparisons to control for violations of the assumption of sphericity (Vassey and Thayer, 1987).

Heart Rate

The analysis of variance revealed that cardiac rate changed significantly across periods as indicated by significant main effects of periods ($F(2.72, 130.96) = 12.97$, $P < .0001$). Post-hoc analyses using Tukey's procedure revealed a significant increase of HR from baseline in all experimental conditions. Means are presented in Table 1. Mental arithmetic ($q(5, 240) = 10.896$, $P < .05$), Stroop color ($q(5, 240) = 4.347$, $P < .05$), Stroop word reading ($q(5, 240) = 4.987$, $P < .05$), and Stroop conflict ($q(5, 240) = 5.251$, $P < .05$) all significant differences from baseline. There were no main effects of gender or any interaction between gender and period.

Cardiac Sympathetic Index (CSI)

An analysis of variance helped explain the differential effects of the tasks on the sympathetic control of the heart (CSI). There were significant main effects of periods for CSI ($F(3.814, 183.09) = 10.95$, $P < .0001$). Post-hoc analyses indicated that there were no differences between baseline and activity during performance of the Stroop task. However there was a significant increase in CSI from baseline to mental arithmetic performance ($q(5,240) = 8.241$, $P < .05$). This analysis revealed an increase in CSI (indicative of sympathetic activation) during the mental arithmetic task with no real effects during the Stroop. There were no significant effects of gender or an interaction between periods and gender.

LRSA

As illustrated in Table 2, analyses of variance indicated that for LRSA a significant main effect for task ($F(3.768, 180.867) = 2.844$, $P < .05$) resulted. Post-hoc tests revealed that there was a significant decrease in parasympathetic control of the heart during the Stroop word reading task ($q(5, 240)= 3.523$, $P < .05$). This effect suggests that during the Stroop word reading task, the heart rate increase that occurred were primary controlled by the loss of parasympathetic control. In other words vagal withdraw resulted in heart rate increase without significant sympathetic activation. There were no significant effects on gender or any interactions between these terms.

Summary of Task Effects and Modes of Autonomic Response

As illustrated in Graphs 2, 3, & 4, across all tasks heart rate was best explained by an uncoupled activation of the parasympathetic and sympathetic responses respectively. The increase in heart rate during the mental arithmetic was primarily controlled by an increase in sympathetic activation, whereas the increase in heart rate during the word reading Stroop task indicated parasympathetic withdraw.

Anxiety and Cardiac Responses to Tasks

The S-R inventory of General Trait Anxiousness was used to assess anxiety levels across situations. Associations between anxiety and the physiological responses of the experimental tasks (mental arithmetic and Stroop task) were determined. The S-R Inventory measures two modes of response, the physiological distress associated with physiological responses (e.g., increase heart beat) and the approach factor looks at factors that can be best associated with an individual's tendency to approach these situations (Endler & Okada, 1975). As previously mentioned, general trait anxiety was measured by summing the two modes of responses (behavioral and physiological) across four situations of interest (Daily situations, New situations, Physical situations, and Interactions with others). The scores on the behavioral mode for both Interactions with others and Physical situations were significantly correlated with several cardiac measures. Specifically, CSI during the word reading Stroop task, was negatively correlated associated with in the behavioral mode of responding to interpersonal interactions ($r = -.311$, $P < .05$). The higher trait anxiety scores reported for this situation were associated with lower levels of sympathetic control of the heart in this experimental task. During the Mental arithmetic task, there was a negative correlation between anxiety in the behavioral mode during physically threatening situations and sympathetic responding ($r = -.283$, $P < .05$). Thus, higher levels of reported trait anxiety scores during physically threating situations were associated with lower levels of sympathetic control of the heart during the mental arithmetic task. With respect to the physiological mode of responding, reports of anxiety during physically threatening situations and novel situations were associated with several measures of cardiac activity. During the mental arithmetic task, there was a negative correlation between anxiety in the physiological mode in the physically threatening situations and sympathetic control ($r = -.362$, $P < .05$). That is, higher levels of reported anxiety in this mode and situation were associated with lower levels of sympathetic control of the heart during this task. During the Conflict Stroop task, there was a negative correlation between reported physiological manifestations of anxiety in novel situations and parasympathetic responding ($r = -.298$, $P < .05$). That is, the tendency to report greater anxiety in physiological modes during novel situations was associated with lower levels of parasympathetic activity during this experimental task. There were no differences across gender and no other patterns across any other traits and situations.

Summary

Overall, HR, CSI and LRSA showed significant change across periods of the experiment from baseline (mental arithmetic and Stroop). During the mental arithmetic task HR increased primarily due to an increase in the cardiac sympathetic index with little change in the parasympathetic system. This effect is indicative of an uncoupled sympathetic activation. Similarly, the Word Reading Stroop task also showed an increase in HR; this resulted primarily from decreases in parasympathetic activity with no significant changes in sympathetic control. Hence the autonomic system was still functioning in an uncoupled mode. Both response modes and situations impacted the relationship between trait anxiety and sympathetic and parasympathetic functioning during the experimental tasks.

CHAPTER 4. DISCUSSION

The aim of this study was to analyze the relationship between anxiety and psychophysiological responding. The explicit goal was to descriptively represent heart rate variability (HRV) and autonomic balance of the participants as a function of their state and trait anxiety. As expected, the present study found evidence supporting current literature citing reciprocal relationships between sympathetic and parasympathetic functioning. However other cardiac patterns also emerged. During both the color Stroop and the word conflict task, the non-invasive measurements of parasympathetic and sympathetic functioning reveal the reciprocal pattern of sympathetic increase coupled with parasympathetic withdraw. This pattern was found to be the basis of heart rate increases in those two phases of the experiment. Along with this common autonomic response pattern, an analysis of the specific branches of the cardiac autonomic nervous system indicated that the mental arithmetic task and the word reading Stroop task could be best explained by an uncoupled response (Bernston, 1991). As reported in several similar studies, (Knepp & Friedman, 2008; Perlstein, Carter, Barch, & Baird, 1998) the mental arithmetic task elicited a significant increase in sympathetic activation; whereas there was an uncoupled parasympathetic withdrawal during the word reading Stroop task.

Along with the group findings, marked individual differences in responding were observed that were a function of anxious predispositions. Individuals who reported higher anxious responding behaved differently in both areas of sympathetic and parasympathetic control. Specifically, the highly anxious individuals showed a pattern of responding that suggests that the mechanisms that control the heart rate differ by these individual patterns. Further discussion will focus on the individual difference across experimental tasks and focus on the role that individual anxiety predisposition play on these findings.

Individual differences in the response to tasks

Along with graphically representing task specific autonomic responses, autonomic space depictions can be utilized to show individual patterns of autonomic responses (Gary G Berntson et al., 2008). The findings explicated above indicate that during the mental arithmetic and word reading Stroop, responses in the autonomic branches were to an extent uncoupled, resulting in an increased heart rate during those tasks.

What is most significant about these findings are that group differences in responding appear to be affected by individuals differences. The effect of the experimental tasks is best captured by increased heart rate, but as graph 2,3, and 4 show, individual variance that is evidenced in autonomic space representations indicates participants varied considerably in the patterns of their responses. Similar findings of marked variability have been reported by Berntson et al (2008). These multiple patterns of responses on the individual level might be best accounted for by anxious predispositions.

Anxiety Responses and cardiac activation.

HRV has been correlated with several behavioral process related to both affective responding and attentional control. In the multidimensional view of anxiety, the extent of anxious responding is determined by the congruence between the situation specific trait level of anxiety and the current threatening situation (Endler & Okada, 1975). This study sought to define the pattern of multidimensional responding in the presence of laboratory tasks and explain the effect on autonomic response.

According to Endler and colleagues (2001), in order for a person by situation interaction to increase state anxiety the threatening situation must correspond with trait being observed. In other words, it is theorized that situational (trait) threats must be congruent to the type of state anxiety being reported, such as physical danger increasing autonomic-emotional arousal in one who reports anxiety in the face of threats to bodily well-being. Incongruent threats are not hypothesized to affect changes in the individual's state anxiety. In the current study, the behavioral mode of state anxiety is conceptualized as the individual's willingness to approach situations. The present findings indicate that higher levels of state anxiety in the behavioral mode are associated with threats caused by interpersonal situations. A decreased willingness to approach interpersonal situations correlated negatively with cardiac sympathetic responses. In other words, when these individual's perception of a threatening situation of interpersonal interactions was congruent with their unwillingness to approach situations, this component of state anxiety had as a concomitant sympathetic withdraw. This effect was constant across laboratory tasks involving Stroop reading and the math stressor. This pattern differed from the group main effect of increased heart rate due to sympathetic contributions.

Initially the finding of reduced cardiac sympathetic activation where interpersonal anxiety is elevated might seem counter to the empirical findings suggesting that anxiety is physiologically classified as a sympathetic increase with vagal withdraw (Kreibig, 2010). However under close investigation the findings illuminate a distinct characteristic with individuals who have this high state anxiety. This particular effect might be best explained by the theory of attentional bias that is often exhibited by anxious individuals (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007; Mennin, Heimberg, Turk, & Fresco, 2005). Attentional bias is defined as the increased attention to the threat situations paired with the inability to disengaged attention or attentional avoidance (Cisler, 2010). Thus during the laboratory tasks, the individuals with threat congruence of behavioral avoidance in interpersonal situations where matched with tasks that allow them to elicit typical responses such as attentional avoidance to threat cues (Cisler, 2010). In both the Stroop reading and the mental arithmetic, it is hypothesized that the participants might have been threatened by assumed social evaluation of the tasks, which is often associated with interpersonal interactions.

Similarly, in the multidimensional theory of anxiety, the physiological distress classification is derived from and individual's reported autonomic-emotional arousal. A congruent threat situation that might elicit autonomic-emotional arousal can include physical danger or novel situations (Endler, Parker, Bagby, & Cox, 1991). The findings of the present study indicate that individuals who reported high levels of physiological distress state anxiety with the congruent threat of a perceived physical dangerous situation showed lower sympathetic control during the mental stressor task. Typically, mental stressors have been utilized to induce stressful cardiac responses through sympathetic activation and parasympathetic withdraw and is often used as a stressors due to the low motor demand of the task (Knepp & Friedman, 2008; William R Lovallo, 2005). In this experiment, as expected the math stressor showed the typical significant main effect on heart rate and sympathetic control of the heart. However on the individual level those participants with reported higher physiological trait anxiety in congruent physical danger situations showed a contrasting pattern of responding. Like in the behavioral mode, more anxious individuals showed a loss of sympathetic influence during the math stressor. However, unlike the participants in the behavioral mode, this relationship seems to be illuminating the effect of a preexisting pattern of high levels of sympathetic control within certain individuals.

These individual patterns of responding can also account for variance in parasympathetic control of the heart. Typically, the “Stroop interference” is the effect of the word conflict task on the individual’s ability to inhibit the tendency to read the words in the presence of counter instructions (Y. N. Boutcher & Boutcher, 2006; Perlstein et al., 1998). Physiologically, this task increases the heart rate due to the associated attentional processes that are influenced by the parasympathetic system. In this study, individuals who reported higher levels of physiological distress within congruent threats in novel situations showed a decrease in parasympathetic functioning. This may be interpreted as meaning physiological response are reflecting the situational context of the Stroop as opposed to the attentional demands of the task. The present findings is typical several empirical findings that report that high trait anxiety has a negative correlation with HRV, and emotional responding (Kreibig, 2010; Van Diest et al., 2006). Highly physical anxious individuals in the congruent threat of novel situations differed from their experimental counterparts due to the underlying mechanism of their increased heart rate. During the Stroop task, highly anxious individuals appeared to be reacting to the apprehension of the situation rather than to the actual physiological and attentional demands.

Physiologically, anxiety is best categorized by sympathetic activation and vagal deactivation, which is indicative of reciprocal inhibition (Kreibig, 2010). The patterns from this study support the multidimensional theory of anxiety with corresponding physiological representations. The laboratory stressors were able to elicit physiological anxious responses when the person by situation threat was congruent. The significant findings indicate individuals who tended to be more anxious tended to exhibit cardiovascular hyporeactivity in the presences of laboratory tasks. This hyporeactivity tended to affect performance on the experimental tasks due to situational influences rather than actual task difficulties. Although there were significant increases in heart rate across all experimental tasks, it is suspected that individual variability affected the specificity in detecting large patterns in the physiological responding of the group.

Implications

This study was able to provide support for the multidimensionality of the both state and trait anxiety in-vivo. The facets of anxiety expressed by the dependency between the individual's states and traits were quantified by contributions of the autonomic nervous system. Findings suggest that anxious individuals in the face of a congruent threats act on situational cues to mitigate situational interactions. Unlike non-anxious individuals, these individuals are affected by perceptions of threatening situations and their physiological activations are protective responses facilitating avoidance or escape. Under the excess physiologic lability present in anxious individuals, increased sympathetic control and decreased vagal tone, which is often associated with clinical anxiety, is often associated with diminished HRV (Friedman, 2007)

The benefit of this particular study adds to the literature an attempt to show physiological correlates to multidimensional aspect of anxiety. Findings are consistent with the current literature that suggests highly anxious individuals exhibit high sympathetic activation (Bruce H Friedman, 2007; Kreibig, 2010; Norris et al., 2010). Being that the pattern of high sympathetic activation has been found to be a risk factor to myocardial infarction other chronic health diseases (Gary G Berntson et al., 2008; Wang, Thayer, Treiber, & Snieder, 2005) , this cohort of healthy 19-22 year olds illuminate how early risk factors look physiologically in the presence of average health markers (e.g., HR). Future directions will continue to observe the relationship between state and trait anxiety and its role on the individual's autonomic space, but also attempt to measure what level of environmental factors might affect the development and maintenance of individual traits that lead to greater physiological reactivity. In vivo representation of HRV in this population holds great potential for furthering the investigation to mechanistic issues that play a role in the physiological development of negative health outcomes.

APPENDIX: TABLES AND FIGURES

Table 1. Means and Standard Deviations of Cardiac Measures across Tasks

	Heart Rate		CSI		LRSA	
	M	(SD)	M	SD	M	SD
Baseline	73.87	(14.55)	2.09	(1.0)	6.41	(1.44)
Mental arithmetic	82.82	(12.96)	2.93	(1.35)	6.41	(1.07)
Stroop Color	77.26	(10.3)	1.87	(.68)	6.28	(1.03)
Stroop word	78.19	(11.46)	2.21	(1.07)	6.02	(1.28)
Stroop conflict	78.45	(11.74)	2.2	(.851)	6.21	(1.39)
Rest	75.47	(9.67)	2.07	(.928)	6.47	(1.07)

Table 2. Analysis of Variance (ANOVA) of Cardiovascular Measures

		Sum of Squares	DF	Mean Square	F	Sig
Heart Rate						
	Between Groups (periods)	2576.82	2.73	944.45	12.97	.0001
	Within group (error)	33111.82	48	689.82		
	Total					
CSI						
	Between Groups (periods)	34.124	3.18	8.946	10.95	.0001
	Within group (gender)	149.59	183.1	.817		
	Total					
LRSA						
	Between Groups (periods)	6.981	3.77	1.85	2.844	.016
	Within group (gender)	117.83	180.87	.651		
	Total					

Table 3. Correlations of Parasympathetic and Sympathetic Functioning by personal physical distress across situation measurement of anxiety.

Measure of physical distress			Situation			
	M	SD	*Daily*	*New*	*Physical*	*Interpersonal*
CSI Math	.843	1.329	.114	-.270	-.362*	-.140
LRSA Math	-.0028	1.216	-.024	-.223	-.127	-.152
CSI Stroop word	.1287	1.333	.083	-.165	-.205	-.165
LRSA Stroop word	-.3923	1.257	-.155	.030	-.105	.235
CSI Stroop conflict	.1191	1.092	.002	-.060	-.162	-.097
LRSA Stroop Conflict	-.2053	1.232	-.164	-.298*	-.187	-.198

Table 4. Correlations of Parasympathetic and Sympathetic functioning by personal approach distress across situation measurement of anxiety.

Measure of Approach distress			Situation			
	M	SD	*Daily*	*New*	*Physical*	*Interpersonal*
CSI Math	.843	1.329	-.142	.070	-.283*	-.053
LRSA Math	-.0028	1.216	-.035	.121	.037	-.091
CSI Stroop word	.1287	1.333	-.169	-.023	-.167	-.311*
LRSA Stroop word	-.3923	1.257	-.087	.077	.114	-.262
CSI Stroop conflict	.1191	1.092	.049	.036	-.156	-.201
LRSA Stroop Conflict	-.2053	1.232	-.156	.143	.039	-.223

Figure 2. Change in cardiovascular measurement across experimental tasks.

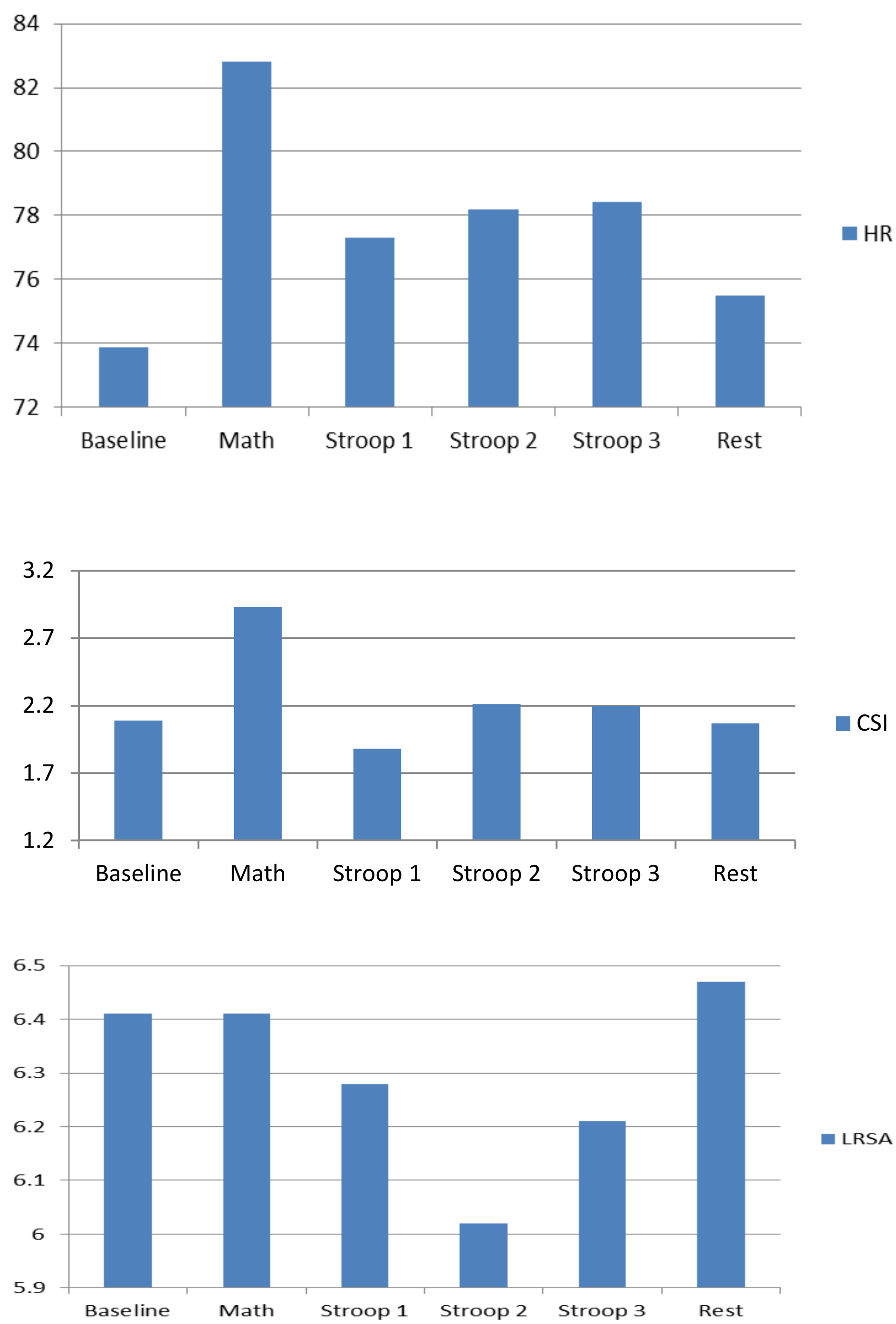


Figure 3. Changes in Autonomic Space by mental arithmetic condition from baseline.

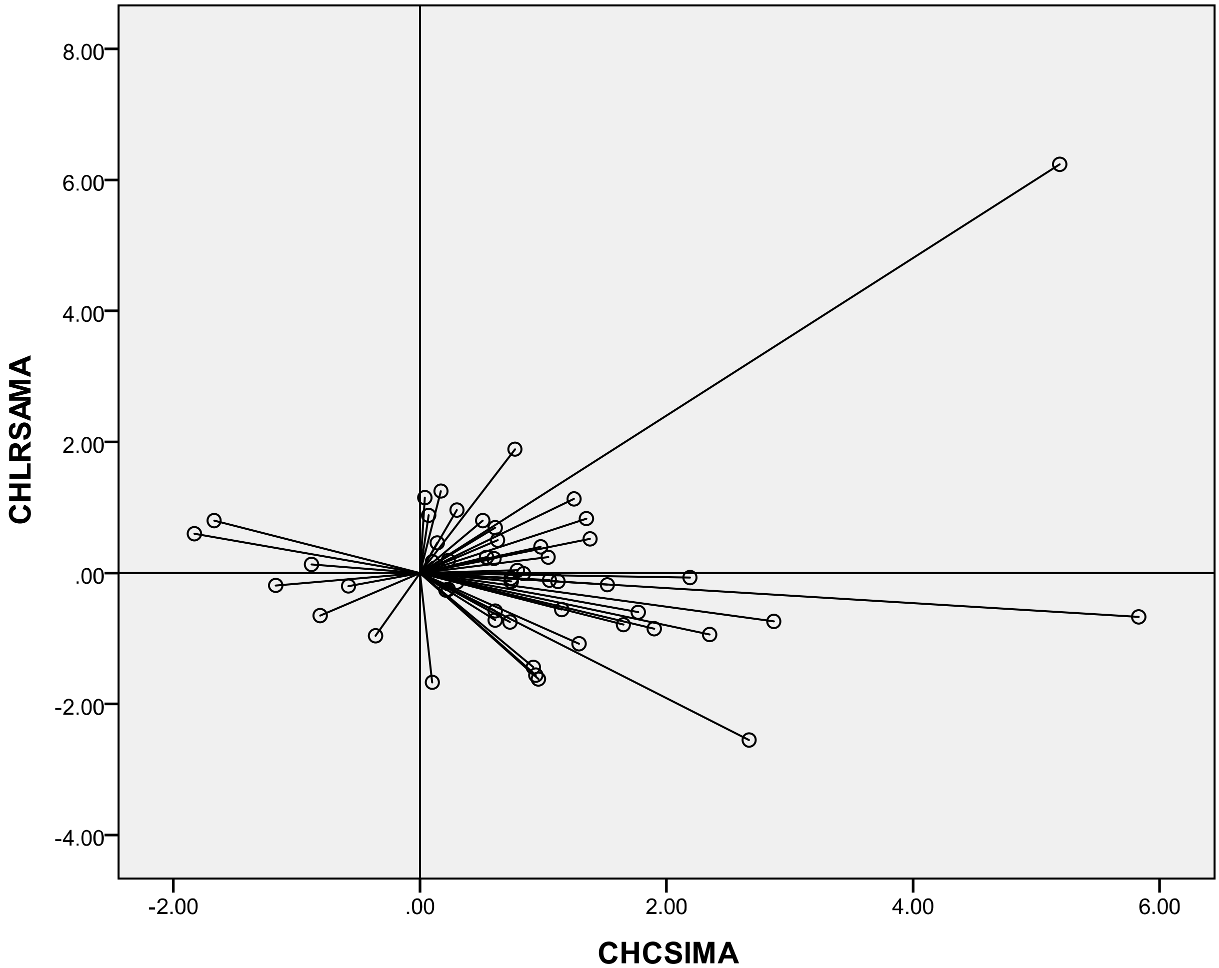


Figure 4. Changes in Autonomic Space by Stroop read condition fromm baseline.

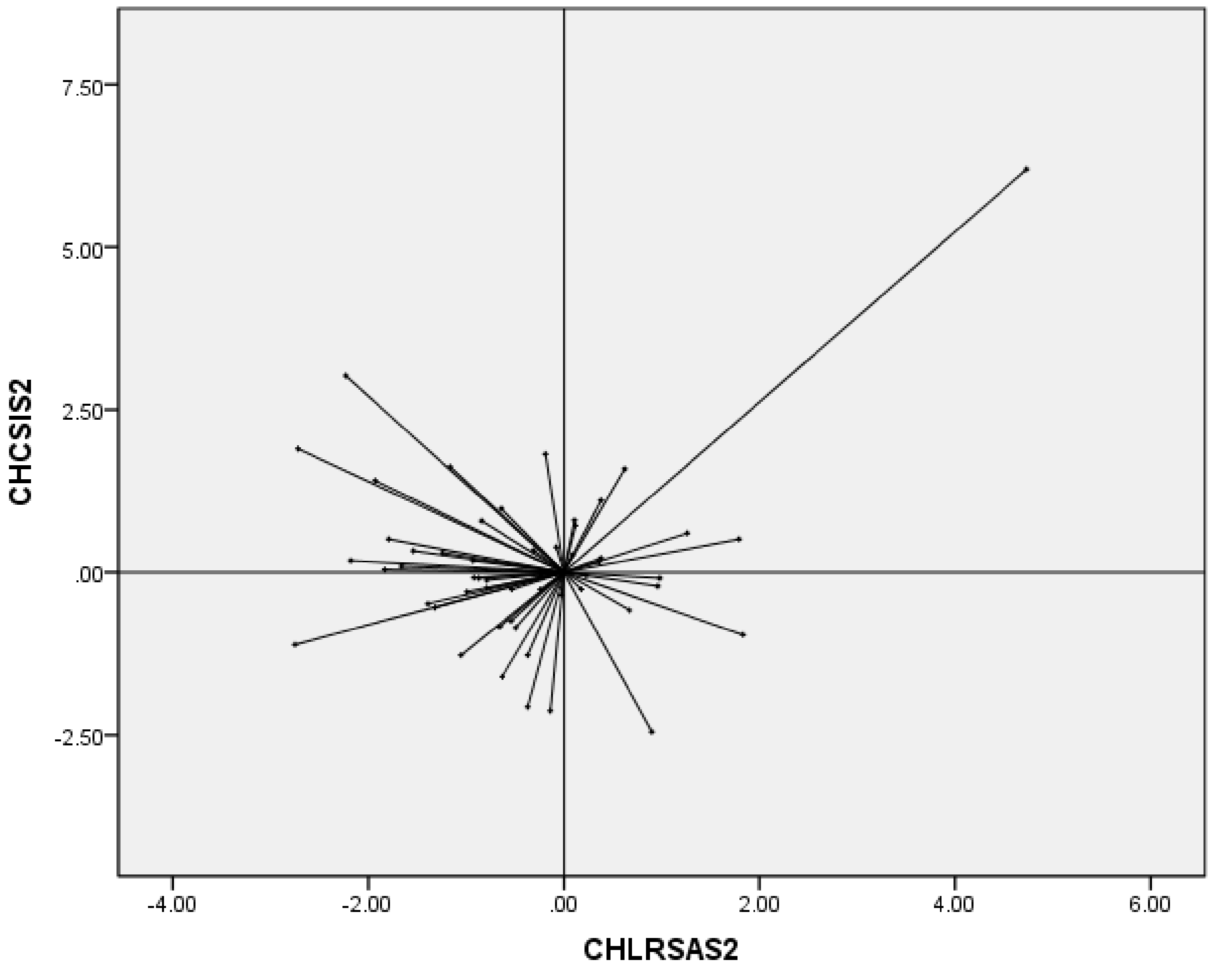
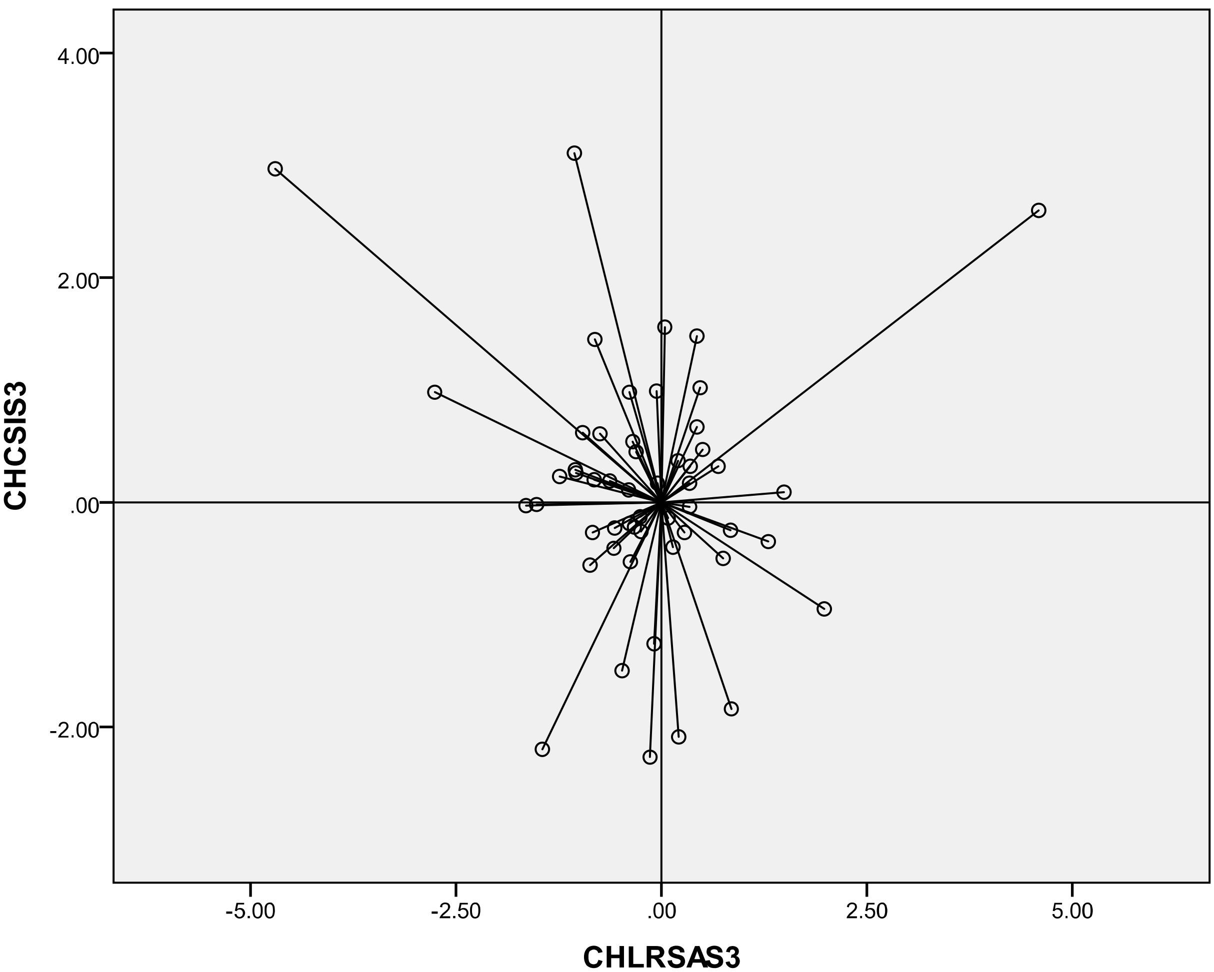


Figure 5. Change in Autonomic Space by Stroop Conflict condition from baseline.



REFERENCES

Appelhans, B. M., & Luecken, L. J. (2006). Heart rate variability as an index of regulated emotional responding. *Review of General Psychology*, *10*(3), 229-240. doi:10.1037/1089-2680.10.3.229

Bar-Haim, Y., Lamy, D., Pergamin, L., Bakermans-Kranenburg, M. J., & van IJzendoorn, M. H. (2007). Threat-related attentional bias in anxious and nonanxious individuals: a meta-analytic study. *Psychological bulletin*, *133*(1), 1-24. doi:10.1037/0033-2909.133.1.1

Berntson, G G, Cacioppo, J. T., & Quigley, K. S. (1991). Autonomic determinism: the modes of autonomic control, the doctrine of autonomic space, and the laws of autonomic constraint. *Psychological review*, *98*(4), 459-87. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/1660159

Berntson, Gary G, Norman, G. J., Hawkley, L. C., & Cacioppo, J. T. (2008). Cardiac autonomic balance versus cardiac regulatory capacity. *Psychophysiology*, *45*(4), 643-52. doi:10.1111/j.1469-8986.2008.00652.x

Berntson, G.G., Cacioppo, J. T., & Quigley, K. S. (1994). Autonomic space and psychophysiological response. *Psychophysiology*, *31*(1), 44–61. Wiley Online Library. Retrieved from http://onlinelibrary.wiley.com/doi/10.1111/j.1469-8986.1994.tb01024.x/abstract

Boutcher, Y. N., & Boutcher, S. H. (2006). Cardiovascular response to Stroop: effect of verbal response and task difficulty. *Biological psychology*, *73*(3), 235-41. doi:10.1016/j.biopsycho.2006.04.005

Cacioppo, J. T., Berntson, G. G. (1992). Social psychological contributions to the decade of the brain: Doctrine of multilevel analysis. American Psychologist, 47(8), 1019-1028.

Cacioppo, J. T., Malarkey, W. B., Kiecolt-Glaser, J., Uchino, B. N., Sgoutas-Emch, S. A., Sheridan, J. F., Berntson, G. G., Glaser, R. (1995). Heterogeneity in Neuroendocrine and immune responses to brief psychological stressors as a function of autonomic cardiac activation. *Psychosomatic Medicine*, 57, 154-164.

Cisler, J. (2010). Mechanisms of attentional biases towards threat in anxiety disorders: An integrative review. *Clinical psychology review*, *30*(2), 1-29. doi:10.1016/j.cpr.2009.11.003.

Endler, N. S., Parker, J. D., Bagby, R. M., & Cox, B. J. (1991). Multidimensionality of state and trait anxiety: factor structure of the Endler Multidimensional Anxiety Scales. *Journal of personality and social psychology*, *60*(6), 919-26. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/1865327

Friedman, Bruce H. (2007). An autonomic flexibility-neurovisceral integration model of anxiety and cardiac vagal tone. *Biological psychology*, *74*(2), 185-99. doi:10.1016/j.biopsycho.2005.08.009

Knepp, M. M., & Friedman, B. H. (2008). Cardiovascular activity during laboratory tasks in women with high and low worry. *Biological psychology*, *79*(3), 287–293. Elsevier. doi:10.1016/j.biopsycho.2008.07.002

Kreibig, S. D. (2010). Autonomic nervous system activity in emotion: a review. *Biological psychology*, *84*(3), 394-421. Elsevier B.V. doi:10.1016/j.biopsycho.2010.03.010

Lovallo, W. R. (2003). Psychophysiological Reactivity: Mechanisms and Pathways to Cardiovascular Disease. *Psychosomatic Medicine*, *65*(1), 36-45. doi:10.1097/01.PSY.0000033128.44101.C1

Lovallo, William R. (2005). Stress & health biological and psychological interactions. Thousand Oaks, Calif.: Sage Publications. Retrieved from

Mennin, D. S., Heimberg, R. G., Turk, C. L., & Fresco, D. M. (2005). Preliminary evidence for an emotion dysregulation model of generalized anxiety disorder. *Behaviour research and therapy*, *43*(10), 1281-310. doi:10.1016/j.brat.2004.08.008

Norris, C. J., Gollan, J., Berntson, G. G., & Cacioppo, J. T. (2010). The current status of research on the structure of evaluative space. *Biological psychology*, *84*(3), 422-36. Elsevier B.V. doi:10.1016/j.biopsycho.2010.03.011

Perlstein, W. M., Carter, C. S., Barch, D. M., & Baird, J. W. (1998). The Stroop Task and Attention Deficits in Schizophrenia: A Critical Evaluation of Card and Single-Trial Stroop Methodologies. *Neuropsychology*, *12*(3), 414-425.

Porges, S. W. (2007). The Polyvagal Perspective. *Biological psychology*, *74*(2), 116-143. doi:10.1016/j.bbi.2008.05.010

Thayer, J. F., & Brosschot, J. F. (2005). Psychosomatics and psychopathology: looking up and down from the brain. *Psychoneuroendocrinology*, *30*(10), 1050-8. doi:10.1016/j.psyneuen.2005.04.014

Toichi, M., Sugiura, T., Murai, T., Sengoku, A., 1997. A new method of assessing cardiac autonomic function and its comparison with spectral analysis and coefficient of variation of R-R interval. *Journal of Autonomic Nervous System*, (62), 79-84.

Van Diest, I., Thayer, J. F., Vandeputte, B., Van de Woestijne, K. P., & Van den Bergh, O. (2006). Anxiety and respiratory variability. *Physiology & behavior*, *89*(2), 189-95. doi:10.1016/j.physbeh.2006.05.041

Wang, X., Thayer, J. F., Treiber, F., & Snieder, H. (2005). Ethnic differences and heritability of heart rate variability in African- and European American youth. *The American journal of cardiology*, *96*(8), 1166-72. doi:10.1016/j.amjcard.2005.06.050