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BIS-BAS, dispositional influences on cardiac reactivity to naturally occurring stressors

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BIS-BAS, Dispositional Influences on Cardiac Reactivity to Naturally Occurring Stressors

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MASTER'S THESIS

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Nicholas Goodman

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A Thesis
Presented to
The Faculty of
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ABSTRACT

Research has relied primarily on laboratory settings to examine how emotions and physiology are affected by acute experiences of stress. This is because it is difficult to manipulate acute stress outside the lab and without a discrete manipulation it is difficult to measure physiological and emotional arousal during acute stress. This study found evidence that everyday stress predicts temporary changes in blood pressure. The purpose of this study was to investigate Gray's (1987) behavioral inhibition (BIS) and behavioral activation (BAS) systems, and to identify divergent cardiovascular and emotional outcomes to natural stressors for each of these systems. The data from a set of within-day analyses do not suggest that BIS and BAS moderate the association between blood pressure, heart rate, and momentary affect (frustration, happiness, sadness, and stress) to everyday stress. End of day analyses examined potential enduring effects of stress. The data suggest that there are gender differences in the extent to which everyday stress predicts end of day averages of blood pressure and heart rate. Women had lower overall systolic blood pressure, including on more stressful days. In contrast, men tended to have higher systolic and diastolic blood pressure during stress, and a trend suggested that they have higher diastolic blood pressure on more stressful days. In addition, the data suggest that sensitivity to BIS and BAS is associated with daily affect. In particular, BIS sensitivity predicted daily negative affect and BAS sensitivity predicted both daily positive affect as well as greater positive affect on days with more stressors.

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BIS-BAS, Dispositional Influences on Cardiac Reactivity to Naturally Occurring Stressors

"When life hands you a lemon, make lemonade" (Norman Vincent, 1955). This is a wise philosophy. In reality some people can turn sour situations into something sweet, while others may get frustrated or angry and allow stress to pile up. A person's appraisal of stress and psychological response to stressful events has implications for consequences of bodily stress responses (Smith & Lazarus, 1993; Heponiemi, Keltikangas-Jarvinen, Kettunen, Puttonen & Ravaja, 2004; Sterling & Eyer, 1988; Trieber, Kamarack, Schnudeman, Scheffield, Kapuken, & Taylor, 2003). Acute stressors such as uncomfortable social interactions (Lehman & Conley, 2010) and chronic stressors like a long-term illness of a family member (Trieber et al., 2003) can affect health. Stressful events like these may trigger the sympathetic nervous system, producing elevated cardiac activity including a faster heart rate and increased blood pressure (Trieber et al., 2003). Activation of the sympathetic nervous is the body's way of rising to a challenge and preparing to deal with a tough situation with focus, strength, stamina, and heightened alertness (Girdano, Everly, & Dusek, 2001). Changes that occur as part of a stress response can cause harm if stress is prolonged or very intense. Thus, stress responses have consequences for long-term health and well-being. Differences in how individuals appraise and respond to stress, either by approaching or withdrawing, may influence the activation of the sympathetic nervous system and its associated effects on the body (Heponiemi et al., 2004; Smith & Lazarus, 1993; Trieber et al., 2003).

The purpose of this study is to examine individual differences in responding to everyday stress. Evidence suggests that both acute and chronic stress activate important biological functions, including those influencing the autonomic, endocrine, and immune

systems (Cohen & Williamson, 1991). In general, stress is a feeling of pressure or strain caused by physical (e.g., disease), emotional (e.g., unhappiness) or psychological (e.g., anxiety) threat (Cohen & Williamson, 1991). A variety of sources suggest that both emotional and psychological stress are reliably associated with sympathetic nervous system reactivity (Anderson, Kiecolt-Glaser, & Glaser, 1994; Cohen & Williamson, 1991; Fleming, Baum, Davidson, Rectanus & McArdle, 1987). Individuals who show greater cardiovascular responses (reactivity) to stress are at greater risk for stress-induced hypertension and cardiovascular disease (Trieber et al., 2003). However, relatively little research has considered how naturally occurring stressors influence cardiovascular responses. This investigation therefore focuses on how individual differences in responding to naturally occurring stress may increase or decrease the activation of the sympathetic nervous system and help produce associated effects on the body. Specifically, it is expected that individuals who are predisposed to respond to stress with more negative affect, anxiety and avoidance behavior are more likely to be emotionally reactive to naturally occurring stressors, and in turn, more likely to show greater cardiac reactivity to those stressors.

Differences in how people respond to stressful situations can occur because stress does not exist objectively "out there" in the environment. Stress occurs as the result of the subjective reaction of the person to events (Lazarus & Folkman, 1984; McEwen, 1998). The process of appraising stressors begins with an individual first determining a stimulus' nature, quality, and significance for personal well-being and goals (Lazarus & Folkman, 1984). In particular, individuals may appraise whether the stimulus is positive, negative, or neutral, and whether it presents a potential threat, is benign or provides potential benefit. The nature and the intensity of the emotional and sympathetic arousal are believed to be determined through

this appraisal process (Lazarus & Folkman, 1984, Smith & Lazarus, 1993). Appraisal can be best understood as the process of sorting through an encounter, with respect to personal well-being (Smith & Lazarus, 1993).

Some individuals may be especially likely to appraise events or stimuli as threatening rather than as challenging, triggering negative emotions and sympathetic arousal. Threat can be defined as having the potential to put something that is valued into jeopardy (Smith & Lazarus, 1993). Challenge is similar to threat in that it too relies on mobilizing resources, but the main difference is that challenge appraisals focus on potential growth and gain. Other individuals may appraise the same particular stressor with less negative emotion, but may instead consider how this situation may benefit them now or in the future (Gable et al., 2000; Smith & Lazarus, 1993). For example, if a professor announces that class participation is mandatory, student "A" may experience extreme anxiety and reticence, hoping to avoid being called on. In contrast, student "B" may experience alertness, and work to seek the rewards of participation by preparing for and participating in class. Individual differences in the desire to avoid punishment and seek reward may drive this behavior. Student "A" stops his or her current behavior and redirects his or her behavior to avoid potential emotional distress or negative or painful outcomes, whereas student "B" seeks to benefit from the situation. Although the objective experience was identical, individuals differed considerably in the extent to which the situation was appraised as potentially beneficial or harmful for well-being.

Behavioral Inhibition and Behavioral Activation

Considerable individual variation exists in stress responses and in the consequences of stress for different individuals (Beauchaine, 2001). Genetic and social-developmental

factors help to influence the way a person experiences the external world (Fox, Henderson, Marshall, Nichols, & Ghera, 2005). Converging evidence suggests that individual behavioral predispositions may modulate behavioral responses to stress (Carver & White, 1994; Elliot & Thrash, 2002; Gable et al., 2000; Gray, 1987; Heponiemi et al., 2004). Specifically for some, a typical response to an unfamiliar stimulus or a stressor is one of approach and positive emotions, while for others the most likely response is one of withdrawal and negative emotions. Gray (1987) proposed two systems he theorizes underlie much of our behavior and personality. One system is characterized by avoidance or withdrawal behavior and is called the Behavioral Inhibition System (BIS). The other system, characterized by approach behavior, is called the Behavioral Approach System (BAS). Gray has proposed that the individual differences in the functioning of these systems and their interaction underlie differences in human temperament.

BIS and BAS are valuable tools for understanding individual differences in motivation and personality (Gray 1970; 1987). Gray perceived these systems as two neurological systems that form dimensions in personality (Gray 1970; 1987). Individual sensitivity to BIS and BAS are generally measured using Carver and White's BIS/BAS self assessment scale (Carver & White, 1994; Gable et al., 2000; Jorm, Christensen, Henderson, Jacomb, Korten, & Rodger, 1999; Sutton & Davidson, 1997). Because Gray did not develop a way to measure sensitivity to BIS and BAS, many researchers reappropriated instruments that were designed for other purposes (such as the extraversion scale from the Eysenck personality scale; Carver & White, 1994) in an attempt to assess BIS and BAS (Carver & White, 1994). Carver and White's (1994) BIS-BAS scale (see Appendix A), was developed specifically to measure individual differences in the sensitivity of the presumed underlying

neurological motivational systems. The Carver and White BIS-BAS scales are the most

comprehensive and specific measure of BIS-BAS sensitivities. Several validation studies

have found support for the validity of the BIS-BAS scales, common reported correlations for

Carver and White's (1994) BIS and BAS scale range from, $r = -.13$ to $.06$ (Huebeck et al.,

1998; & Jorm et al., 1999), and showed generalizability across samples.

Behavioral characteristics of persons with high predisposition to BIS include

situational and momentary anxiety, avoidance, neuroticism, and withdrawal-oriented

behavior (Gomez & Gomez, 2001; Gray, 1987). The BAS on the other hand is characterized

by reward/goal-directed and approach behavior. In the presence of a stressor or unfamiliar

stimulus the BAS' primary function is to begin or to increase movement toward goals,

primarily to achieve reward (Carver & White, 1994; Fowles, 1980; Heponiemi et al., 2004).

For example, more approach oriented (high BAS) student may react positively to the extra

effort of participating in class in an attempt to increase the probability of social or academic

reward. The transitory behavior elicited from BIS (anxiety, avoidance, & negative affect)

and from BAS (extraversion, impulsivity, & positive affect) may function as either a

damaging or protective factor for well-being (Smith & Lazarus, 1993) and for health

(Heponiemi et al., 2004). High sensitivity to BIS may be likely to lead to uninhibited

activation of the sympathetic nervous system. High sensitivity to BAS may also elicit

sympathetic nervous system activity, but this activity may be mediated by the

parasympathetic nervous system (Beauchaine, 2001), so that activation is proportional to

situational demand and the body returns to baseline levels more quickly. Therefore, because

of the duration of sympathetic arousal for those individuals high in BIS, BIS activation may

lead to both temporary and enduring effects of higher than normal blood pressure, heart rate

and negative affectivity. On the other hand, BAS activation may elicit momentary sympathetic and parasympathetic activation at the same time of a stressful event, but this activation would be less enduring than BIS activation.

Gray's theory of BIS and BAS is based on physiological evidence derived mainly from animal studies and lesion research (Gray, 1970). It has been suggested BIS and BAS have separate biological bases and operate as independent mechanisms (Amodio, Master, Yee, & Taylor, 2008). This theory has been supported by EEG studies (Amodio et al., 2008; Sutton & Davidson, 1997) and computerized go/no-go tasks (Gomez & McLaren, 1997), both suggesting that behavioral inhibition and behavioral activation activate distinct areas of the brain. These two systems encompass separate physiological and neurobiological connections that underlie individual differences in behavioral responses to stress (Amodio et al., 2008; Gomez & McLaren, 1997; Gray, 1991; Heponiemi et al., 2004). Specifically, EEG research suggests that greater activity is shown on the right side of the brain during BIS activation, while during BAS activation greater left-sided activity is shown (Amodio et al., 2008; Sutton & Davidson, 1997). In both cases activation occurs in cognitive judgment processing regions, but the activation occurs on different sides of the brain. This asymmetry suggests that the two mechanisms may be independent. Many reports have noted that unilateral left and right-sided lesions produce different emotional reactions in patients (Wheeler, Davidson, & Tomarken, 2007). Greater right prefrontal activation during laboratory induced stress may correspond to negative emotions, while greater left prefrontal activation may be linked with positive emotions (Amodio et al., 2008; Fox et al., 2005; & Sutton & Davidson, 1997). Such neurobiological evidence helps both to clarify the

independent root of BIS and BAS, and to suggest the ways in which the activation of each system predicts autonomic nervous system arousal.

BIS and BAS may orient and predispose individuals toward a specific sort of stress response. The arrows in Figure 1 highlight the hypothesized activation profile of BIS and BAS with the sympathetic and parasympathetic nervous system. Individuals higher in BIS are more likely to react negatively to stress and assess stressors as threatening; increasing the likelihood that an individual actively avoids the stressor and experiences negative emotions (Gable et al., 2000; Heponiemi et al., 2004; Smith & Lazarus, 1993). As indicated by the solid arrows, those higher in BAS are more likely to react positively to stress, manage stressful events and return more quickly to a calm resting state. Individuals higher in BAS are likely to be active in response to stress, and are more likely to be reward-driven. This often results in an approach response.

Emotional Reactivity

Watson and Clark (1984) proposed that stress reactivity may most accurately be measured by the increase in emotional distress that occurs as the individual moves from a neutral environment to a stressful environment. Evidence suggests that emotional processes are mediators of many associations between psychosocial variables and health outcomes (Taylor & Aspinwall, 1993). That is, negative affectivity (NA) has been associated with negative health outcomes, and positive affectivity (PA) with positive health outcomes (Denollet, Brutsaert, 1998; Denollet, Vaes, & Brutsaert, 2000). In addition, stressors that do not provoke a negative emotional response often fail to produce the basic stress response (Baum, Davidson, Singer, & Street, 1987; Mason, 1975). Further, evidence suggests a

connection between the BIS and negative affect, and the BAS and positive affect (Dillard & Peck, 2001; Gable et al., 2000; Heubeck et al., 1998; Jorm et al., 1999).

Many researchers recognize that behavioral inhibition and behavioral activation predict predispositions for specific affective states (Carver & White, 1994; Elliot & Thrash, 2002; Gable et al., 2000). In laboratory settings, for instance, those participants who were more sensitive to BIS reported they felt more negative emotions (Carver & White, 1994). In contrast, higher sensitivity to BAS predicted more positive emotions (Heubeck et al., 1998; Jorm et al., 1999). In addition, Dillard and Peck (2001) had participants view emotional public service announcements and found BIS sensitivity predicted greater negative emotional arousal whereas BAS sensitivity predicted more reporting of positive emotions.

Examining the effects of BIS and BAS using a within-subject approach in a naturalistic setting may lead to very different conclusions than those that would be obtained using laboratory approach. To examine how BIS and BAS sensitivity influence affect in a naturalistic setting, Gable et al., (2000) conducted a fourteen day study in which at the end of each day participants responded to daily event checklists composed of positive and negative social events. Gable et al., (2000) asked participants to complete Watson and Clark's (1984) measure of positive and negative affect (PANAS) at the end of each day. They found that BIS sensitive persons reported more negative affect and BAS sensitive persons more positive affect in everyday life. The authors also found a moderating effect of BIS on emotional reactivity to negative events; individuals higher in BIS tended to be more reactive to negative events than those lower in BIS. A moderating effect was not found in BAS. Heponiemi, Keltikangas-Jarvinen, Kettunen, Puttonen & Ravaja (2003) similarly reported that higher BIS predicted greater emotional reactivity to stressors, while Bolger and Schilling (1991)

suggested that emotional reactivity to stressors is twice as important as exposure to stressors in predicting overall daily affect.

Several authors have argued that behavioral inhibition may underlie much of our behavior and personality (Gray, 1987; Turner, Beidel, & Wolff, 1996). Neuroticism can be defined as psychological instability and proneness to experiencing negative emotions, and thus bears a strong resemblance to behavioral inhibition. Bolger and Schilling (1991) used a naturalistic design to compare the importance of exposure to daily stressors and reactivity to these stressors for individuals rated high in neuroticism. They found that among individuals who were high in neuroticism, emotional reactivity was associated with ineffective coping efforts (i.e., self-blame). As will be discussed later, greater emotional reactivity may also be linked with heightened cardiovascular activity (Heponiemi et al., 2003).

Cardiovascular Reactivity

The function of the cardiovascular system is to distribute oxygenated blood, containing nutrients, metabolites and hormones, to the cells to meet bodily metabolic needs. As outlined by Berntson, Quigley, and Lozano (2007), the heart is a pump that circulates blood through arteries, veins, and capillaries. Increasing the heart rate is the main way to increase blood flow from the heart. In healthy adults, heart rate typically varies between 45 (resting) and 200 (active) beats per minute and can change within seconds, while blood pressure typically ranges from 110 to 120 systolic and 75 to 85 diastolic. Prolonged elevated blood pressure increases the force with which blood is circulating oxygenated blood through the circulatory system.

With chronically elevated blood pressure, the smallest vessels must work harder to control blood pressure and to provide resistance. They eventually develop a thick layer

surrounding the vessel wall. As a result these vessels become more inflexible, and may cause increased blood pressure throughout the circulatory system. These events lead to increased force of the blood when returning to the heart which is harmful to the heart. The heart compensates for blood returning with greater force by increasing its' output (HR and force) to diffuse pressure within the heart. Eventually the deleterious effect of force impacting the heart wall results in the heart wall developing thick muscles surrounding the heart wall (myocardium), especially surrounding the left ventricle, called ‚Left ventricular hypertrophy' (LVH; Verrier, & Lown, 1984). Alone, LVH is not a disease, although it is the single best predictor of cardiac illness. At the very least, having a lopsided heart can lead to abnormal activity in the heart termed cardiac arrhythmias. Thus, stress has considerable impact on physiological parameters. Research suggests that many negative cardiovascular health outcomes may be attributed to exaggerated cardiovascular stress-responses (Berntson et al., 2007).

Heponiemi et al. (2003) and Heponiemi et al. (2004) examined BIS-BAS sensitivity and cardiovascular reactivity to laboratory stressors. These studies measured momentary heart rate reactivity to mental arithmetic, speech and reaction time tasks. Both of these studies found that BAS activation predicted significant increases in heart rate, and BIS activation was not associated with increases in heart rate. Heponiemi et al. (2004) reported that individuals with a high sensitivity to BAS exhibited increased heart rate reactivity independently of the nature of the stressors. Heponiemi et al. (2004) suggested that future studies examining individual differences in reactivity to stress should use of a broad range of cardiovascular parameters. Indeed, Beauchaine's (2001) model of BIS-BAS sensitivity and autonomic functioning suggests that BIS and BAS sensitivity determines several divergent

biological and psychological outcomes. To date, no studies have assessed the effects of BIS and BAS sensitivity on emotional and cardiovascular reactivity to naturally occurring stressors.

Beauchaine's (2001) model of BIS-BAS sensitivity and autonomic functioning suggests that BIS activation should be mediated through the sympathetic nervous system (SNS) but not the parasympathetic nervous system (PNS). The full extent of the relationship between SNS and PNS and BIS-BAS remains unknown, especially in the context of naturally occurring stressors. Beauchaine (2001) and Heponiemi et al. (2004) suggest that in response to BAS activation, the SNS temporarily increases heart rate and cardiac output while the PNS helps moderate SNS activation to control breathing and return the body to a state of rest. Activation of the SNS has the following effects: stimulating the sweat glands, dilating the blood vessels in large muscles, constricting the blood vessels in the rest of the body, and increasing cardiac activity. One of the SNS' most important effects is to cause the adrenal glands to release epinephrine, which has a cascading effect and eventually stimulates the above physiological responses. The timeline and progression of these physiological changes are determined in part by whether the PNS inhibits the SNS. Generally speaking the PNS brings the body back from the emergency status activated by the sympathetic nervous system. If the PNS does not inhibit the SNS, as many researchers predict in cases of BIS activation (Blascovich & Katkin, 1993; Beauchaine, 2001; Brenner, Beauchaine, Sylvers, 2005; Cacioppo, 1994; & Heponiemi et al., 2004), then increased cardiovascular activity may last considerably longer and delay reestablishing a state of rest. This pattern would be expected to correspond to temporary increases in blood pressure and heart rate, as well as more enduring cardiovascular elevations over the course of the day.

Figure 1 is a proposed model of the stress activation profile and includes the major components of the stress response system that are relevant to this thesis (Beauchaine, 2001; Brenner et al., 2005; Lazarus & Folkman, 1984). BAS activation is highlighted by the solid arrows and BIS activation is highlighted by hollow arrows. It is predicted that sensitivity to BIS and BAS will result in divergent psychological and biological outcomes to stress. That is, sensitivity to BIS and BAS should be associated with differential activation of positive and negative affect, and parasympathetic and sympathetic nervous system activation. Beauchaine (2001) suggests that BIS sensitivity is associated with sympathetic nervous system (SNS) activation to unpleasant or punishing stressors, whereas BAS sensitivity is linked to both sympathetic and parasympathetic nervous system (PNS) activation to challenging, potentially rewarding stressors.

The current study examines momentary cardiovascular and emotional responses to naturally occurring stress as well as more enduring effects of daily stress on blood pressure, heart rate and affect. It is predicted that during momentary stress, those with a high sensitivity to BIS should report relatively greater negative affect and exhibit SNS arousal, corresponding with temporary increases in blood pressure and heart rate. More enduring effects of stress may be observed by examining cardiovascular and emotional differences at the level of the day; on more stressful days, those with a high sensitivity to BIS should report greater negative affect and higher averages of blood pressure and heart rate for the day. These expectations parallel Beauchaine's (2001) suggestion that BIS should contribute to SNS arousal. In contrast, it is predicted that during momentary stress, those with a high sensitivity to BAS should report relatively greater positive affect and exhibit arousal of the SNS and PNS; resulting in increased heart rate but not blood pressure. These expectations

parallel Heponiemi et al. (2003) and Heponiemi et al. (2004) findings, and Beuachaine's (2001) prediction that BAS activation coincides with both SNS and PNS activation; with the PNS actively inhibiting SNS arousal to reestablish a state of rest, and therefore reduce the chances that momentary blood pressure would be elevated. At the level of the day, it is expected that on more stressful days, those with a high sensitivity to BAS should report greater overall positive affect. Because the PNS actively inhibits the SNS activity, there should be considerably less enduring cardiovascular effects of BAS activation. Thus, blood pressure and heart rate should not be greater on days that high BAS participants experience more stress.

Allostasis and Allostatic Load

Sterling and Eyer (1988) introduced the term ‚allostasis' (literal meaning: remaining stable by being variable), to explain how the cardiovascular system governs the active and resting states of the body. The nervous system achieves allostasis through the discharge of sympathetic neurotransmitters called catecholamines, causing both general physiological changes of muscles and organs (including increased blood glucose levels) and broad physiological changes in the heart (increased heart rate, and blood pressure; McEwen, 1998). To control resting states, the vagal nerve, governed by the parasympathetic nervous system, sends messages to the heart to decrease heart rate and blood pressure. Even mild to moderate momentary elevations in systolic or diastolic blood pressure are associated with an increased risk of cardiovascular disease (Kannel, 2005). The wear and tear (cumulative negative effects) that the body experiences from recurring cycles of allostasis is referred to as allostatic load (McEwen, 1998).

It is clear that many aspects of an individual's life, including early development (abuse and neglect), health behavior (nutrition, exercise), chronic psychosocial stress, environmental factors, as well as genetic predispositions together contribute to allostatic load (McEwen, 1998). Together these factors place a destructive toll on the body's resources and can ultimately lead to sickness and disease (McEwen, 1998; Sterling & Eyer, 1988). In healthy individuals the stress-response system is typically proportional to the intensity of the stressor (Seyle, 1974). Evidence suggests that individual differences in sensitivity to BIS and BAS help to produce variability in cardiovascular responses to stressors (Heponiemi et al., 2003, 2004). Whereas evidence for BAS suggests a healthy proportional response to stress (Cacioppo, 1994; Cohen & Hamrick, 2003), Heponiemi et al. (2003) suggests that high sensitivity to BIS is associated with greater negative emotional distress in response to stressors. This reactivity may partially explain why some individuals exhibit greater sympathetic arousal to naturally occurring stressors.

Laboratory studies consistently demonstrate dispositional influences, including BIS and BAS, on heart rate reactivity to laboratory stressors (Heponiemi et al., 2003; 2004; Pacak, Palkovits, Yadid, Kvetnansky, Kopin, & Goldstein, 1998; Verrier & Lown, 1984). There is considerable empirical evidence for consistent cardiovascular arousal across several laboratory stressors, but it is less clear whether laboratory cardiovascular reactivity predicts patterns of cardiovascular response in naturalistic settings (Kamarck & Lovallo, 2003). One of the common criticisms of this literature is that comparing cardiovascular reactivity associated with laboratory challenges to ambulatory levels of cardiovascular functioning throughout daily life is somewhat of an apple to oranges comparison. Accordingly, laboratory models measure cardiovascular responses to specific acute laboratory stressors,

while cardiovascular responses to daily stress likely fluctuate naturally over the course of a day.

The current study investigates how dispositional sensitivity to BIS and BAS may predict situational emotional and cardiovascular reactivity to naturally occurring stressors. Cardiovascular activity was measured as fluctuations in heart rate and blood pressure. The approach that is used in this study allows for a within day analysis of emotional reactivity and cardiovascular reactivity at multiple times of the day (i.e. around time of stressor), and an end of the day analysis that examines longer lasting effects of daily stress. This study significantly extends the research by Gable et al. (2000) by assessing cardiovascular responses in addition to emotional responses to naturally occurring stressors. Whereas both Heponiemi et al. (2003; 2004) have examined BIS-BAS emotional and physiological reactions to laboratory tasks, they have not extended their research to naturally occurring stressors. With the current study it is possible to examine the role of BIS and BAS in predicting emotional and cardiovascular reactions to naturally occurring stressors. It is expected that the within day effects will capture momentary cardiovascular and emotional responses, while the end of day assessment will capture more enduring responses.

Hypotheses

Based on the varied data sources available in this study, several approaches were used to test each hypothesis. Two of these hypotheses were tested using information from both within day measures and end of day measures. Within day tests were conducted by examining momentary cardiovascular and emotional responses to naturally occurring stressors. End of day tests were more comprehensive measures of emotional responses over the course of the day and summary measures of cardiovascular functioning.

Differential exposure hypothesis.

It was hypothesized that people who are more sensitive to BIS will experience fewer stressful events than those lower in BIS. Evidence suggests that people more sensitive to BIS may not put themselves in situations where they risk experiencing punishment (Gable et al., 2000). Gable et al. (2000) referred to this as differential exposure.

Emotional reactivity hypotheses.

Within day.

Existing research suggests that those with high sensitivity to BIS may experience greater emotional reactivity to those stressors they do face (Gable et al., 2000; Heponiemi et al., 2003; Heponiemi et al. 2004; & Sutton & Davidson, 1997). Therefore, in regard to within day assessments, the second hypothesis predicts that those higher in BIS will have a more pronounced increase in negative affect associated with stressful events than those lower in BIS. There are no predictions related to BAS sensitivity and emotional reactivity.

End of day.

In regard to end of day measures of emotional affect, it is expected that individuals with high sensitivity to BIS will experience more negative daily emotional affect. Previous findings by Gable et al., (2000) suggest that greater BAS sensitivity may predict more positive daily affect.

Cardiovascular arousal hypotheses.

Within day.

In regard to individual differences in within-day cardiovascular reactivity, the third hypothesis predicts BIS sensitivity should promote a pronounced increase in HR and BP, and BAS sensitivity should coincide with a pronounced increase in HR but not BP. Theory and

research suggests that high sensitivity to BIS should produce SNS arousal, and this should be measurable by a pronounced increase in HR and BP (Beauchaine, 2001). In contrast, high sensitivity to BAS should coincide with both SNS and PNS arousal, and this should be measurable by a marked increase in HR and not BP (Beauchaine, 2001; Cohen & Hamrick, 2003; Heponiemi et al., 2003).

End of day.

In regard to individual differences in end of day cardiovascular functioning, research suggests that behavioral inhibition is linked to SNS arousal and not associated with the PNS. In principle this pattern should result in longer lasting increases in HR and BP (Cohen & Hamrick, 2003; Heponiemi et al., 2003). In contrast, BAS activation is linked with SNS arousal and associated with PNS arousal, indicating that allostasis may be more rapidly reinstated (Beauchaine, 2001; Cohen & Hamrick, 2003; Heponiemi et al., 2003). Although this study's measures cannot directly assess the rate of cardiovascular recovery, the extent and permanence of cardiovascular response may be inferred by an end of day average of HR and BP after statistically removing differences in exposure to stressors. In theory, the cumulative effect of SNS arousal without PNS mediation may result in higher levels of HR and BP. Thus, it is expected that high sensitivity to BIS will predict higher average daily HR and BP, and high sensitivity to BAS should not predict higher average recorded HR and BP.

Method

Participants

This thesis study is a secondary data analysis using data that were collected during the 2006-2008 academic school years. Ninety-nine healthy undergraduate students (30% men, median age = 20) took part in this study. A majority of the sample was European American (77%), followed by Asian American (11%), African American (3%), Native American (1%), and other (7%). Data from two participants were not included because they did not complete two or more days of the study. Participants were students in introductory-level psychology courses at Western Washington University and received course credit for their participation, as well as a gift card to a local business.

The practices for screening and for the procedures of this study followed similar studies using ambulatory blood pressure in healthy populations (e.g. Brady & Matthews, 2006). Participants were excluded if they had existing hypertension or if they were taking medications that could influence blood pressure. In addition, because participant data were collected using an ambulatory blood pressure monitor and blood pressure cuff, participants were asked to refrain from strenuous exercise while wearing the equipment.

Materials

This study drew on data collected through ambulatory blood pressure monitoring, handheld palmtop devices that displayed within day questionnaires that were paired with blood pressure results, end of day reports, and end of study measurements of individual differences in BIS and BAS. See Table 1 for descriptive statistics for variables used in analyses.

Ambulatory blood pressure.

Participants wore a Spacelabs 90217 oscillometric ambulatory blood pressure monitor designed to record systolic and diastolic blood pressure as well as heart rate. Artifact and

outlier blood pressure readings were identified and removed from the data set following filtering recommendations from Marler, Jacobs, Lehoczky, and Shapiro (1988). Outliers for systolic blood pressure readings were those readings less than 70 mmHg and greater than 250 mmHg. Indication of artifact interference and outliers for diastolic blood pressure readings were diastolic blood pressure readings less than 45 mmHg and greater than 150 mmHg. Additionally, heart rate readings less than 40 bpm and greater than 200 bpm were identified as biologically improbable outliers and were removed. As shown in Table 1, mean systolic blood pressure was 121.74 mmHg (13.82), mean diastolic was 75.75 mmHg (10.25), and mean heart rate was 78.57 bpm (14.76). These are all typical cardiovascular readings for a young healthy sample (McEwen, 1998).

Within day reports.

Participants were asked to respond to questions in context of the 10 minutes prior to the blood pressure reading. Responses were made by moving a slider bar from a neutral midpoint (50), toward more, a value of 100, or less, a value of 1. Participants were told they must move the slider bar one way or the other to indicate a response and any response left at the neutral point would not be included. The questions that made up the assessment were designed to gather information on stressful events and other factors that are known to influence cardiovascular functioning. To measure negative and positive emotion, participants responded to a set of emotion survey questions adapted from the Diary of Ambulatory Behavioral States (Kamarck et al., 1998). Within day affect was assessed from the following four questions: "How stressed do you feel" "How sad do you feel", "How frustrated/angry do you feel" and "How happy do you feel?" Means and standard deviations are reported in Table 1. The remainder of the questions in the within day assessment were

included to gather information on potential situational covariates of blood pressure including: "[time of reading]…what was your posture," "Describe your physical movement," "Consumption of food, alcohol and caffeine and cigarettes since last BP reading." And "… [time of reading] were you talking" These potential situational covariates were included in the analysis if they predicted variability in blood pressure and heart rate. This resulted in 3,433 paired readings, an average of 35 per person ($N = 99$).

End of day reports.

A more detailed measure of positive and negative emotions was completed at the end of each day using Watson and Clark's (1984) PANAS scale. This scale consisted of a number of words and phrases that describe different feelings and emotions. Participants indicated to what extent they had felt this way during the day that day on a scale from 1 (not at all) to 5 (extremely). Sample words and phrases include: "cheerful" and "angry at self". The PA and NA measures consist of 10 positive (Cronbach's alpha = .85) and 10 negative emotion adjectives Cronbach's alpha = .81). Scores for these scales were used to assess overall emotional affect. As shown in Table 1, mean positive affect was 2.72 (0.71) and mean negative affect was 1.81 (0.63).

Each night participants were asked to report their most stressful event(s) that had occurred during the day, and to describe why the event(s) was stressful, and the time they occurred. The experiences that participants identified as stressful were then coded by two research assistants as stressful events or not. In this study, stressors were defined as any experience that threatens the self or self-relevant goals. This could include graduating from college, or paying rent. Non-stressors were defined as experiences that did not threaten the self or self-relevant goals (interrater agreement, Kappa = 0.81). Examples include statements

that nothing stressful happened that day, or taking notes in class with an explanation that it was not stressful. Using reported times, ratings of stressful events were then manually paired with ambulatory blood pressure data. Within day analyses used dummy coding to identify the times ambulatory blood pressure readings were taken at when stressful events occurred. This created one dummy variable; all blood pressure readings were coded as occurring during a stressor (coded as 1) or not (coded as 0). For the end of day analyses the reported stressful events were analyzed as a continuous variable (number of distinct events). Distinct stressful events were identified by coding consecutive reports of stressful events as paired events and breaks between consecutive reports indicated the start of a new distinct stressful event. The mean number of stressful events each day was 0.95 (0.76), with a minimum of 0 and a maximum of 4 stressful events.

End of study measures.

At the conclusion of the study participants completed several individual difference assessments. The assessment pertaining to this study was the BIS and BAS scale developed by Carver and White (1994). This measure was composed of ten items, as shown in Appendix A, participants indicated on a Likert-type scale (5 point) the extent to which they strongly disagreed and strongly agreed with each question. In this study, BIS and BAS were not significantly correlated (Pearson correlation, $r = -.041$, $p = 689$). Sample BIS questions include "If I think something unpleasant is going to happen I usually get pretty worked up", and "I worry about making mistakes" (Cronbach's alpha = .79 for the BIS subscale). Higher scores to these questions indicate participants have higher sensitivity to behavioral inhibition. Sample BAS questions include "When I see an opportunity for something I like, I get excited right away" and "It would excite me to win a contest." (Cronbach's alpha = .61 for the BAS

subscale). Higher score to these questions indicate participants have higher sensitivity to behavioral activation.

Procedure

All participants took part in a 5 consecutive day study. On days 1 through 4 beginning at approximately 8am and ending at approximately 11pm, participants wore a Spacelabs 90217 oscillometric ambulatory blood pressure monitor. The blood pressure cuff was fitted on the participant's non-dominant arm by aligning the cuff to the brachial artery. This monitor activated about once per hour to measure systolic and diastolic blood pressure, and heart rate. Following each ambulatory blood pressure reading, participants answered questions presented on a handheld palmtop computer using the program iESP. Both the blood pressure readings and the within-day questionnaires were time-stamped for correspondence. Participants were told that for safety reasons (e.g., driving) they were able to pause the ambulatory blood pressure monitor momentarily and then resume activation all with push of a button. The Spacelabs 90217 ambulatory blood pressure monitors automatically attempted to attain another reading in the event of an unsuccessful reading, such as those resulting from too much movement. On mornings 2 through 4, data were downloaded from the ambulatory blood pressure monitor and the handheld palmtop computer. Research assistants completed a brief assessment of the participants' experiences with the equipment, including answering any questions the participants may have had. Research assistants were available throughout the study to answer questions and address any problems.

At the end of each day participants completed a survey either online or by pen and paper. On the fifth day participants returned their equipment, and completed several

individual difference assessments, including a measure on BIS and BAS. Research assistants debriefed each participant and provided a list of local and University contacts and pamphlets that described ways to manage stress and suggested tools for coping.

Analyses

Data analysis was conducted using Hierarchical Linear Modeling 6.04 statistics software (Scientific Software International Inc., 2005). With HLM it is possible to compare an individual's blood pressure data and emotional responses at times of reported stressful events to their responses at other times.

Tests of within day and end of day effects were examined separately in 2-level hierarchical linear models. Within day variables at level 1 include momentary measures of SBP, DBP, HR, frustrated, happy, sad, and stressed. Level 2 included stable individual characteristics such as sensitivity to BIS and BAS and gender. For the end of day analysis, variables at level 1 included daily affect (reported from the PANAS assessment at the end of each day), and the total number of stressors for each day. Level 2 included sensitivity to BIS and BAS, and gender. Effects of BIS and BAS were tested separately. For within-day analyses, potential situational covariates including: posture, temperature, comfort, physical activity, recent consumption of food, alcohol, caffeine and cigarettes were assessed. These covariates were tested, but were only kept in the model if they significantly influenced outcome variables. Models of random effects were tested and kept in the final model only if they predicted the outcome at $p < .10$. If random effects were not significant, then analyses were conducted using fixed tests. Robust standard errors were used to address non-normality in the data.

Results

This research examined cardiovascular and emotional reactivity to naturally occurring stressors using two data sources: within day measurement, and end of day summary measurement. Within day stressors were identified by coding time of stressor occurrence, using the end of day summaries of stressful events. The current analyses also examined cardiovascular and emotional differences between men and women, and whether men and women differed in their responses to stressful events. All models were initially tested with the predictor variable of stress testing each outcome variable (SBP, HR, and affect). Unless otherwise stated, the reported results in text and in the tables are from analyses that include the effects of BIS, BAS, gender, and covariates. Gender differences are discussed when significant effects were identified. Results are presented in the order they were hypothesized. Within day analyses are reported first, followed by results from the more in depth end of day emotional reports. The cardiovascular reactivity section is further divided into SBP, DBP, and HR.

Differential Exposure to Stressors

The differential exposure hypothesis predicted that individuals who are more sensitive to BIS would report fewer stressful events than those lower in BIS. It was predicted that individuals high in BIS may actively avoid stressful situations and therefore have fewer reported stressful events than those lower in BIS. However, the number of reported discrete stressful events did not differ as a function of sensitivity to BIS, $t(97) = 1.24, p = .221$, or BAS, $t(97) = 0.71, p = .481$. This hypothesis was tested by examining the significance of the effect of BIS on the number of stressful events.

Emotional Reactivity to Natural Stressors

Within Day.

The emotional reactivity hypothesis predicts that individuals who are more sensitive to BIS will experience greater momentary negative emotional reactivity to stressful events than those less sensitive to BIS. For the within day test of this hypothesis, separate analyses were performed for frustrated, happy, sad, and stressed. BIS and BAS (level 2) were considered separately as moderators of momentary affect (level 1). Affect was predicted by the dummy coded stress variable, as coded from the end of day assessment. Slope and intercept differences in affect were expected for BIS. It was expected that those more sensitive to BIS would report more overall feelings of frustrated, sad, and stressed (intercept), and also report relatively greater feelings of frustrated, sad, and stressed during times of momentary stress (slope) than those less sensitive to BIS. There were no formal hypotheses for BAS sensitivity and emotional reactivity to momentary stress

.In contrast to low stress times, during times of momentary stress individuals reported significantly more feelings of frustration $t(98) = 3.64$, $p = .001$. However, as shown in Table 2, BIS sensitivity did not significantly amplify the feeling of frustration during momentary stress, $t(95) = 0.15$, $p = .880$. Conversely, a nonsignificant trend suggested that individuals higher in BAS reported more frustration during momentary stress, $t(95) = 1.73$, $p = .085$. In addition, there was a nonsignificant trend such that women tended to report less frustration than men during reported times of stress, $t(95) = -1.66$, $p = .099$.

Individuals reported significantly less happiness at times of momentary stress $t(98) = -3.72$, $p = .001$. However, BIS sensitivity did not significantly predict differences in happiness during momentary stress, $t(95)$ -0.76, $p = .451$ (See Table 2). BAS sensitivity also did not predict differences in the reports of happiness during momentary stress $t(95) = -0.41$, $p = .685$.

During momentary stress individuals indicated more feelings of sadness, $t(98) = 1.68$, $p = .095$. Neither BIS nor BAS sensitivity accounted for any differences in reported levels of sadness during momentary stress (BIS $t(95) = -0.73$, $p = .465$; BAS $t(95) = 0.94$, $p = .350$; see Table 3).

Individuals also reported feeling more stressed during times of stress (as self reported at each blood pressure reading), $t(98)$ 6.20, $p < .001$. Neither BIS sensitivity, $t(95) = -0.15$, $p = .879$, nor BAS sensitivity, $t(95) = -0.15$, $p = .879$, significantly intensified these temporary elevations in reported stress (See Table 3).

End of Day.

At the end of each day participants provided more in depth summaries of daily events. In this set of analyses, cardiovascular and emotional responses were examined to determine whether they varied with the number of stressful events that individuals reported experiencing each day. These analyses have the potential to examine the longer lasting effects of daily stressors on cardiovascular and emotional functioning. Reported stressful events were analyzed as a continuous variable (number of distinct stressful events), and used in these analyses as a predictor variable with group mean centering. These analyses also tested cardiovascular and emotional differences between men and women. All emotional reactivity results are reported in Tables 4 and 5. For the end of day test of emotional reactivity, BIS and BAS (level 2) were considered separately as moderators of positive and negative affect (level 1), as indicated by the end of day PANAS survey. Slope and intercept differences in emotional affect were expected for BIS, only intercept differences were expected for BAS.

Initially, the association between self reported stressful events and negative affect was tested without including BIS or BAS in the model. Participants reported higher levels of negative affect on days with more reported stressful events $t(98) = 2.75$, $p = .007$. It was predicted that those more sensitive to BIS would have more overall daily negative affect, and that reported levels of negative affect would be especially high on days with more stressful events. Individuals high in BIS did report more overall negative affect, $t(95) = 4.37$, $p < .001$, but not relatively greater negative affect on days with more stress, $t(95) = 0.49$, $p = .624$ (see Table 4). There were no other significant results for BIS and negative affect.

As shown in Table 4, individuals high in BAS reported more overall negative affect, $t(95) = 2.80$, $p = .004$, but did not differ in negative affect on days with more stress, $t(95) = -0.90$, $p = .134$. In addition, a BAS by stress by gender effect was significant, $t(95) = 2.25$, $p = .031$. Men low in BAS were especially prone to reporting greater negative affect on days with more stressors, while men high in BAS reported less negative affect on days with more stressful events (Figure 2). Comparatively, regardless of BAS sensitivity, women were prone to reporting greater negative affect on days with more stressors (see Figure 3).

Overall, the association between positive affect and reported stressful events was not significant $t(98) = 2.91$, $p = .772$ (see Table 5). There were no formal predictions for BIS and positive affect. Predictions for BAS were unclear, but it was anticipated that BAS sensitivity would be associated with more positive daily emotional affect (intercept). Individuals high in BAS did report higher overall levels of positive affect, $t(95) = 4.82$, $p < .001$, as well as greater positive affect on days with more stress, $t(95) = 2.13$, $p = .033$ (see Figure 6). Further, a gender by stress interaction, $t(95) = -2.40$, $p = .017$, suggests that men

were especially prone to greater positive affect on days with more stress, whereas there was no distinction in positive affect based on stress for women.

Cardiovascular Reactivity to Natural Stressors

Within Day.

The cardiovascular reactivity hypothesis predictrf that individual differences in BIS and BAS sensitivity should predict different activation profiles of the autonomic nervous system in response to stressful events. It was expected that BIS sensitivity would promote a pronounced increase in HR, and BP, whereas BAS sensitivity would promote a pronounced increase in HR but not BP associated with a stressful event. BIS and BAS (level 2) were considered separately as moderators of momentary cardiovascular reactivity (level 1) to stressful events. Slope and intercept differences of cardiovascular reactivity are expected for BIS and BAS. It was expected that high sensitivity to BIS would predict more overall SBP, DBP, and HR (intercept), in addition to greater cardiovascular reactivity to stressful events (slope). Cardiovascular reactivity expectations for BAS were unclear, but were tested.

Systolic blood pressure reactivity to stressors.

Results of within day tests of SBP are shown in Table 6. Initially, the association between stress and SBP was tested without including BIS or BAS in the model. This association was tested using systolic blood pressure as the outcome variable and a dummy coded variable representing stress as coded from each end of day report as a predictor variable. SBP was significantly elevated at times of momentary stress, $t(98) = 3.19$, $p = .002$. Readings taken during stressful events were an average of 1.41 mmHg higher than the readings taken at other times.

The first set of hypotheses predicted that: a) BIS sensitivity should moderate the effect of stress on SBP, with those high in BIS showing a pronounced increase in SBP at times of momentary stress; b) BAS sensitivity was not expected to moderate the association between stress and SBP. Tests of these hypotheses suggested that neither high BIS sensitivity nor high BAS sensitivity predicted elevated SBP during momentary stress, $t(95) = 0.93$, $p = .360$, and $t(95) = -1.00$, $p = .325$ (See Table 6). There were no interaction effects of BIS by gender or BAS by gender on the effect of stress and SBP. However, women had significantly lower SBP overall ($t(97) = -4.40$, $p < .001$) and also displayed less pronounced elevations in SBP at times of momentary stress $t(95) = -4.67$, $p < .001$ (see Figure 4). Men had on average 1.23 mmHg higher SBP during times of momentary stress than women.

Diastolic blood pressure reactivity to stressors.

Another goal for this research was to understand whether daily stress predicted a temporary rise in DBP. All results related to momentary DBP are shown in Table 7. The association between momentary stress and DBP was initially tested without BIS and BAS as moderators. DBP was significantly elevated at times of momentary stress, $t(98) = 3.95$, $p < .001$. The readings taken during stressful events were an average of 1.25 mmHg higher than DBP readings taken at other times.

The second set of hypotheses paralleled those tested for SBP. Contrary to expectations, when individuals experienced momentary stress, those with more BIS sensitivity did not show elevated DBP, $t(95) = 0.61$, $p = .544$ (see Table 7). Individuals with high BAS sensitivity also did not show especially elevated DBP during momentary stress, $t(95) = -0.48$, $p = .962$. These hypotheses were tested again including the differences between men and women. As shown in Table 7, there were no interaction effects of BIS by gender or

BAS by gender on the effect of stress and DBP. However, a trend suggested women's DBP was lower at times of momentary stress, $t(95) = -1.89$, $p = .058$.

Heart rate reactivity to stressors.

Another goal for this study was to understand how behavioral dispositions like BIS and BAS influence heart rate responses to daily stressors. As shown in Table 8, in tests of the association between stress and HR (not including BIS or BAS), heart rate was not significantly elevated during times of reported stressful events, $t(98) = 1.40$, $p = .164$. The third set of hypothesis investigated moderating relationships of BIS/BAS on the effects of naturally occurring stressors on heart rate responses. High BIS sensitivity was expected to promote a more pronounced elevation in heart rate at times of momentary stress. Also contrary to expectations, as indicated in Table 8, the association between heart rate and stress was not moderated by BIS sensitivity, $t(95) = 0.52$, $p = .598$ or BAS sensitivity, $t(95) = -1.18$, $p = .244$. Neither disposition toward BIS nor BAS predicted especially elevated heart rate at times of momentary stress. As shown in Table 8, the association between naturally occurring stress and heart rate did not differ for men and women. Similarly, there was no interaction between BIS and gender or BAS and gender.

End of Day.

Cardiovascular responses were averaged over each day so that each value indicates the average SBP, DBP, and HR for a particular day. Each person should therefore have four values, one for each day.

Systolic blood pressure reactivity to stressors.

Evaluating blood pressure at the end of day provides another opportunity to test for potential differences between BIS and BAS. The association between self reported stressful

events and SBP (without including BIS or BAS in the model) produced a nonsignificant

trend suggesting SBP elevations on days when individuals experienced a greater number of

stressful events, $t(98) = 1.67$, $p = .098$.

The first set of end of day hypotheses predicted that BIS sensitivity would moderate

the association between stress and SBP. As shown in Table 9, SBP was not especially

elevated on days when individuals high in BIS experienced more stressful events, $t(95) =$

0.55, $p = .578$. Likewise, SBP was not especially elevated on days when individuals high in

BAS experienced more stressful events, $t(95) = 1.02$, $p = .306$, and BAS did not predict

lower overall SBP, $t(95) = 0.19$, $p = .847$.

Women had significantly lower SBP overall, $t(98) = -4.77$, $p < .001$, and a trend

suggested less elevation in SBP on days when they experienced more stress, $t(95) = -1.81$, p

$= .070$. Overall, women had 5.03 mmHg lower SBP than men (See Table 9). There was a

marginally significant BIS by gender interaction, $t(95) = -1.74$, $p = .084$. Women higher in

BIS were prone to having lower overall SBP, while for men there did not appear to be any

association between BIS and SBP.

Diastolic blood pressure reactivity to stressors.

A trend suggested that DBP was relatively higher on days when individuals

experienced a greater number of stressful events, $t(98) = 1.79$, $p = .075$. As shown in Figure

5, there was a nonsignificant gender by stress interaction, $t(95) = -1.78$, $p = .073$. A trend

suggested that men were especially prone to having higher DBP on days with more stressful

events, while there did not appear to be an effect of daily stress on DBP for women. The

second set of end of day hypotheses predicted that BIS sensitivity should moderate the effect

of the number of stressful events on DBP. As shown in Table 10, neither BIS sensitivity,

$t(95) = -0.79$, $p = .429$, nor BAS sensitivity, $t(95) = 1.45$, $p = .162$, predicted the strength of

the association between DBP and number of stressful events. A nonsignificant trend

suggested gender differences in DBP averages on days with more stress, $t(95) = -1.78$, $p =$

.075. The pattern suggests that men had higher diastolic blood pressure than women on days

with more stress (see Figure 5).

Heart rate reactivity to stressors.

Heart rate was not elevated on days with reported stress, $t(98) = 0.474$, $p = .636$, and

as shown in Table 11, the association between stress and heart rate was not moderated by

BIS sensitivity, $t(95) = -0.01$, $p = .992$, or BAS sensitivity, $t(95) = -0.37$, $p = .712$.

Individuals high in BAS had an average 2.40 bpm lower overall heart rate $t(98) = -3.12$, $p =$

.003. In addition, a significant BAS by gender effect suggested that men higher in BAS had

lower overall heart rate, $t(98) = 4.23$, $p < .001$, while for women heart rate was not patterned

by BAS sensitivity.

Discussion

The results from the present study indicate that everyday stressful events do

significantly predict temporary elevations in blood pressure and are associated with both

momentary and daily negative affect. However, there was no evidence of differential

cardiovascular reactivity for individuals with sensitivities to BIS or BAS. On the other hand,

sensitivity to BIS and BAS did predict daily positive and negative affect. In particular, BIS

sensitivity predicted daily negative affect and BAS sensitivity predicted daily positive affect

as well as greater positive affect on days with more stressors. There were also several

significant gender effects ($p < .05$), and several more gender effects that resulted in

nonsignificant trends (p < .10). Generally speaking, women had overall lower systolic blood

pressure, including on days with more stress. In contrast, men tended to have higher systolic and diastolic blood pressure during stress, as well as a trend to have higher diastolic blood pressure on more stressful days. Results are further discussed in the order they were hypothesized.

Differential Exposure to Stressors

Although people probably do not actively seek out negative events, negative events do happen in the interactions of everyday life. The differential exposure hypothesis posited that participants high in BIS might be especially likely to actively avoid situations that could involve or produce stress (Gable et al., 2000). Gable et al. (2000) reported thst BIS-BAS sensitivity predicted the number of reported stressful events. Results from the present study suggest that the number of stressful events reported at the end of each day did not differ as a function of sensitivity to BIS or BAS. In other words, participants high in BIS were no more likely to report fewer stressful events than persons low in BIS. Thus, participants high in BIS did not seem to be actively avoiding situations that could involve or produce stress. As discussed later, the difference between this study and Gable et al.'s (2000) may be due to methodological differences in reporting stressful events at the end of each day.

Emotional Reactivity

Many researchers recognize that behavioral inhibition and behavioral activation predict predispositions for specific affective states and daily affect (Carver & White, 1994; Bolger & Schilling, 1991; Elliot & Thrash, 2002; Gable et al., 2000). In laboratory settings, individuals who are more sensitive to BIS tend to report more negative emotions throughout the day. In contrast, high sensitivity to BAS predicts more positive emotions (Heubeck, Wilkinson, & Cologon, 1998; Jorm et al., 1999). As predicted, sensitivity to BIS predicted

daily negative affect, and BAS sensitivity predicted daily positive affect. Thus, sensitivities of these two independent motivational systems are related to everyday affect states. It was also predicted that BIS sensitivity might predispose a person to experience emotional distress with exposure to stressful situations. However, there was no evidence that individuals high in BIS reacted to stressors with added emotional distress. Baum, Davidson, Singer, and Street (1987) suggested that stressors that do not provoke a negative emotional response often fail to produce the basic stress response. It may be possible there was no moderating effect of BIS because the stressors were not sufficiently negative to activate BIS. The participants in this study were college students with comparatively less professional and financial responsibilities, and presumably with fewer daily stress than an older occupational sample. Seemingly, these individuals may not only have more daily stress, but also the stressful events may provoke stronger emotional responses than the stressors in this study.

The measure of momentary affect assessed four distinct emotions (frustrated, happy, sad, and stressed). Frequently emotion measures are recorded with longer emotion scales, such as the State Anxiety Inventory (Spielberger, 1985). Self-reported assessments of single-item adjectives indicating discrete emotions like frustrated and sad may not reliably capture the complexities of emotional responses to stress. Perhaps these measures did not assess a full range of negative emotions and so important emotional dimensions such as power and level of activation may have been neglected (Feldman-Barrett, Mesquita, Ochsner, & Gross, 2007). Of course, researchers must also consider the length of momentary reports such as those used in this study. Future studies might include a wider range of emotional responses.

Measures of daily positive and negative affect at the end of the day provided another way to examine how individual differences in BIS and BAS sensitivity may predict

differential reactions to stress. It was predicted that BIS sensitivity would moderate negative affect in response to stressful events, but this was not found in the within day or end of day analysis. However, BAS sensitivity predicted relatively greater positive affect on days when participants reported more stressful events. In other words, those high in BAS who experienced above normal stressful days reported greater increases in positive affect than an average or low BAS person who had a similar day. This was a non-hypothesized finding, and differed from what Gable et al. (2000) reported. Although Gable et al. (2000) reported a nonsignificant interaction, the direction of their results also suggested that those higher in BAS reported greater positive affect on more stressful days. The effect may not have been significant in Gable et al.'s (2000) study because they had a much smaller sample size than the current study.

There was an unpredicted finding that sensitivity to BAS predicted greater daily negative affect. Typically, high sensitivity to BIS is associated with negative affect and high BAS sensitivity is associated with greater positive affect, but not negative affect (Bolger & Schilling, 1991; Gable et al., 2000). It has been reported that BAS is occasionally associated with negative affect during poor performance or when an individual is disengaging from goals (Carver, 2004). Because individuals with a high sensitivity to BAS regularly engage in reward driven tasks (Carver & White, 1994), it is possible that the outcome of some routine tasks may have been poor and that may have resulted in negative affect. Future research might incorporate into their study's momentary assessments, a brief assessment on how well individuals believe they are doing on daily tasks and events.

There were also a couple of gender and affect interactions reported in the current study. There was a nonsignificant gender by stress interaction that suggested a trend that

men high in BAS were prone to greater positive affect on days with more stress, whereas women were not. A nonsignificant three-way interaction suggested a trend that men higher in BAS reported lower negative affect on days with more stress (see Figure 2). Thus, men who are high in BAS who experienced an above normal stressful day reported less negative affect than average or low BAS males who had similar days. Males with high BAS sensitivity seemed to report comparatively greater positive affect and lesser negative on more stressful days. The differences in affect relative to sensitivity of BAS and gender suggest that gender to some degree moderates everyday affect states. High BAS males may have engaged in more goal-oriented and reward seeking behavior resulting in relatively greater positive affect and lesser negative affect. Similar trends in gender differences have not generally been reported in other studies on BIS and BAS (Gable et al., 2000; & Heponiemi et al., 2003); observed differences in this study may be influenced by the large proportion of women relative to men in the current sample. Future research may help establish whether or not these gender effects are replicable.

The present study was shaped in part by Gable et al.'s (2000) diary study. Different results were obtained; Gable et al. (2000) reported that BIS moderated negative affect on above normal stressful days, and found that BIS and BAS sensitivity predicted the number of reported stressful events (differential exposure hypothesis). The lack of consistency between the two studies may be in part because Gable et al., (2000) used a different method for identifying daily stressful events. Daily events in their study were identified using a thirty-six item positive and negative event checklist (Butler, Hokanson, & Flynn, 1994), while in the current study participants provided more in depth summaries of daily events, including an open-ended description of each stressful event. This assessment therefore required active

participation. The checklist approach might have served to prompt individuals to identify and recall a greater number of stressful events each day and also may have led to preserving aspects of positive and negative emotions. The checklist approach is more of a passive activity, requiring less involvement than the current study's open ended questionnaire. The open ended format may have required more attention and thus resulted in not as much participation. In the current study the maximum number of discrete stressful events reported on a day was four. The maximum number of stressful events each participant reported in Gable et al.'s (2000) study is not clear, but if there were substantially more reported stressors each day then a restriction of range might explain why they found moderating effect for BIS and BAS while this study did not.

Cardiovascular Reactivity

Beauchaine's (2001) model of autonomic nervous system functioning suggests that both BIS and BAS may be innervated through the sympathetic branch of the autonomic nervous system, and that the activation of either the BIS or BAS systems should produce short-term increases in cardiac output. Participants in the present study exhibited increased blood pressure to naturally occurring stressful events, but there was no evidence that sensitivity to BIS or BAS was linked to greater cardiovascular activity. Support for Beauchaine's (2001) model comes from a few laboratory studies (Heponiemi et al., 2003; Pacak et al., 1998; & Verrier & Lown, 1984). For example, Knyazev, Slobodskaya and Wilson (2002) found that those higher in BAS showed greater HR acceleration during difficult mental arithmetic tasks. Heponiemi et al. (2003) examined BIS-BAS sensitivity and cardiovascular reactivity to laboratory stressors. Heponiemi et al. (2003) found significant increases in HR were associated with BAS, but did not find significant changes in HR were

associated with BIS sensitivity. In contrast, the current study found no evidence for an influence of BAS on HR acceleration in response to a stressor. Turner et al. (1996) suggested that laboratory stressors are more productive in eliciting strong stress responses compared to natural stressors because the laboratory settings can manipulate the nature and difficulty of tasks. As discussed below, it is possible that the stressors in the present study were stressful enough to cause temporary elevations in blood pressure but not stressful enough or enduring enough for the elevations to be captured in the readings (Corr, 2001). The stressors available may not have been challenging or threatening enough to activate BIS and BAS.

If the natural stressors in the current study did not contain sufficient positive or negative motivational cues to produce enduring HR acceleration, then these cues may also have not been strong enough to activate BIS and BAS systems. Corr (2001) suggested that strong positive and negative motivational cues are necessary for BIS and BAS activation. Laboratory studies purposefully expose individuals to aversive stimuli that are potentially strong enough to activate BIS and BAS. However BIS and BAS may not be easily activated in natural settings because BIS and BAS may have evolved to activate in moments of exceptionally demanding need. In other words, BIS and BAS could be useful in the same was as a truck's four-wheel drive, practical during demanding situations but impractical during the mundane. Constant activation of the BIS and BAS systems could be harmful in everyday situations, just as repeated arousal of the cardiovascular system is harmful (McEwen, 1998).

In the current study, there were several significant gender differences in blood pressure that are consistent with previous research (Wang, Poole, Treiber, Harshfield,

Hanevold, & Snieder, 2006; Reckelhoff, 2001). Gender differences in blood pressure are commonly reported (Wang et al., 2006; & Reckelhoff, 2001); men typically have higher resting blood pressure and also exhibit higher elevations in blood pressure than women in response to a stressor. In the current study men were especially prone to having higher SBP during times of momentary stress compared to women (see Figure 4). Men were also prone to having relatively higher DBP than women on days with more stress (see Figure 5). BAS sensitivity was linked to lower overall heart rate. A significant interaction of BAS by gender suggested that it was men high in BAS that were especially prone to having lower heart rate, while heart rate among women did not appear to be associated with BAS sensitivity. Low resting heart rate is associated with good health (McEwen, 1998) and is typically determined by exercise and genetics (Wang et al., 2006). The best explanation for why men high in BAS were prone to having lower heart rates is that men high in BAS may typically engage in more exercise routines than women (McArthur & Raedeke, 2009). Future research might assess differences between men and women in association between BAS and level of exercise

Limitations

The current study examines cardiovascular reactivity with a sample of healthy undergraduate students. The average age of the sample was 21 years old. A majority of the sample has a membership to the university's gym and whether or not they used the facility they are presumably not comparable to an older more sedentary sample. Future studies may benefit from broadening the sample to a middle-aged sample that more closely matches the population of individuals at immediate risk of developing hypertension.

Possibly the most important difference between laboratory and natural research are the limitations in measuring ambulatory cardiovascular levels. Ambulatory research is

generally limited to blood pressure and heart rate monitoring. It is challenging to measure individual differences in physiological and emotional responses to momentary stress using ambulatory equipment (Ming, Adler, Kessler, Fogg, Matthews & Herd, 2004). First, blood pressure monitoring is typically scheduled once an hour so that it does not interfere with daily life, but this method limits the ability to measure the changes in blood pressure associated with stressors with accuracy. In addition, because the apparatus used in this study uses the blood pressure readings to calculate heart rate, measurement of heart rate is also restricted. Second, because blood pressure is a function of both cardiac output and vascular resistance (Hilmert, & Kvasnicka, 2010), measurement of blood pressure alone may fail to capture the potentially wide variability of individual differences in cardiac output and vascular resistance. Moreover, measurement of markers such as cardiac output and peripheral resistance would be generally too cumbersome for an ambulatory study and would interfere with daily life. Consequently, the aim of future research is to progressively revise new methods of measurement and utilize the most of current ambulatory technology.

Conclusion

BIS and BAS are valuable tools for understanding motivation and personality and may underlie much of our behavior and personality (Gray 1970; 1987). When studied in a laboratory setting, sensitivity to BIS and BAS systems are strong predictors of behavior (Amodio et al., 2008; Heubeck, Wilkinson, & Cologon, 1998; Jorm et al., 1999). From a health perspective, one of the ultimate goals was to test whether everyday life stress predicts temporary elevations in blood pressure, and whether some individuals are especially prone to such temporary changes. This research is important because the cumulative negative effect of reoccurring cycles of elevated blood pressure may contribute to the development of heart

disease (McEwen, 1998). The results from the present study indicate that everyday stressful events do predict temporary elevations in blood pressure and are associated with both momentary and daily negative affect. Future research should continue to investigate the contribution of such occurrences on the development of heart disease. The present results also provide evidence that individual differences in sensitivities to reward and punishment are related to daily affect. In particular, BIS sensitivity predicted daily negative affect and BAS sensitivity predicted daily positive affect as well as greater positive affect on days with more stressors. Continued improvements in the ambulatory assessment and measurement of emotional and cardiovascular reactivity to stress may enhance the understanding of the factors related to the development of heart disease as well as identifying persons at greater risk for heart disease.

References

Amodio, D. M., Master, S. L., Yee. C. M., & Taylor, S. E. (2008). Neurocognitive

components of the behavioral inhibition and activation systems: Implications for

theories of self-regulation. *Psychophysiology, 45,* 11-19.

Anderson, B., Kiecolt-Glaser, J. K., and Glaser, R. (1994). A biobehavioral model of cancer

stress and disease course. *American Psychological Association, 49,* 389-404.

Baum, A., Street, T., Davidson, L. and Singer, J., 1987. Stress as a psychophysiological

process. In: Baum, A. and Singer, J., Editors, 1987. *Handbook of Psychology and*

Health Vol. 5, Lawerence Erlbaum, Hillsdale, NJ, pp. 1–19.

Berntson, G.G., Quigley, K.S., & Lozano, D. (2007). *Cardiovascular Psychophysiology.* In

J.T., Tassinary, L. G., & Bernston, G. G. (eds.). *Handbook of Psychophsiology, 3rd*

edition (pp. 182-210). Cambridge UK: Cambridge University Press.

Blascovich J., & Katkin, E. S. (Eds.). (1993). *Cardiovascular Reactivity to Psychological*

Stress and Disease. Washington, DC: American Psychological Association.

Bolger, N., & Schilling, E. A. (1991). Personality and problems of everyday life:

The role of neuroticism in exposure and reactivity to daily stressors. *Journal of*

Personality, 59, 356–386.

Beauchaine, T. P. (2001). Vagal tone development, and Gray's motivational theory: Toward

and integrated model of autonomic nervous system functioning in psychopathology.

Development and Psychopathology, 13, 183-214.

Brenner, S. L., Beauchaine, T. P., Sylvers, P. D. (2005). A comparison of

psychophysiological and self-reportmeasures of BAS and BIS activation.

Psychophysiology, 42, 108–115.

Butler, A. C., Hokanson, J. E., & Flynn, H. A. (1994). A comparison of self-esteem stability and low trait self-esteem as vulnerability factors for depression. *Journal of Personality and Social Psychology, 66,* 166–177.

Cacioppo, J. T. (1994). Social neuroscience: Autonomic, neuroendocrine, and immune responses to stress. *Psychophysiology, 31*, 113-128.

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,* 319-333.

Carver, C. S. (2004). Negative affects deriving from the behavioral approach system. *Emotion, 4,* 3-22.

Cohen, S. & Williamson, G. M. (1991). Stress and infectious disease in humans. *Psychological Bulletin, 109,* 5-24.

Cohen, S. & Hamrick, N. (2003). Stable individual differences in physiological response to stressors: implications for stress-elicited changes in immune related health. *Brain, Behavior, and Immunity, 17,* 404-414.

Corr, P. J. (2001). Testing problems in J. A. Gray's personality theory: A commentary on Matthews and Gilland (1999). *Personality and Individual Differences, 30*, 333-352.

Denollet, J. & Brutsaert, D. L. (1998). Personality, disease severity, and the risk of long-term cardiac events in patients with a decreased ejection fraction after myocardial infarction. *Circulation*, 97, 167-173.

Denollet, J., Vaes, J., & Brutsaert, D. L. (2000). Inadequate response to treatment in coronary heart disease: adverse effects of type D personality and younger age on 5-year prognosis and quality of life. *Circulation, 102,* 630-635.

Dillard, J.P., Peck , E. (2001). Persuasion and the structure of affect: dual systems and discrete emotions as complementary models. *Human Communication Research 27*, 38–68.

Elliot, A. J., & Thrash, T. M. (2002). Approach-Avoidance Motivation in Personality: Approach Avoidance Temperaments and Goals. *Journal of Personality and Social Psychology, 82,* 804-818.

Fowles, D. C. (1980). The three arousal model: Implications of Gray's two-factor learning theory for heart rate, electrodermal activity, and psychopathy. *Psychophysiology, 17,* 87-104.

Fox, N. A., Henderson, H. A., Marshall, P. J., Nichols, K. E., & Ghera, M. M. (2005). Behavioral inhibition: linking biology and behavior within a developmental framework. *Annual Review of Psychology, 56,* 235-262.

Fleming, I., Baum, A., Davidson, E.R., Rectanus, E. and McArdie, S., (1987). Chronic stress as a factor in physiologic reactivity to challenge. *Health Psychology, 6,* 221–237.

Gable, S. L., Reis, H. T., & Elliot, A. J. (2000). Behavioral activation and inhibition in everyday life. *Journal of Personaility and Social Psychology, 78,* 1135-1149.

Gomez, A., & Gomez, R. (2001). Personality traits of the behavioral approach and inhibition systems: associations with processing of emotional stimuli. *Personality and Individual Differences, 32,* 1299–1316.

Gomez, R**.**, & McLaren, S. (1997). The effects of reward and punishment on response inhibition, moods, heart rate and skin conductance level during instrumental learning. *Personality and Individual Differences,* 23, 305-316.

Girdano, D. A., Everly, G. S., Jr., and Dusek, D. E. (1990). *Controlling Stress and Tension: A Holistic Approach* (161). Englewood Cliffs. NJ: Prentice-Hall.

Gray, J. A. (1970). The psychophysiological basis of introversion-extraversion. *Behaviour Research and Therapy, 8,* 249–266.

Gray, J. A. (1987). Perspectives on anxiety and impulsivity: A commentary. *Journal of Research in Personality, 21,* 493-509.

Feldman-Barrett, L., Mesquita, B., Ochsner, K. N., Gross, J. J., (2007). The experience of emotion. *Annual Review of Psychology, 58*, 373-403.

Harmon-Jones, E. (2003). Anger and the behavioral approach system. *Personality and Individual Differences, 35,* 995-1005.

Heponiemi, T., Keltikangas-Järvinen, T., Kettunen, J., Puttonen, S., & Ravaja, N. (2004). BIS–BAS sensitivity and cardiac autonomic stress profiles. *Psychophysiology, 40*, 998-999.

Heponiemi, T., Keltikangas-Järvinen, T., Kettunen, J., Puttonen, S., & Ravaja, N. (2003). BIS/BAS sensitivity and self-rated affects during experimentally induced stress. Personality *and Individual Differences, 34,* 943-957.

Heubeck, B.G., Wilkinson, R.B., Cologon, J. (1998) A second look at Carver and White's (1994) BIS/BAS scales. *Personality and Individual Differences 25,* 785–800.

Jorm, A.F., Christensen, H., Henderson, A.S., Jacomb, P.A. , Korten, A.E., and Rodgers , B. (1999). Using the BIS/BAS scales to measure behavioural inhibition and behavioural activation: factor structure, validity and norms in a large community sample. *Personality and Individual Differences 26,* 49–58.

Kamarck, T.W., Lovallo, W.R. (2003). Cardiovascular reactivity to psychological challenge: conceptual and measurement considerations. *Psychosomatic Medicine, 65,* 9–21.

Kannel, W. B. (2005). Historic perspectives on the relative contributions of diastolic and systolic blood pressure elevation to cardiovascular risk profile. *American Heart Journal, 138,* 205-210.

Knyazev, G.G., Slobodskaya, H.R., Wilson, G.D. (2002). Psychophysiological correlates of behavioural inhibition and activation. *Personality and Individual Differences, 33,* 647–660.

Lazarus, R., Folkman, S (1984). *Stress, Appraisal, and Coping.* New York: Springer Publishing company.

Lazarus, R. S., Kanner, A. D., & Folkman, S. (1980). Emotions: A cognitive-phenomenological analysis. In R. Plutchik & H. Kellerman (Eds.), *Theories of Emotion* (189-217), New York: Academic Press.

Marler, M. R., Jacob, R. G., Lehoczky, J. P., & Shapiro, A. P. (1988). The statistical analysis of treatment effects in 24-hour ambulatory blood pressure recordings. *Statistics in Medicine, 7,* 697–716.

Mason, J. W. (1975). A historical view of the stress-field: Part II. *Journal of Human Stress,* 22-36.

McArthur, L. H., Raedeke, T. D. (2009). Race and sex differences in college student physical activity correlates. *American Journal of Health Behavior, 33*, 80-90.

McEwen, BS. (1998b). Stress, adaptation, and disease: Allostasis and allostatic load. *Annals of the New York Academy of Sciences, 840,* 33-44.

Ming, E. E., Adler, G. K., Kessler, R. C., Fogg, L. F., Matthews, K. A., Herd, J. A. (2004).

    Cardiovascular reactivity to work stress predicts subsequent onset of hypertension:

    The air traffic controller health change study. *Psychosomatic Medicine, 66,* 459–465

Pacak, K., Palkovits, M., Yadid, G., Kvetnansky, R., Kopin, I. J., & Goldstein, D. S. (1998).

    Hetereogeneous neurochemical responses to different stressors: a test of Selye's

    doctrine of nonspecificity. *American Journal of Physiology Regulatory Integrative*

    Comparative Physiology, 275, 4, 1247-1255.

Reckelhoff, J. F. (2001). Gender differences in the regulation of blood pressure.

    Hypertension, 37, 1199-1208.

Russell, J. A., & Barrett, L. F. (1999). Core affect, prototypical emotional episodes, and other

    things called emotion: Dissecting the elephant. *Journal of Personality and Social*

    Psychology, 76, 805–819.

Scientific Software International Inc. (2005). HLM 6.04 for windows. Scientific Software

    International Inc., Lincolnwood, IL.

Selye, H. **(**1974). *The Stress of Life.* New York: McGraw-Hill.

Shekelle, R. B., Gale, M., & Norusis, M. (1985). For the aspirin myocardial infarction study

    group: Type A score (Jenkins Acitivity Survey) and risk of recurrent coronary heart

    disease in the aspirin myocardial study. *American Journal of Cardiology, 56*, 221-

    235.

Smith, C. A. & Lazarus, R. S. (1993). Appraisal components, core relational themes, and the

    emotions. *Cognition & Emotion*, 7, 233-269.

Sterling, P. and Eyer, J., 1988, Allostasis: A new paradigm to explain arousal pathology. In: S. Fisher and J. Reason (Eds.), *Handbook of Life Stress, Cognition and Health.* John Wiley & Sons, New York.

Spielberger, C. D. (1985). Assessment of state and trait anxiety: Conceptual and methodological issues. *Southern Psychologist, 2*, 6–16.

Sutton, S. K., & Davidson, R. J., (1997). Prefrontal brain asymmetry: A biological substrate of the behavioral approach and inhibition systems. *Psychological Science, 8,* 204-210.

Taylor, S. E., & Aspinwall, L. G. (1993). Coping with chronic illness. In. L. Goldberger & S. Breznitz (Eds.), *Handbook of Stress: Theoretical and Clinical Aspects* (pp. 511-531). New York, NY: Free Press.

Trieber, F. A., Kamarack, T., Schneiderman, N., Sheffield, D., Kapuku, G, & Taylor, T. (2003). Cardiovascular reactivity and development of preclinical and clinical disease states. *Psychosomatic Medicine, 65*, 46-62.

Turner, S. M., Beidel, D. C., & Wolff, P. L. (1996). Is behavioral inhibition related to the anxietdisorders? *Clinical Pyschology Review,16,*157–172.

Verrier, R. L., & Lown, B. (1984). Behavioral Stress and Cardiac Arrhythmias. *Annual Review of Physiology, 46,*155-176.

Wang, X., Poole, J. C., Treiber, F. A., Harshfield, G. A., Hanevold, C. D., & Snieder, H. (2006). Ethnic and gender differences, in ambulatory blood pressure trajectories. *Circulation, 10,* 2780-2787.

Watson, D., Clark, L. A. (1984). Negative affectivity: the disposition to experience aversive emotional states. *Psychological Bulletin 96,* 465–490.

Appendix A

Carver and White's (1994) BIS-BAS Assessment

Listed below are a number of statements concerning personal attitudes and characteristics. Please read each statement and consider the extent to which you <u>TYPICALLY OR GENERALLY</u> agree or disagree with it, using the scale below each statement.

1. When I see an opportunity for something I like, I get excited right away.
   - Strongly Disagree
   - Disagree
   - Neutral
   - Agree
   - Strongly Agree

2. [a] I worry about making mistakes.
   - Strongly Disagree
   - Disagree
   - Neutral
   - Agree
   - Strongly Agree

3. I'm always willing to try something new if I think it will be fun.
   - Strongly Disagree
   - Disagree
   - Neutral
   - Agree
   - Strongly Agree

4. I go out of my way to get things I want.
   - Strongly Disagree
   - Disagree
   - Neutral
   - Agree
   - Strongly Agree

5. [a] Even if something bad is about to happen to me, I rarely experience fear or nervousness.
   - Strongly Disagree
   - Disagree
   - Neutral
   - Agree
   - Strongly Agree

6. When goo things happen to me, it affects me strongly.
    Strongly Disagree
    Disagree
    Neutral
    Agree
    Strongly Agree

7. [a] I have very few fears compared to my friends.
    Strongly Disagree
    Disagree
    Neutral
    Agree
    Strongly Agree

8. When I get something I want, I feel excited and energized
    Strongly Disagree
    Disagree
    Neutral
    Agree
    Strongly Agree

9. [a] Criticism or scolding hurts me quite a bit.
    Strongly Disagree
    Disagree
    Neutral
    Agree
    Strongly Agree

10. I crave excitement and new sensations.
    Strongly Disagree
    Disagree
    Neutral
    Agree
    Strongly Agree

11. When I go after something I don't hold back.
    Strongly Disagree
    Disagree
    Neutral
    Agree
    Strongly Agree

12. [a] If I think something unpleasant is going to happen I usually get pretty "worked up."
   Strongly Disagree
   Disagree
   Neutral
   Agree
   Strongly Agree

13. When I want something, I usually go all-out to get it.
   Strongly Disagree
   Disagree
   Neutral
   Agree
   Strongly Agree

14. [a] I feel pretty worried or upset when I think or know somebody is angry at me.
   Strongly Disagree
   Disagree
   Neutral
   Agree
   Strongly Agree

15. If I see a chance to get something I want, I move on it right away.
   Strongly Disagree
   Disagree
   Neutral
   Agree
   Strongly Agree

16. It would excite me to win a context.
   Strongly Disagree
   Disagree
   Neutral
   Agree
   Strongly Agree

17. I will often do things for no other reason than they might be fun.
   Strongly Disagree
   Disagree
   Neutral
   Agree
   Strongly Agree

18. [a] I feel worried when I think I have done poorly at something.
    Strongly Disagree
    Disagree
    Neutral
    Agree
    Strongly Agree

19. When I'm doing well at something, I love to keep at it.
    Strongly Disagree
    Disagree
    Neutral
    Agree
    Strongly Agree

20. I often act on the spur of the moment.
    Strongly Disagree
    Disagree
    Neutral
    Agree
    Strongly Agree

Note: [a] = questions related to BIS.

Table 1

Mean and Standard Deviations for Variables (N=99; 3433 paired readings).

Measure	Possible Range	Observed Min	Observed Max	*Mean*	*SD*
Within Day					
SBP	-	79.00	184.00	121.74	13.82
DBP	-	45.00	127.00	75.75	10.25
HR	-	41	178	78.57	14.76
Frustrated	1 – 100	1	100	25.88	23.21
Happiness	1 – 100	1	100	62.56	22.86
Sad	1 – 100	1	100	24.67	22.86
Stressed	1 – 100	1	100	36.65	27.69
End of Day					
SBP	-	83.00	152.30	121.53	10.81
DBP	-	51.00	102.00	75.46	6.85
HR	-	52.08	118.00	78.32	10.23
Positive Affect	1 – 5	1.00	4.70	2.72	0.71
Negative Affect	1 – 5	1.00	3.90	1.81	0.63
End of Study					
Behavioral Inhibition	1 – 5	1.86	5.00	3.63	0.68
Behavioral Activation	1 – 5	2.23	5.00	3.86	0.46

Note: 274 reported unique stressful events. Within day values are unweighted means of all level 1 values. End of day means for SBP, DBP, and HR represent the mean of all day-level means for each person on each day.

Table 2

Two-level Hierarchical Linear Model Predicting Feeling Frustrated and Feeling Happy from Momentary Stress and Behavioral Inhibition and Behavioral Activation.

	Coefficient	S.E.	t	p
Frustrated	25.62	1.51	16.91***	< .001
Stress (Slope)	5.63	1.65	3.41**	.001
BIS	0.36	2.38	0.15	.880
Gender	-2.38	1.64	-1.45	.148
BIS X Gender	1.27	2.38	0.53	.594
BAS	1.85	1.06	1.73+	.085
Gender	-2.44	1.46	-1.66+	.099
BAS X Gender	-1.56	1.06	-1.46	.147
Happy	63.03	1.31	48.11***	< .001
Stress (Slope)	-5.13	1.69	-3.04*	.003
BIS	-1.65	2.18	-0.76	.451
Gender	1.35	1.58	0.85	.397
BIS X Gender	-0.81	2.18	-0.37	.709
BAS	-0.43	1.05	-0.41	.685
Gender	1.00	1.30	0.78	.436
BAS X Gender	1.32	1.05	1.25	.213

Note: Gender was coded men as 0, women as 1. Models were initially estimated as random effects at both L1 and L2, but if a random component was not statistically significant (p >.10)*,* effects were estimated as fixed. + = p < .10, * = p < .05, ** = p < .01, *** = p < .001.

Table 3
Two-level Hierarchical Linear Model Predicting Sad and Feeling Stressed from Momentary Stress and Behavioral Inhibition and Behavioral Activation.

	Coefficient	S.E.	t	p
Sad	24.77	1.60	15.51***	< .001
Stress (Slope)	1.08	1.12	0.96	.339
BIS	-1.14	1.56	-0.73	.465
Gender	0.68	1.10	0.62	.536
BIS X Gender	2.00	1.56	1.25	.214
BAS	0.86	0.91	0.94	.350
Gender	0.25	1.13	0.22	.823
BAS X Gender	-1.45	0.91	-1.58	.116
Stressed	35.12	1.67	21.03***	< .001
Stress (Slope)	8.43	1.50	5.61***	< .001
BIS	-0.26	1.67	-0.15	.879
Gender	-0.27	1.44	-0.18	.852
BIS X Gender	1.32	1.67	0.79	.430
BAS	1.33	1.30	1.04	.302
Gender	-0.47	1.33	-0.35	.727
BAS X Gender	-0.52	1.28	-0.41	.684

Note: Gender was coded men as 0, women as 1. Models were initially estimated as random effects at both L1 and L2, but if a random component was not statistically significant ($p > .10$), effects were estimated as fixed. $^+ = p < .10$, $^* = p < .05$, $^{**} = p < .01$, $^{***} = p < .001$.

Table 4

Two-level Hierarchical Linear Model Predicting Negative Affect from End of Day measure of Stress and Behavioral Inhibition and Behavioral Activation.

	Coefficient	S.E.	*t*	*p*
Test of BIS				
Negative Affect	1.83	0.05	35.21***	< .001
BIS	0.30	0.06	4.37***	< .001
Gender	-0.004	0.05	-0.09	.927
BIS X Gender	-0.07	0.06	-1.12	.264
Stress	0.06	0.05	1.26	.206
BIS	0.03	0.07	0.49	.624
Gender	0.04	0.05	0.73	.463
BIS X Gender	-0.01	0.07	-0.20	.844
Test of BAS				
Negative Affect	1.80	0.05	36.01***	< .001
BAS	0.14	0.05	2.80**	.004
Gender	0.05	0.05	1.00	.371
BAS X Gender	0.03	0.05	0.60	.500
Stress	0.06	0.04	1.50	.142
BAS	-0.06	0.04	-1.50	.134
Gender	0.05	0.04	1.25	.231
BAS X Gender	0.09	0.04	2.25	.031

Note: Gender was coded men as 0, women as 1. Models were initially estimated as random effects at both L1 and L2, but if a random component was not statistically significant (*p* >.10)*,* effects were estimated as fixed. Negative Affect was estimated as fixed. $^{+} = p < .10$, $^{*} = p < .05$, $^{**} = p < .01$, $^{***} = p < .001$.

Table 5

Two-level Hierarchical Linear Model Predicting Positive Affect from End of Day measure of Stress and Behavioral Inhibition and Behavioral Activation.

	Coefficient	S.E.	t	p
Test of BIS				
Positive Affect	2.75	0.06	43.81***	< .001
BIS	0.04	0.08	0.46	.642
Gender	-0.08	0.06	-1.31	.193
BIS X Gender	-0.04	0.08	-0.57	.569
Stress	0.03	0.06	0.51	.612
BIS	-0.11	0.06	-1.61	.159
Gender	0.07	0.05	-1.41	.206
BIS X Gender	0.11	0.07	1.60	.114
Test of BAS				
Positive Affect	2.75	0.05	54.52***	< .001
BAS	0.22	0.05	4.82***	< .001
Gender	-0.09	0.05	-1.80†	.074
BAS X Gender	-0.22	0.05	-0.60	.557
Stress	0.06	0.08	1.22	.222
BAS	0.13	0.06	2.13**	.033
Gender	-0.12	0.05	-2.40**	.017
BAS X Gender	-0.08	0.06	-1.41	.161

Note: Gender was coded men as 0, women as 1. Models were initially estimated as random effects at both L1 and L2, but if a random component was not statistically significant (p >.10)*,* effects were estimated as fixed. Positive Affect was estimated as fixed. † $= p < .10$, * $= p < .05$, ** $= p < .01$, *** $= p < .001$.

Table 6
Two-level Hierarchical Linear Model Predicting Systolic Blood Pressure with Behavioral Inhibition and Behavioral Activation and Momentary Stress.

Test of BIS	Coefficient	S.E.	t	p
Systolic Blood Pressure	115.70	1.19	97.23***	< .001
Gender	-4.09	0.93	-4.40***	< .001
Stress	2.45	0.45	5.44***	< .001
BIS	0.54	0.58	0.93	.360
Gender	-1.96	0.42	-4.67***	< .001
BIS X Gender	-0.33	0.58	-0.57	.578

Test of BAS	Coefficient	S.E.	t	p
Systolic Blood Pressure	115.72	1.19	97.24***	< .001
Gender	-4.13	0.93	-4.44***	< .001
Stress	2.30	0.46	5.00***	< .001
BAS	-0.38	0.38	-1.00	.325
Gender	-1.80	0.43	-4.18***	< .001
BAS X Gender	0.63	0.38	1.66	.101

Note: Gender was coded men as 0, women as 1. Models were initially estimated as random effects at both L1 and L2, but if a random component was not statistically significant ($p > .10$), effects were estimated as fixed. Covariates, standing, sitting, cigarette use, food, temperature, and physical activity were included in the model. All analyses for SBP were estimated as random effects, with exception of cigarette use, temperature and food. † $= p < .10$, * $= p < .05$, ** $= p < .01$, *** $= p < .001$.

Table 7
Two-level Hierarchical Linear Model Predicting Diastolic Blood Pressure with Behavioral Inhibition and Behavioral Activation and Momentary Stress.

Test of BIS	Coefficient	S.E.	t	p
Diastolic Blood Pressure	67.74	0.84	79.92***	< .001

Stress	1.52	0.38	3.88***	< .001
BIS	0.24	0.39	0.61	.544
Gender	-0.74	0.39	-1.89+	.058
BIS X Gender	0.38	0.39	0.99	.322

Test of BAS	Coefficient	S.E.	t	p
Diastolic Blood Pressure	67.73	0.85	79.97***	< .001
Stress	1.63	0.37	4.43***	< .001
BAS	-0.015	0.32	-0.48	.962
Gender	-0.70	0.37	-1.89+	.058
BAS X Gender	-0.33	0.32	-0.05	.309

Note: Gender was coded men as 0, women as 1. Models were initially estimated as random effects at both L1 and L2, but if a random component was not statistically significant (p >.10), effects were estimated as fixed. Covariates, standing, sitting, cigarette use, and physical activity were included in the model. All analyses for DBP were estimated as random effects, with exception of food, caffeine, and alcohol. + = $p < .10$, * = $p < .05$, ** = $p < .01$, *** = $p < .001$.

Table 8
Two-level Hierarchical Linear Model Predicting Heart Rate with Behavioral Inhibition and Behavioral Activation and Momentary Stress.

Test of BIS	Coefficient	S.E.	*t*	*p*
Heart Rate	72.76	1.06	68.64***	< .001
Stress	0.84	0.75	1.12	.271
BIS	0.43	0.82	0.52	.598
Gender	-0.15	0.73	-0.21	.841
BIS X Gender	0.26	0.82	0.32	.752

Test of BAS	Coefficient	S.E.	*t*	*p*
Heart Rate	72.80	1.06	68.68***	< .001
Stress	0.76	0.71	1.07	.275
BAS	-0.71	0.60	-1.18	.244
Gender	-0.02	0.67	-0.03	.974
BAS X Gender	1.40	0.60	2.33	.244

Note: Gender was coded men as 0, women as 1. Models were initially estimated as random effects at both L1 and L2, but if a random component was not statistically significant (*p* >.10)*,* effects were estimated as fixed. Covariates, standing, sitting, caffeine, alcohol use, food, and physical activity were included in the model. All analyses for HR were estimated as random effects, except for food, caffeine, and alcohol use. + = $p < .10$, * = $p < .05$, ** = $p < .01$, *** = $p < .001$.

Table 9
Two-level Hierarchical Linear Model Predicting Systolic Blood Pressure from End of Day measure of Stress and Behavioral Inhibition and Behavioral Activation.

Test of BIS	Coefficient	S.E.	*t*	*p*
Systolic Blood Pressure	122.61	1.05	117.26***	< .001
BIS	-0.40	1.32	-0.294	.769
Gender	-5.03	1.05	-4.77***	< .001
BIS X Gender	-2.31	1.32	-1.74+	.084
Stress	1.23	0.54	2.26**	.024
BIS	0.43	0.78	0.55	.578
Gender	-0.98	0.54	-1.81+	.070
BIS X Gender	0.0003	0.78	0.00	1.000

Test of BAS	Coefficient	S.E.	*t*	*p*
Systolic Blood Pressure	123.15	1.00	127.76***	< .001
BAS	0.21	1.10	0.19	.847
Gender	-4.93	1.00	-5.12***	< .001
BAS X Gender	0.42	1.10	0.38	.701
Stress	1.14	0.54	2.12**	.034
BAS	0.71	0.70	1.02	.306
Gender	-1.0	0.54	-1.75+	.080
BAS X Gender	0.08	0.70	-0.12	.908

Note: Gender was coded men as 0, women as 1. Models were initially estimated as random effects at both L1 and L2, but if a random component was not statistically significant ($p > .10$), effects were estimated as fixed. All analyses for SBP were estimated as random effects, with exception of cigarette use, temperature and food. + = $p < .10$, * = $p < .05$, ** = $p < .01$, *** = $p < .001$.

Table 10
Two-level Hierarchical Linear Model Predicting Diastolic Blood Pressure from End of Day measure of Stress and Behavioral Inhibition and Behavioral Activation.

Test of BIS	Coefficient	S.E.	*t*	*p*
Diastolic Blood Pressure	75.47	0.75	100.84***	< .001
BIS	-0.55	0.81	-0.68	.497
Gender	-0.31	0.75	-0.41	.683
BIS X Gender	-0.13	0.81	-0.16	.874

Stress	0.77	0.40	$1.92^{\dagger}$	.056
BIS	-0.34	0.43	-0.79	.429
Gender	-0.72	0.40	$-1.78^{\dagger}$	.075
BIS X Gender	0.52	0.43	1.20	.232

Test of BAS	Coefficient	S.E.	t	P
Diastolic Blood Pressure	75.50	0.75	100.67^{***}	$< .001$
BAS	0.10	0.84	0.12	.905
Gender	-0.41	0.75	-0.55	.590
BAS X Gender	0.16	0.84	0.19	.849
Stress	0.91	0.37	2.46^{**}	.015
BAS	0.80	0.55	1.45	.162
Gender	-0.90	0.37	-2.43^{**}	.018
BAS X Gender	-0.40	0.55	-0.73	.162

Note: Gender was coded men as 0, women as 1. Models were initially estimated as random effects at both L1 and L2, but if a random component was not statistically significant ($p > .10$), effects were estimated as fixed. $^{\dagger} = p < .10$, $^{*} = p < .05$, $^{**} = p < .01$, $^{***} = p < .001$.

Table 11
Two-level Hierarchical Linear Model Predicting Heart Rate from End of Day measure of Stress and Behavioral Inhibition and Behavioral Activation.

Test of BIS	Coefficient	S.E.	*t*	*p*
Heart Rate	78.50	1.04	75.77***	< .001
BIS	-0.49	1.40	-0.35	.728
Gender	-0.12	1.04	-0.11	.911
BIS X Gender	-1.21	1.40	-0.86	.390
Stress	-0.42	0.82	-0.05	.960
BIS	-0.01	0.98	-0.01	.992
Gender	0.16	0.82	0.20	.845
BIS X Gender	-0.49	0.98	-0.05	.992

Test of BAS	Coefficient	S.E.	*t*	*p*
Heart Rate	77.93	0.90	88.04***	< .001
BAS	-2.40	0.76	-3.12**	.003
Gender	0.21	0.90	0.24	.811
BAS X Gender	3.20	0.76	4.23***	< .001
Stress	-0.10	0.70	-0.13	.897
BAS	-0.30	0.80	-0.37	.712
Gender	0.20	0.70	0.23	.819
BAS X Gender	0.66	0.80	0.84	.401

Note: Gender was coded men as 0, women as 1. Models were initially estimated as random effects at both L1 and L2, but if a random component was not statistically significant (*p* >.10)*, effects were estimated as fixed. + = *p* < .10, * = *p* < .05, ** = *p* < .01, *** = *p* < .001.

Figure Captions

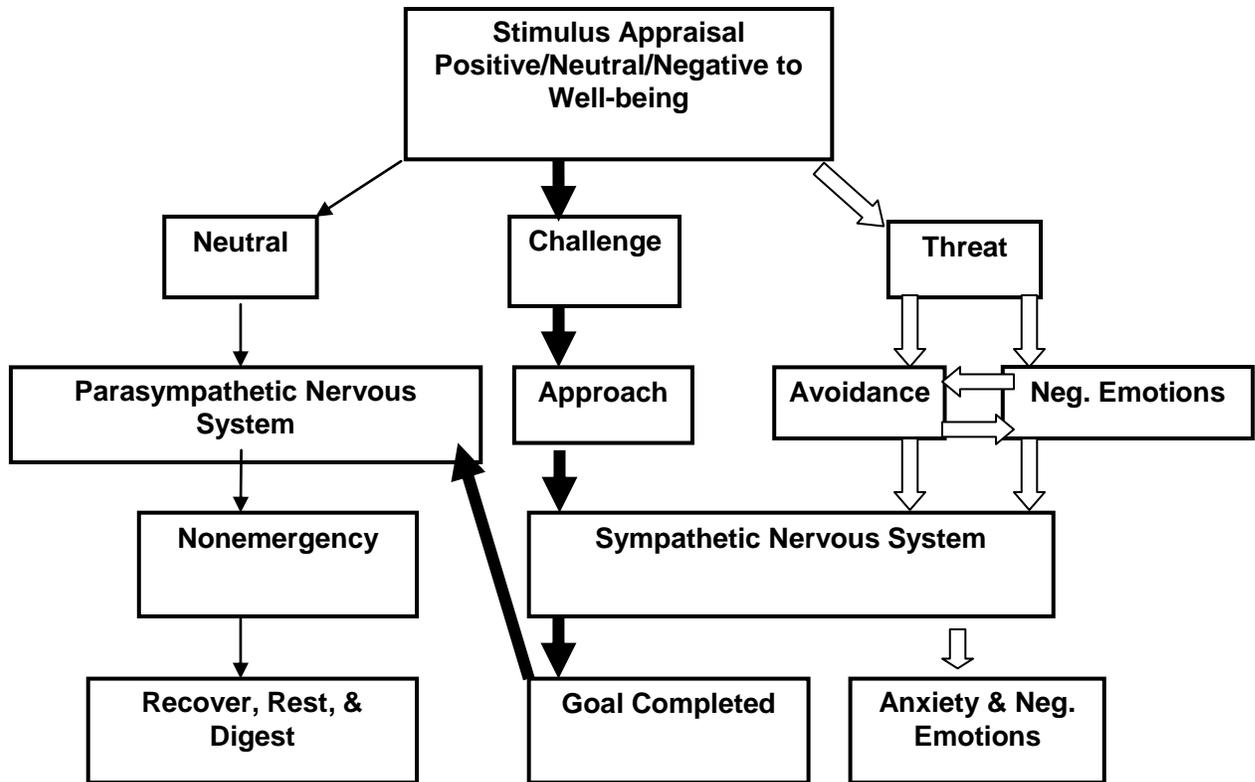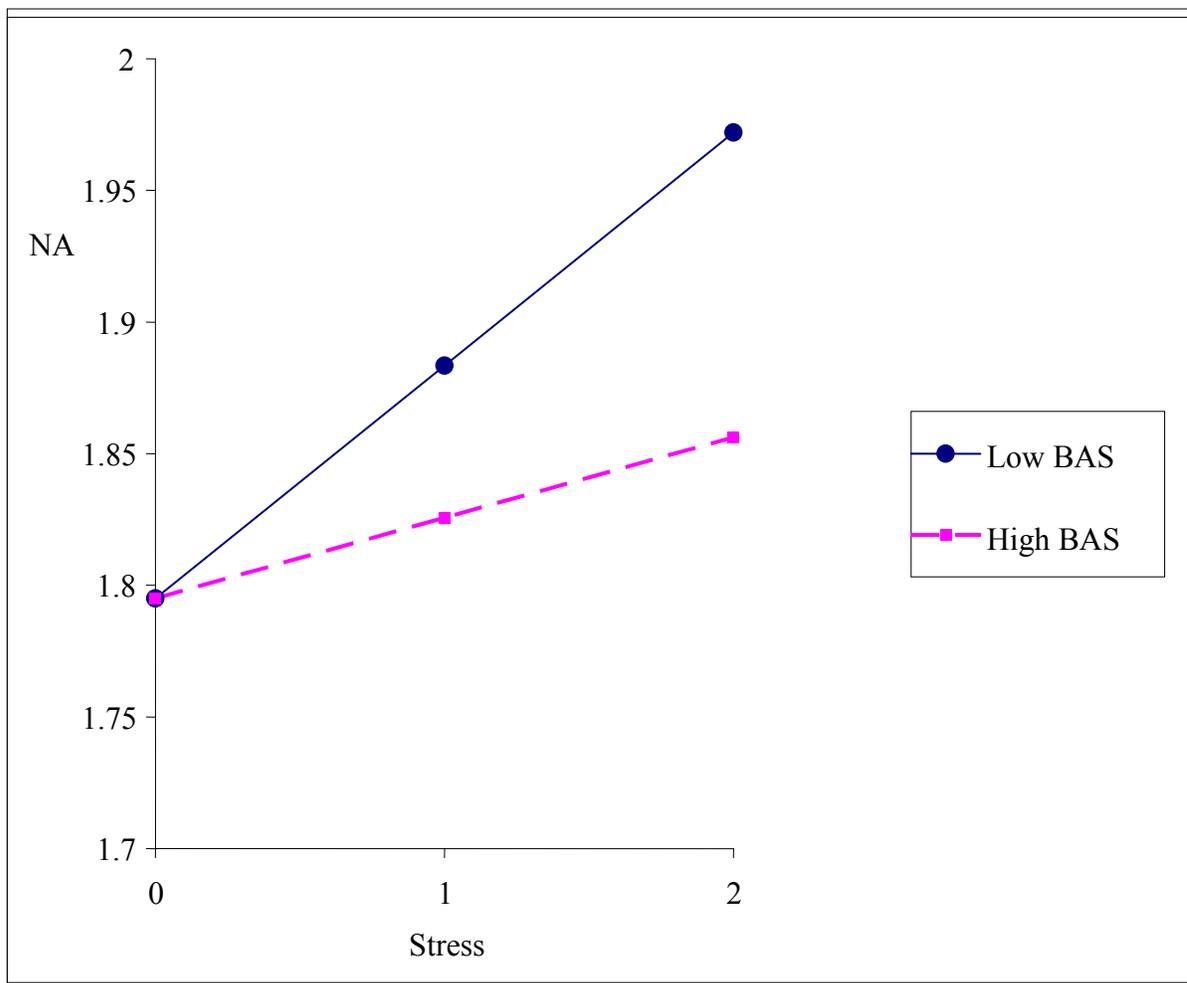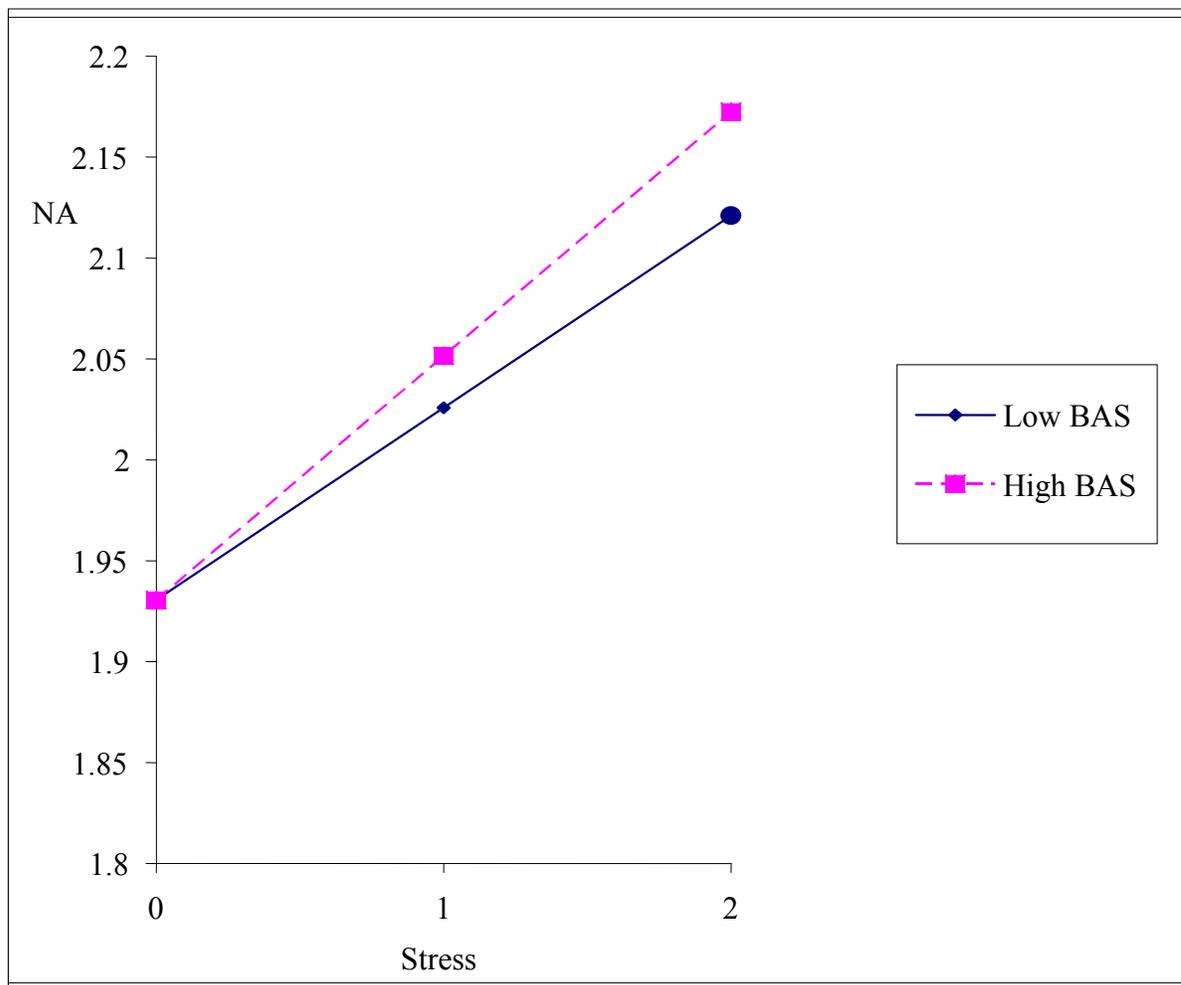*Figure 1.* BIS and BAS Autonomic Stress Activation Profiles.

Figure 2. End of Day Analysis of BAS and Negative Reactivity to Stressors for Men.

Figure 3. End of Day Analysis of BAS and Negative Reactivity to Stressors for Women.

Figure 4. Within Day Analysis of Stressor by Gender on SBP.

Figure 5. End of Day Analysis of DBP Reactivity to Stressors.

Figure 6. End of Day Analysis BAS and Positive Affect.

Figure 1. BIS and BAS Autonomic Stress Activation Profiles. BAS activation indicated by

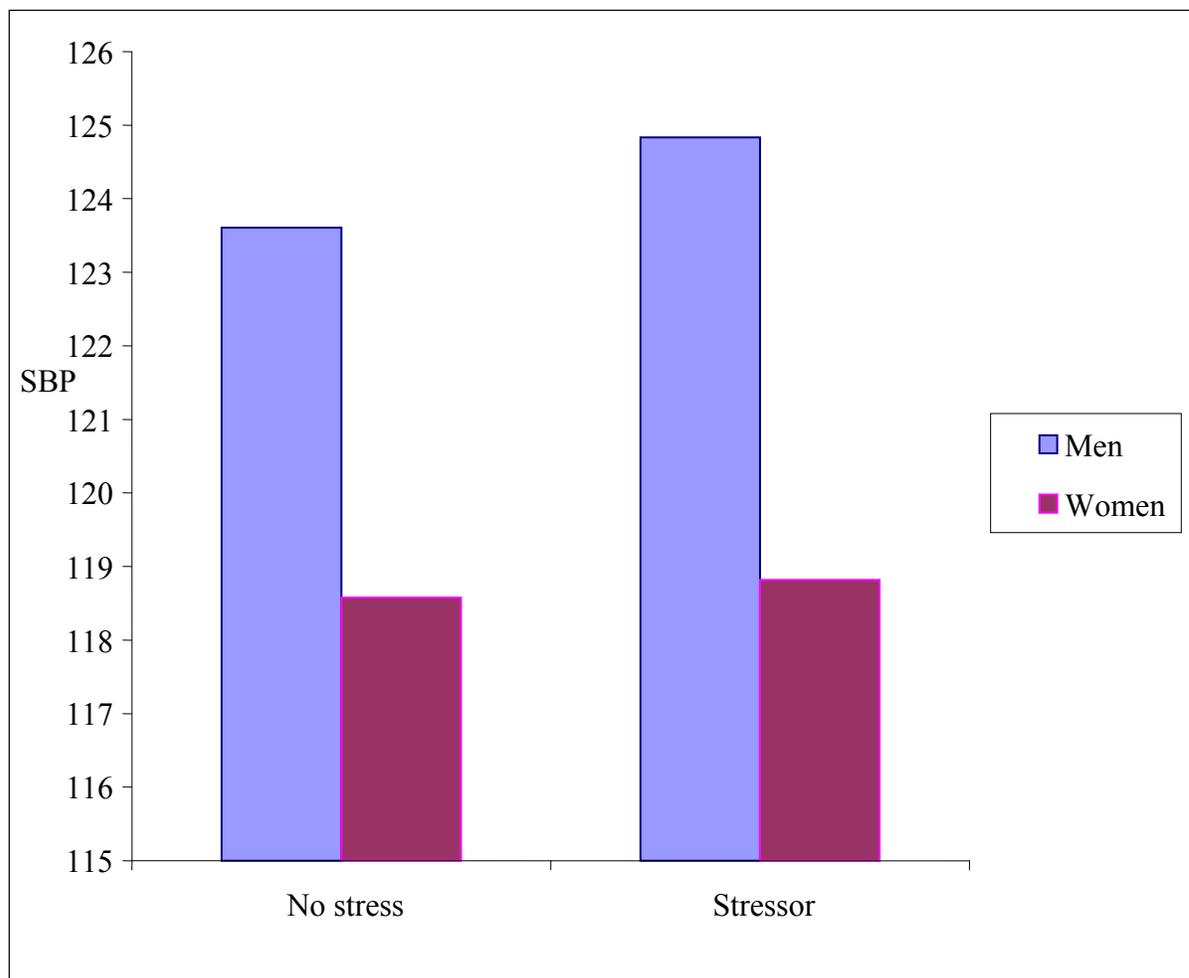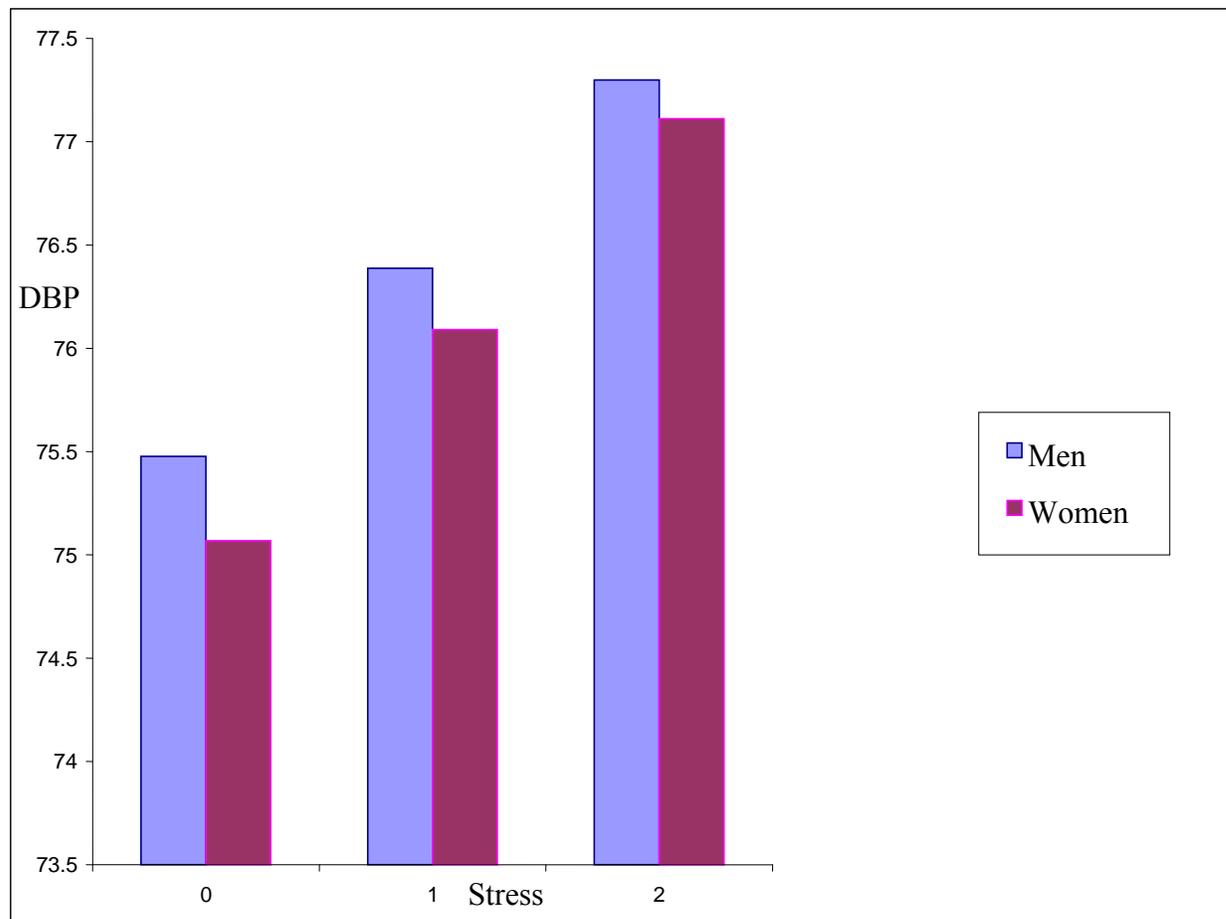solid lined arrows. BIS activation indicated by hollow arrows.

Figure 2. End of Day Analysis of BAS and Negative Affect Reactivity to Stressors for Men.

Figure 3. End of Day Analysis of BAS and Negative Affect Reactivity to Stressors for Women.

Figure 4. Within Day Analysis of Stressor by Gender on SBP.

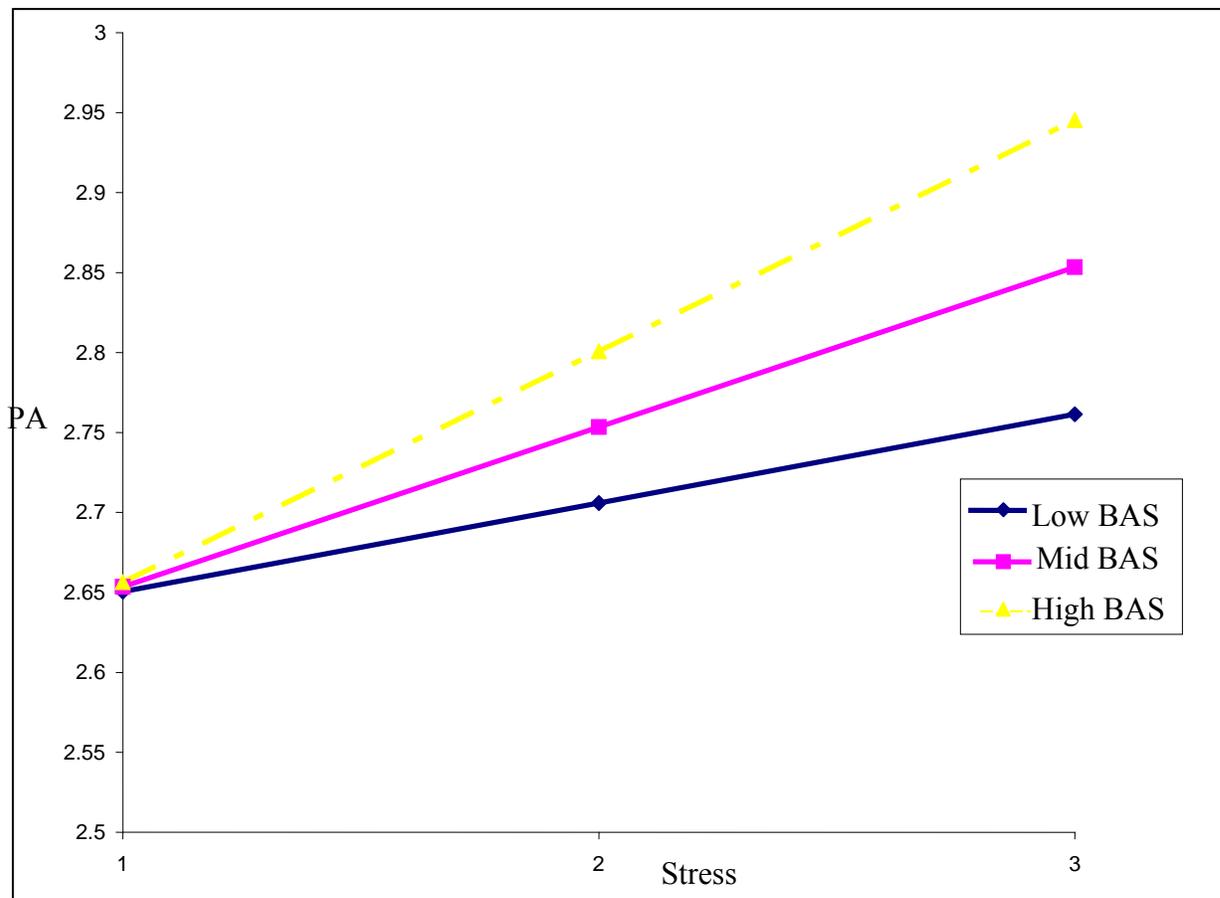*Figure 5.* End of Day Analysis of DBP and stressors.

Figure 6. End of Day Analysis BAS and Positive Affect.