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Neurobiological Correlates Of Personality And Emotional Expression In Traumatic Brain Injury

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NEUROBIOLOGICAL CORRELATES OF PERSONALITY AND EMOTIONAL EXPRESSION IN TRAUMATIC BRAIN INJURY

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CHAPTER 1

INTRODUCTION

Traumatic brain injury (TBI) is a prominent health problem, with 3 to 5 million Americans living with long-term disabilities as a result of brain injury (Zaloshnja, Miller, Langlois, & Selassie, 2008). Many TBI survivors experience cognitive, emotional, and functional deficits (Morton & Wehman, 1995), all of which can contribute to chronic stress. Previous research has demonstrated that difficulties related to coping with stress predict worse rehabilitation outcomes in TBI (Kervick & Kaemingk, 2005), and that individuals with TBI tend to engage in less effective coping strategies than individuals without TBI (Krpan, Stuss, & Anderson, 2011). Deficits in appraisal of stressful stimuli or lack of awareness of problems as a result of brain injury may also contribute to ineffective coping and reactivity to stress (Prigatano & Schacter, 1991). Further, as disclosure about traumatic events can lead to positive health outcomes (Frattaroli, 2006; Pennebaker, Kiecolt-Glaser, & Glaser, 1988), impaired emotional expression in TBI is likely to impede coping with stress during recovery.

Differences in personality traits have been linked to individual differences in cognitive appraisal (Gunthert, Cohen, & Armeli, 1999), coping styles (DeLongis & Holtzman, 2005; Suls, David, & Harvey, 1996), neuroendocrine stress reactivity (Pruessner et al., 1997), emotional disclosure (Zakowski, Herzer, Barrett, Milligan, & Beckman, 2011), and health outcomes (Turiano et al., 2012). To date, few studies have examined the relationship between personality and coping with stress among TBI survivors. Information about personality differences as predictors of coping after TBI could help identify individuals who typically face increased challenges in daily living. Interventions targeting coping skills and emotional disclosure for these individuals may lead to improved long-term outcomes and quality of life.

Chronic Stress and Health

Chronic psychological stress has been associated with increased risk of numerous health problems such as cardiovascular disease, autoimmune diseases, and impaired wound healing (Cohen, Janicki-Deverts, & Miller, 2007; Maggio, Guralnik, Longo, & Ferrucci, 2006). The neuroendocrine response to stress involves the hypothalamic-pituitary-adrenal (HPA) axis, which is primarily indexed by cortisol, and the sympathetic adrenal-medullary (SA) axis, which is indexed by various measures such as heart rate and blood pressure (for a review see Herman & Cullinan, 1997). Individuals under chronic stress are subjected to increased HPA activation, and in turn, increased cortisol exposure, which suppresses immune function (McEwen, 2000). Additionally, as the prefrontal cortex and the hippocampus are involved in inhibition of the HPA axis, damage to these structures during brain injury may result in amplified dysregulation of this stress response pathway, putting individuals with TBI at risk of higher exposure to cortisol.

HPA dysregulation, along with environmental and genetic factors, has also been linked to mental health disorders, such as depression (Bosch, Seifritz, & Wetter, 2012). In individuals with TBI, stress and poor coping responses have been found to contribute to psychosocial and emotional difficulties following injury (Bay, Hagerty, Williams, Kirsch, & Gillespie, 2002). Bay et al. (2002) found that perceived post-brain injury stress alone explained the majority of variability in depressive symptoms, whereas cognitive abilities, such as directed attention and memory, were not meaningfully related to depressive symptoms. As strong immune functioning and optimal mental health is crucial for recovery from any injury, studying how HPA activation is affected by stress and coping is of significant importance in TBI.

Cognitive Appraisal and Stress

Whether a person perceives a stimulus as stressful or threatening depends on his or her

cognitive appraisal of the stimulus. According to Lazarus (1985), “all emotions, including stress emotions, depend on cognitive appraisals and reappraisals of the immediate and potential significance of a person’s adaptive transactions with the environment for her or his well-being” (p. 400). Making evaluative judgments about environmental stimuli serves an adaptive purpose, as being able to distinguish between benign and harmful stimuli is essential for survival. The same stimulus can elicit different responses in different individuals, depending on their experiential history and innate characteristics, providing evidence of the important role of appraisal.

Research has demonstrated that accurate cognitive appraisal and awareness of deficits in TBI lead to improved compensation of deficits, and, therefore, improved functional outcomes (Kervick & Kaemingk, 2005). Unfortunately, TBI survivors often have impaired cognitive appraisal abilities, which can negatively affect rehabilitation and outcomes. Research suggests that severity of injury is related to perception of cognitive difficulties after TBI, with individuals with mild or moderate injury perceiving greater impairment and survivors with severe injury perceiving less impairment than reported by family members (Kervick & Kaemingk, 2005).

Emotional Expression and Health

Inhibiting emotional expression about a negative or traumatic topic has been linked to poor health outcomes (Pennebaker & Beall, 1986). Research has demonstrated both short-term (e.g., increased autonomic activity) and long-term (e.g., heart disease) negative health consequences of expending effort to avoid disclosing about emotional topics. Researchers have also examined whether talking or writing about traumas can improve mental or physical health in different patient populations (Lumley et al., 2011; Pennebaker, 1993; Petrie, Fontanilla, Thomas, Booth, & Pennebaker, 2004; Zakowski et al., 2011). Beneficial effects, such as decreased

physician visits, increased T-helper cell growth, and long-term mood improvement, have been found when individuals write about emotional topics compared to superficial control topics (Pennebaker & Seagal, 1999). Studies of talking about emotional experiences found comparable effects (Pennebaker & Seagal, 1999). Conversely, other studies have found that disclosure of emotions does not have significant positive effects on health (Meads & Nouwen, 2005). These discrepancies in the emotional disclosure literature demonstrate the importance of further research in this area.

As TBI survivors often have cognitive and language impairments (Marini et al., 2011), they may have differences in their ability to express themselves about emotional or stressful topics compared to non-brain injured individuals. Additionally, impaired cognitive appraisal of stressful stimuli after TBI frequently results in impaired awareness of deficits (Prigatano, 2005a), which, in turn, could disrupt addressing stress through emotional disclosure and other forms of coping. Limitations in emotional expression may put individuals with TBI at higher risk of worse mental and physical health outcomes.

Emotional Expression after TBI

Deficits in emotion perception and recognition in individuals with TBI may lead to inaccurate cognitive appraisal of emotions, and, in turn, differences in reactivity to emotional stimuli and expression. The right hemisphere has been identified as being particularly important for emotion processing (Starkstein & Tranel, 2012). Damage to the somatosensory cortex in the right hemisphere is associated with impaired recognition of emotions in other people (Adolphs, Damasio, Tranel, Cooper, & Damasio, 2000). The amygdala is another key structure involved in affective processing. It has bidirectional connections with multiple brain structures necessary for emotional functioning such as the orbitofrontal cortices, hippocampus, and basal ganglia. Due to

the highly connected nature of these structures, it is likely that damage to any parts of the system as a result of brain injury would potentially impair emotion processing. Also, the frontal lobe is often damaged in TBI, leading to emotion-processing deficits, including notable differences in emotion recognition (Spikman, Timmerman, Milders, Veenstra, & van der Naalt, 2012).

Other impairments seen in individuals with TBI, such as anosodiaphoria (reduced concern about deficits), and anosognosia (loss of insight about deficits), may also contribute to differences in emotional expression via impaired reactivity to emotional stimuli. If individuals with TBI do not care about their deficits or are not aware of their deficits, the stressful aspects of recovery would not be readily apparent. Inability to recognize stressful stimuli or situations as stressful undoubtedly reduces the ability to cope with stress. Additionally, individuals with TBI have often been found to have alexithymia, meaning that they have difficulty identifying and describing their emotions (Becerra, Amos, & Jongenelis, 2002). Considering the large body of literature supporting deficits in emotion processing in TBI, the use of emotional expression as a coping strategy is likely to be impaired.

Research on emotional functioning after TBI has focused primarily on deficits in emotional perception and processing, rather than on changes in the expression of emotions following a brain injury. Further, no studies of persons with TBI have examined both verbal and nonverbal emotional expression in relation to personality. According to Berry and Pennebaker (1993), verbal and nonverbal emotional communication styles should be considered individual differences, which are probably related to temperament. They describe two types of nonverbal emotional expression: symbolic communication, which is partially under conscious control, and spontaneous communication, which is automatic and more difficult to suppress than symbolic emotional expression (Berry & Pennebaker, 1993; Buck, 1984). Trying to hide that you are

feeling upset by modifying facial behaviors is an example of symbolic communication, whereas flinching in pain due to injury is an example of spontaneous communication. Because spontaneous nonverbal expression occurs automatically (which is likely to have an adaptive purpose), inhibition of this type of emotional expression takes work and causes changes to the autonomic system. Verbal emotional expression is similar to symbolic nonverbal expression, as they are under conscious control. As seen with suppression of spontaneous communication, suppression of verbal and symbolic nonverbal communication is linked to poor health outcomes (Berry & Pennebaker, 1993). Furthermore, these authors posit that verbal expression allows for the organization of emotions stemming from stress or trauma into words, possibly creating a coherent story. Putting feelings or thoughts into words may turn abstract concepts into concrete concepts, which a person can easily review and contemplate. Therefore, verbal emotional expression is likely to facilitate coping with stress.

Neurobiological Theories of Personality

Neurobiological theories of personality (Gray, 1981; Rothbart, Ahadi, & Evans, 2000) have been proposed as alternatives to lexically-based theories of personality, such as the Five Factor model (McCrae & Costa, 1987). Rothbart et al. (2000) define temperament as "individual differences in reactivity and self-regulation assumed to have a constitutional basis" (p. 123). Assuming that temperament has a constitutional basis means temperament is viewed as a product of biological makeup, influenced by heredity, development, and experience. This definition of temperament emphasizes reactivity (responsivity of behavioral and physiological systems to internal and external change) and self-regulation (neurobiological processes that modulate reactivity). This view of temperament incorporates genetic and biological influences, the functioning and control of physiological arousal and inhibition systems, and environmental

influences over time.

Gray (1972) proposed a psychophysiological approach to explaining behavior and personality. Gray's theory consists of two systems: the *Behavioral Inhibition System* (BIS), relating to avoidance behavior, and the *Behavioral Approach System* (BAS) related to approach behavior, (BAS). The BIS has been linked to trait anxiety and is considered the system responsible for stopping behavior that could potentially lead to punishment or loss of reward (Gray, 1990). The BAS is described as being activated by reward stimuli or by opportunities to eliminate punishment. Therefore, whereas activation of the BIS causes inhibition of movement toward goals, activation of the BAS causes initiation of or increased movement toward goals. In terms of affect, the BIS is assumed to be related to the broad dimension of negative affect and the BAS to positive affect. Gray's theory is unique in that it proposes that stable individual differences in the responsiveness of these two systems can be used to explain and predict reactivity to stimuli. Accordingly, this theory of personality would appear to be an appropriate explanatory mechanism for differences in the way individuals perceive stressful stimuli, react to those stimuli, express emotions, and cope overall.

Carver and White (1994) created a scale to examine BIS/BAS sensitivity and assess Gray's theorized dimensions of personality. To generate the scale, Carver and White generated a pool of items that were intended to tap the overall conceptualization of BIS and BAS functioning. They considered the role of the BIS and BAS systems in generating emotional reactions and wrote the items accordingly. Items designed to assess BIS sensitivity included statements that reflect concern about negative events ("I worry about making mistakes") or reactions to such events ("Criticism or scolding hurts me quite a bit"). Items aimed at addressing BAS sensitivity reflected strong pursuit of goals ("I go out of my way to get things I want"),

responsiveness to reward ("When I get something I want I feel excited and energized"), the tendency to seek rewards ("I'm always willing to try something new if I think it will be fun"), or a tendency to act quickly in pursuit of rewards ("I often act on the spur of the moment"). A factor analysis supported one BIS scale and three BAS subscales: BAS-Reward Responsiveness, BAS-Drive, and BAS-Fun Seeking.

The Carver and White BIS/BAS scale has been compared to the Five Factor Model of personality. Smits and Boeck (2006) reported that the BIS is positively correlated with Neuroticism, and the three BAS scales are positively correlated with Extraversion. Agreeableness was also positively related to the BIS and negatively related to one of the BAS scales (BAS-Drive). Conscientiousness had a negative correlation with the BAS-Fun Seeking scale. There was not strong evidence for a relationship between the BIS/BAS and Openness.

Although the BIS/BAS scale has not been specifically studied in people with TBI, other measures of personality have been examined, yielding mixed findings. Evidence from one study examining pre-injury and post-injury personality in TBI patients found small but significant increases in neuroticism, addiction, and criminality (Tate, 2003). In contrast, other studies have reported that post-injury personality profiles of individuals with TBI are similar to those of healthy adults and that personality remains stable in brain injury survivors over a 6-month period (Kurtz, Putnam, & Stone, 1998). As there is much to learn about personality in TBI survivors, and even more about how personality is related to stress reactivity and emotional expression in this population, the importance of studies on such topics is evident. Increased knowledge about reactivity to stress in patients with TBI has the potential to aid in predicting vulnerability to stress-related health problems. Identifying and intervening with individuals who may have more difficulties coping after TBI may lead to better functional outcomes and improved quality of life.

Aims and Hypotheses

Overview

The primary purpose of the current research project was to examine the relation between the BIS/BAS theory of personality and stress coping among adults with TBI. To accomplish this broad aim, the study examined the extent to which the BIS/BAS scales are associated with measures of physiological reactivity to stress and emotional expression as reflected in verbal and nonverbal output as well as self-reported emotional experience among adults with TBI compared to adults without TBI. Further, the study was conducted to provide support for the validity of using the BIS/BAS scale, as well as to enhance knowledge about personality and stress, among persons with TBI.

Specific Aims and Associated Hypotheses:

(1) **Aim:** The first aim was to examine the absolute levels of BIS/BAS scores between individuals with and without TBI.

- **Hypotheses:** Given that TBI survivors often have impaired awareness of deficits and may not accurately appraise stressful stimuli (Spikman et al., 2012), it was expected that the TBI group would have a lower average BIS score and a higher average BAS score compared to individuals without brain injury.

(2) **Aim:** The second aim was to examine the relation of BIS/BAS to demographic and injury-related characteristics among adults with TBI.

- **Hypothesis:** To date, no study has examined theoretical or psychometric issues related to the BIS/BAS model among people with TBI. An important initial step is to evaluate the extent to which injury severity characteristics and demographics relate to BIS/BAS. It was hypothesized that modest relationships among these characteristics would be observed.

Specifically, consistent with Hypothesis 1, it was expected that TBI severity would show positive relation to BAS and inverse relation to BIS. Moreover, because time since injury, education and IQ are positively associated with functioning after TBI, it was expected that that these characteristics would show inverse relation to BAS and positive relation to BIS.

(3) **Aim:** The third aim of this study was to examine the personality correlates of the BIS/BAS, including (a) self-report of affectivity, (b) content of verbal emotional expression and (c) nonverbal emotional expression.

- **Hypothesis 3(a): Self-report of affectivity.** For the non-TBI group, it was expected that BIS scores would be positively related to negative affect and inversely related to positive affect. Relationships in the opposite directions were expected between BAS scores and affectivity (BAS scores would be inversely related to negative affect and positively related to positive affect). It was expected that the TBI group would not show the same pattern of correlations between the BIS/BAS scale and self-reported affect.
- **Hypothesis 3(b): Verbal emotional expression.** For the non-TBI group, BIS scores were expected to be positively related to negative emotion words and inversely related to positive emotion words. The converse was expected between BAS scores and emotion words in the non-TBI group (i.e., BAS would be inversely related to expression of negative emotion words and positively related to expression of positive emotion words). These relationships were expected to differ in the TBI group. For example, because cognitive appraisal and expression of emotions are frequently impaired after TBI, it was thought that a nonspecific pattern would emerge.
- **Hypothesis 3(c): Nonverbal emotional expression.** Among adults without history of TBI, it was hypothesized that BIS scores would be inversely related to average intensity of positive

emotions (Happiness), and positively related to average intensity of negative emotions (Anxiety, Sadness, Anger, and Helplessness). The converse was expected between BAS scores and emotion intensity in the non-TBI group (i.e., BAS scores would be inversely related to average intensity of negative emotions, and positively related to average intensity of positive emotions). As per Hypotheses 3a and 3b, the pattern of relations for the TBI group were expected to be different than those observed for their healthy counterparts, because they are known to misperceive emotional input, and these types of deficits may adversely affect experience and expression of emotion when stressed.

(4) **Aim.** The final aim was to examine the extent to which the BIS/BAS systems are associated with physiological reactivity to stress in individuals with and without TBI.

- **Hypotheses 4(a):** For the non-TBI group, it was expected that the BIS would be positively related to physiological reactivity to stress, whereas the BAS would be inversely related to physiological stress reactivity. In contrast, this pattern of relations between the BIS and BAS scale with physiological stress reactivity was not expected in the TBI group, given frequent deficits of awareness and appraisal of stress observed among individuals with TBI.
- **Hypothesis 4(b):** Prior research has indicated that post-TBI impairments in social cognition and affect recognition are not caused solely by general cognitive deficits (Spikman et al., 2012); therefore, it was hypothesized that personality characteristics would be uniquely related to stress coping after TBI, beyond that explained by severity of injury and demographics.

CHAPTER 2

METHOD

Participants

The sample included 81 adults who sustained moderate to severe TBI and 76 adults identified as significant others of the individuals with TBI (N = 157). People with TBI were recruited for this independent study from the participant pool of the Southeastern Michigan Traumatic Brain Injury System (SEMTBIS), which is affiliated with the national collaborative Traumatic Brain Injury Model Systems (TBIMS) project. Each participant with TBI identified a significant other (e.g., a relative or close friend) who knew them well before the injury and provided support during their recovery to participate in the study.

Inclusion criteria for TBI participants were as follows: (1) medically documented moderate to severe TBI; (2) treatment at an affiliated Level-I trauma center within 24 hours of injury; (3) receipt of inpatient rehabilitation within the model system; (4) admission to inpatient rehabilitation within 72 hours of discharge from acute care; (5) at least 18 years of age at the time of injury; and (6) provision of informed consent by the person with injury or a legal proxy. TBI participants were excluded if they were (1) non-English speaking; (2) individuals with mild injuries who discharged from the Emergency Department without requiring inpatient rehabilitation (e.g., lacerations and/or bruises of the scalp or forehead who do not meet criteria for medically documented TBI); (3) persons with primary injuries due to anoxic encephalopathy (loss of oxygen); (4) individuals with injuries so severe that they could not tolerate or benefit from inpatient rehabilitation.

General Procedure

Participants completed questionnaires and provided demographic information. A subset

of the two groups completed the Stressful Speech Task (see Measures). For this behavioral sample, TBI survivors were asked to prepare and deliver a 3-minute speech about the most stressful aspects of their recovery from brain injury. Significant others were asked to prepare and deliver a 3-minute speech about the most stressful aspects of the survivor's recovery. Speeches were videotaped, coded for nonverbal emotional expression by independent raters, and analyzed for verbal emotional expression. Physiological measures of stress were collected before (baseline), during, and after the speech task (the stressor). Participants with TBI and their significant others provided informed consent for the SEMTBIS study and were compensated monetarily for their time.

Measures

Demographic and injury-related characteristics included age, gender, and years of education. For TBI participants, injury severity was measured via the Glasgow Coma Scale (Teasdale & Jennett, 1974) at the time of injury.

Personality and Affect

Behavioral Inhibition System/Behavioral Approach System (BIS/BAS) Scale (Carver & White, 1994). Participants completed the Behavioral Inhibition System/Behavioral Approach System (BIS/BAS) scale, which is a 24-item self-report personality measure developed by Carver and White (1994) on the basis of Gray's physiological model of temperament. It can be examined as a two-factor model (BIS and BAS) or as a four-factor model (BIS and three BAS scales: Drive, Fun Seeking, and Reward Responsiveness). The test authors recommend interpreting the scale in its four-factor model. The BIS/BAS scales have been used widely in personality research with healthy adults (Erdle & Rushton, 2010; Smits & Boeck, 2006).

Positive and Negative Affect Schedule (PANAS; Watson, Clark, & Tellegen, 1988). The

PANAS is a 20-item self-report of current positive and negative affect. Positive affect and negative affect represent dispositional dimensions, with individuals high in positive affect being more content, secure, and less anxious, whereas individuals high in negative affect are characterized as being more distressed, upset, and as having a negative view of the world. High internal consistency has been found for the positive affect scale (α = .89) and the negative affect scale (α = .85) of the PANAS (Crawford & Henry, 2004). The PANAS is widely used in research, and has been successfully used with TBI populations (Paradee et al., 2008; Rapport, Bryer, & Hanks, 2008).

Stressful Speech Task

Acute stress was elicited using a paradigm based in part on the Trier Social Stress Test (TSST; Kirschbaum, Pirke, & Hellhammer, 1993): Both groups completed a 3-minute speech task. TBI participants were instructed to prepare and present a 3-minute speech about the most stressful aspects of their recovery and non-TBI participants were to talk about the most stressful aspects about caring for the TBI survivor during his or her recovery. After 5 minutes of preparation, participants were asked to give the speech to the examiner who was video recording the session. The examiner stood facing the participant, maintaining eye contact, holding a stopwatch in an obvious fashion, and prompted the participant to continue speaking if they stopped before the 3 minutes were complete. Multiple measures were associated with the speech task, including physiological indices of stress, as well as indices gleaned from verbal and nonverbal content produced during the speech task.

Verbal Emotional Expression. The Linguistic Inquiry and Word Count (LIWC; Pennebaker, Francis, & Booth, 2001) program was used to examine emotional verbal content from verbatim transcripts of the 3-minute videotaped speeches by participants. The LIWC

program calculates the proportion of words and word stems in several lexical categories that reflect emotional, cognitive, structural and process characteristics of speech. Specifically, the percentages of positive and negative emotion words were examined for the proposed study.

Nonverbal Emotional Expression. Independent raters made observational ratings of emotional expression during the speeches. The videos were coded for intensity of nonverbal emotional expression (based on facial expressions, gestures, tone, affect, volume and rate of speech, etc.) in several categories of positive (Happiness, Excitement) and negative (Anxiety, Fear, Sadness, Anger, Helplessness, Guilt) emotions. The intensity of the Emotional Observation ratings were on a scale from 0 to 3 with 0 being not observed/very low intensity and 3 being very high intensity. Inter-rater reliability of the observations was conducted.

Physiological Measures of Stress. Systolic and diastolic blood pressure (BP) were assessed using a blood pressure monitor with the occluding cuff placed on the participant's left arm; heart rate (HR) was simultaneously estimated.

Salivary cortisol samples were collected using the Salimetrics Oral Swab (SOS). Participants were asked to refrain from smoking, vigorous exercise, and caffeine and alcohol intake the day of the assessment. Ten minutes before the collection, participants thoroughly rinsed their mouths with water to minimize risk of contaminating the samples. The SOS was placed on a participant's tongue for 1 to 2 minutes until the swab became saturated with saliva. Cortisol samples were frozen then shipped on dry ice to Salimetrics Labs in Pennsylvania to be analyzed. Salimetrics used an Enzyme-Linked Immunosorbent Assay (ELISA) cortisol kit with a reported sensitivity of 12 micrograms per 100mL (12 μg/dL) and a mean intra-assay coefficient of variation of 4.8% (van Eck, Berkhof, Nicolson, & Sulon, 1996). All samples were assayed in duplicate and the mean value was used for the study.

The examiners adhered to the same timing procedures as closely as possible for cortisol, HR, and BP measurements. The first measurements were taken immediately after consent to acclimate the participants to the procedures for collecting the physiological data. As first BP measurements taken by a health professional are often higher than those taken at a later time, these measurements were not included in analyses. Baseline measurements were taken 20 minutes into the procedure. HR and BP were taken after a preparation period, immediately before the speech task, and immediately after the speech was delivered. The measurement point after the speech task was considered the High Stress measurement for BP and HR. Baseline cortisol measurements were taken at the same time as baseline HR and BP. High Stress cortisol measurements were taken 12 minutes after the speech and Recovery measurements were taken 22 minutes after participants completed the speech task.

Statistical Analyses

Independent t tests were conducted to compare individuals with and without TBI on each of the BIS/BAS scales. Effect sizes in Cohen's d were also calculated. Correlation analyses examined the extent to which BIS/BAS is related to demographic characteristics in both groups. Correlations between BIS/BAS and injury-related characteristics were also conducted within the TBI group. Hierarchical multiple regressions examined whether personality characteristics as assessed via the BIS/BAS are uniquely related to stress coping after TBI, beyond that explained by severity of injury and demographics.

Correlation analyses were conducted between the BIS/BAS and PANAS scores to assess the relationship of *BIS/BAS to self-report of affect* in individuals with and without TBI. The relationship of *BIS/BAS to verbal emotional expression* was assessed with correlations conducted between BIS/BAS scores and the LIWC indices for percentages of positive and negative emotion

words used in the speech task. Similarly, *BIS/BAS and nonverbal emotional expression* was assessed using correlations conducted between BIS/BAS scores and average intensity for positive (Happiness) and negative (Anxiety, Sadness, Anger, Helplessness) emotions, based on observational ratings of the speech task. Correlation analyses were also used to examine the extent to which the *BIS/BAS systems are associated with physiological reactivity to stress* for cortisol, heart rate, and blood pressure indices. Analyses of stress reactivity included partial correlations adjusting for baseline physiologic indices. By request, as a learning exercise, these analyses explored various metrics of the physiological indices, including raw scores, percent change scores, and regression-based scores (i.e., accounting for baseline levels).

CHAPTER 3

RESULTS

Preliminary Analyses

The data were screened for violations of univariate and multivariate assumptions as recommended by (Tabachnick & Fidell, 2007). Cortisol values were winsorized to reduce the influence of outliers. No variables were transformed to revise skewness or kurtosis.

Description of Sample

Eighty-one individuals with a history of moderate or severe TBI from the SEMTBIS research pool and 76 of their significant others were included in the present study. The entire sample completed the BIS/BAS, WTAR and PANAS. Physiological data were collected during the Stressful Speech Task for 75 participants in the TBI group and 70 SOs; of these participants, audio-visual data were available for subset of the sample (n = 66 TBI group, n = 62 SO group) to evaluate verbal emotional expression (speech content using the LIWC) and nonverbal emotional expression (observational ratings).

Demographic Characteristics. Descriptive statistics for the TBI and SO groups are summarized in Table 1. The sample ranged in age from 20 to 82 years (M = 47.1, SD = 13.6) and ranged in education from 7 to 19 years (M = 12.4, SD = 2.1). The majority of the sample identified themselves as African American (74.5%), whereas 22.3% identified as white and 1.9% as other ethnicities. There were significantly more men (75.3%) in the TBI group than in the significant other (SO) group (30.3%; χ^2 (1) = 31.98, p < .001). On average, significant others had approximately 8 months more education (F(1, 155) = 5.76, p = .018) and scored 4 points higher on the WTAR (estimated full-scale IQ; F(1, 148) = 5.72, p = .018) than did individuals with TBI.

Injury Characteristics. Individuals with TBI took an average of 6.5 days (SD = 8.6,

range = 0.5 – 37) to obtain a motor score of 6 or greater on the Glasgow Coma Motor Scale (i.e., obey commands for movement) and 26.1 days (*SD* = 19.7, range = 0 – 76) to clear post-traumatic confusion. They participated in the study an average of 117.4 months (*SD* = 66.1) after injury.

TBI participants were classified as severe (either > 24 hours to follow commands or > 7 days of post-traumatic confusion), moderate (1 – 24 hours to follow commands or 1 – 7 days of post-traumatic confusion), or mild complicated (time to follow commands < 1 hour and < 1 day of post-traumatic confusion, but acute intracranial pathology on neuroimaging). Eighty-three percent were classified as severe TBI, 10% as moderate and 7% as mild complicated.

BIS/BAS and TBI

Descriptive statistics for personality questionnaires, including BIS/BAS and PANAS, are summarized as a function of group membership (TBI and SO) in Table 2. On the BIS/BAS, the present sample produced scores generally similar to those provided by Carver and White (1994) in their original description of the scales. As compared to the original normative sample (college students), both the TBI and SO groups scored within a standard deviation of each scale mean, ranging from BAS Drive (SO group, z = -0.82) to BAS Reward Responsiveness (SO group z = 0.00).

As shown in Table 2, the Cronbach's alpha reliability of BAS Drive was good (.80 for both groups); however, reliabilities for the Fun Seeking and Reward responsiveness scales were fairly low (alphas < .70 among people with TBI). Item analyses indicated that the low reliabilities did not result from specific poorly fitting items in the separate BAS scales; rather, the low reliabilities appear to reflect the brevity of the scales. BIS as calculated according to the manual showed low reliability in both groups (< .60); however removal of two poorly fitting

items in both groups improved the reliabilities to acceptable levels for research (.70).

Hypothesis 1: Levels of BIS/BAS and TBI

Independent t tests compared individuals with and without TBI on each of the BIS/BAS scales. Results are presented in Table 2, including t statistics, 95% confidence intervals, and effect sizes in Cohen's d (Cohen, 1966). As shown in Table 2, the TBI group endorsed significantly higher levels ($p < .05$) of BAS Drive ($d = 0.38$) and BAS Fun Seeking ($d = 0.27$) than did the SO group. The two groups did not differ significantly on the BAS Reward Responsiveness or BIS scales.

Hypothesis 2: Examine the Relation of BIS/BAS to Demographic and Injury-Related Characteristics Among Adults with TBI

Correlations among BIS/BAS scales and demographic characteristics are presented in Tables 3a (Significant Other group) and 3b (TBI group). Table 3b also presents correlations between BIS/BAS and TBI injury-related characteristics. As seen in Table 3a, the three BAS scales show modest to strong correlations (*rs* .40 to .57) among the significant others as expected. The BIS scale was also correlated with the BAS Fun Seeking ($r = .30$) and Reward Responsiveness ($r = .28$). Among the SO group, age was inversely related to BAS scales (*rs* -.11 to -.29). Education showed small to medium inverse relationship with the BIS ($r = -.32$) as did estimated IQ ($r = -.21$) but both were unrelated to BAS scales (*r*s .06 to -.13).

The correlations between the BAS scales in the TBI group were similar to those seen in the SO group (i.e., the three BAS scales were intercorrelated, *rs* .40 to .58). The BIS scale also showed small to moderate relation to the BAS scales (*rs* .23 to .42) in the TBI group. In contrast

to the significant others, age was not related to the BIS/BAS scales for individuals with TBI. The TBI group also had a different pattern of relations between the personality scales and education. Education showed small to medium inverse correlations with the BAS scales (*rs* -.24 to -.30) but was unrelated to BIS (*r*s -.03).

Injury severity showed moderate positive correlation to BAS scales (*r*s .25 to .35) but was unrelated to BIS (*r* = .02). Individual indices of severity such as days in post-traumatic confusion showed modest relation to BAS Drive (*r* = .21) and Fun Seeking (*r* = .21) but was not related to Reward Responsiveness (*r* = .09) or BIS (*r* = -.06). Neither days to follow commands (*r*s .03 to .16) nor time since injury (*r*s -.01 to .12) were related to the BIS/BAS scales.

Hypothesis 3: Personality Correlates of the BIS/BAS

Hypothesis 3a – Self-Report of Affectivity (PANAS). Table 2 presents descriptive statistics and t-test results for the PANAS, and Tables 3a and 3b present correlations between BIS/BAS and the PANAS for the two groups. As can be seen in Table 2, the TBI group and the SO group did not differ significantly on the PANAS Positive Affect (PA) scale, $t(1, 154) = 0.40$, $p = .70$, $d = 0.06$. Scores were also not significantly different between the TBI group and the SO group on the PANAS Negative Affect (NA) scale, $t(154) = 1.37$, $p = .17$, $d = 0.22$. Additionally, compared to normative data for nonclinical populations on the PANAS (Watson et al., 1988) both groups scored within the normal range on PA (TBI z = 0.10; SO z = 0.04) and NA (TBI z = -0.61; SO z = 0.80).

Hypothesis 3a – Significant Other Group. As presented in Table 3a, Pearson correlations were used to examine the relationships between the BIS/BAS scales and self-report of affectivity as measured by the PANAS. Consistent with hypotheses, the relation between BAS Drive and

Positive Affect was significant ($p < .05$) and positive ($r = .24$). Also, BAS Reward Responsiveness showed a significantly positive correlation with Positive Affect, ($r = .22$). The relations between the BIS scale and Positive and Negative Affect were also as hypothesized. BIS was inversely correlated with Positive Affect ($r = -.31$) and positively correlated with Negative Affect ($r = .41$).

Hypothesis 3a – Traumatic Brain Injury Group. As can be seen in Table 3b, BAS Drive was significantly related to both Positive Affect ($r = .19$) and Negative Affect ($r = .24$), though both correlations were small. BAS Fun Seeking was positively related to Negative Affect ($r = .37$), which was not an expected pattern as the BAS scales tend to be associated with positive affect. There was a significant positive relation between BAS Reward Responsiveness and Positive Affect ($r = .27$). As seen in the SO group, the BIS scale was significantly related to Negative Affect in the TBI group ($r = .29$), though the correlation was weaker for the TBI group.

Hypothesis 3b – Verbal Emotional Expression. Table 2 summarizes means and standard deviations for Linguistic Inquiry and Word Count (LIWC) index z scores for each group. Individuals in the SO group generated significantly more words during the speech task than individuals in the TBI group, $t(126) = -3.38$, $p = .001$, $d = 0.59$. The groups did not differ on the proportions of Positive Emotion or Negative Emotion words used during their speeches (i.e., accounting for total word count).

Hypothesis 3b – Significant Other Group. The relationship between the BIS/BAS scales and the LIWC indices was examined using Pearson correlations. As can be seen in Table 3a, the BIS scale was positively correlated with the LIWC Negative Emotion index ($r = .23$). The three BAS scales were not significantly related to either of the LIWC indices in the SO group.

Hypothesis 3b –Traumatic Brain Injury Group. Table 3b shows a different pattern of correlations between the BIS/BAS and the LIWC indices for the TBI group than that observed in the SO group. The relationship between BAS Drive and LIWC Negative Emotion was positive (r = .24), whereas BIS was not significantly related to LIWC Negative Emotion. One of the largest correlations between the BIS/BAS scales and LIWC indices was between BAS Reward Responsiveness and LIWC Negative Emotion (r = .32).

Hypothesis 3c – Nonverbal Emotional Expression. The video taped speeches were coded for intensity (0-3) of several Emotional Observation variables including Happiness, Excitement, Anxiety, Fear, Sadness, Anger, Guilt, and Helplessness. Excitement, Fear, and Guilt were very rarely observed, and therefore, were dropped from subsequent analyses.

As independent raters rated the Emotional Observation variables, interrater reliability analyses were completed. Table 4 presents the average intraclass correlation coefficients (ICC) for each group. ICCs were calculated using a two-way mixed effects model yielding the average measure of the raters. This model is appropriate when each case is assessed by each rater, and the reliability of the specific raters employed in a specific context is of interest (i.e., these are the only raters of interest, not generalized to a larger population of raters). The ICC reflects the average of the raters' measurements. Guidelines by (Cicchetti & Sparrow, 1981) were used to interpret the reliability coefficients. According to these guidelines, a reliability coefficient below .40 is poor; .40 to .59 is fair; .60 to .74 is good; and .75 to 1.00 is excellent in terms of clinical significance (Cicchetti & Sparrow, 1981) In the TBI group, the interrater reliability coefficients for all of the Emotional Observation variables were at levels of clinical significance in the good

to excellent range (*ICC* 0.68 to 0.93). Reliability analyses showed similar results for the SO group with reliability coefficients in the good to excellent range as well (*ICC* 0.64 to 0.91).

Table 4 also summarizes means and standard deviations for the observer ratings of emotions for each group. Because the data were skewed, nonparametric Mann-Whitney tests were conducted to compare the groups. On average, individuals in the TBI group displayed more Happiness ($U(126) = 1403.0$, $Z = -3.33$, $p = .001$, $d = 0.62$) and less Anxiety ($U(126) = 1565.5$, $Z = -2.47$, $p = .01$, $d = 0.45$) than the individuals in the SO group. The TBI group also showed slightly less Helplessness ($U(126) = 1696.5$, $Z = -1.88$, $p = .06$, $d = 0.34$) than the SO group. The groups did not significantly differ on the variables Sadness and Anger.

Hypothesis 3c – Significant Other Group.

The relationship between the BIS/BAS scales and the Emotional Observations was examined using Spearman correlations as much of the data were markedly skewed. As can be seen in Table 3a, BAS Drive was inversely correlated with Sadness ($r_s = -.23$) whereas the relationship between BAS Fun Seeking and Anxiety was positive ($r_s = .23$) in the SO group. Anger showed stronger correlations with the BIS/BAS; it was positively related to both BAS Reward Responsiveness ($r_s = .31$) and the BIS scale ($r_s = .38$). The BIS scale also was positively correlated with Helplessness among significant others ($r_s = .22$).

Hypothesis 3c – Traumatic Brain Injury Group.

Spearman correlations between the BIS/BAS scales and Emotional Observations are presented in Table 3b for the TBI group. Fewer Observation variables were significantly related to the BIS/BAS compared to the SO group. Only Anxiety had a positive relationship with BAS Fun Seeking ($r_s = .26$) and BAS Reward Responsiveness ($r_s = .31$) among participants with TBI.

Hypothesis 4: BIS/BAS and Physiological Reactivity to Stress

Table 5 provides the means and standard deviations for absolute and percent change values of cortisol, systolic blood pressure (SBP), diastolic blood pressure (DBP), and heart rate (HR), as a function of group membership (TBI and SO). Reactivity indices calculated from physiologic data include percent change from baseline to high stress (Change 1), from high stress to recovery (Change 2) and from baseline to recovery (Change 3). Negative change scores indicate a stress response, such that the index has risen between the two time points, whereas positive change scores indicate a drop in the index between the two points.

Hypothesis 4(a) – Significant Other Group. A series of correlations were conducted between the BIS/BAS scales and the four physiological measures of stress. Both the zero-order correlations and the partial correlations adjusting for baseline measures are summarized in Tables 6a (Significant Others) and 6b (TBI).

Cortisol. Of note, although the majority of the sample (57%) showed a rise in cortisol over the course of the experiment, overall mean levels of cortisol for the groups do not show the expected pattern of cortisol rise in relation to stress condition. The frequency of participants who showed cortisol rise for SO (62%) and TBI (53%) groups did not differ significantly, $X^2(1, N = 147) = 1.20$, $p = .273$, phi = .10.

As shown in Table 6a, BAS Drive scores had a significant inverse relationship with High Stress ($r = -.26$) and Recovery ($r = -.31$) cortisol. After controlling for Baseline, the correlations between BAS Drive and High Stress and Recovery were still significant, *partial correlation* (*pr*) = -.23, $pr = -.28$, respectively. Results also demonstrate that BAS Drive was significantly correlated with change in cortisol from baseline to high stress (Change 1 $pr = .32$) and from baseline to recovery (Change 3 $pr = .35$), after controlling for Baseline cortisol. BAS Fun

Seeking and BAS Reward Responsiveness were not significantly associated with cortisol in the SO group.

In contrast to the hypothesis, BIS scores were inversely correlated with Baseline (r = -.25), High Stress (r = -.30), and Recovery (r = -.34) cortisol. BIS scores were significantly correlated to Change 1 (pr = .23) cortisol, after controlling for Baseline cortisol, indicating low stress response (positive change score) among participants who reported high BIS.

Blood Pressure. Table 6a shows that BAS Drive was significantly correlated to systolic blood pressure (SBP) at Recovery after controlling for Baseline SBP (pr = .21). BAS Drive showed a significant inverse relationship with change from high stress to recovery (Change 2 pr = -.32). Thus, high BAS Drive was associated with BP increase (negative Change 2 scores) whereas low BAS Drive was associated with BP decrease (positive Change 2 scores) over time.

BAS Fun Seeking showed inverse correlation with Baseline SBP (pr = -.22) and High Stress SBP (pr = -.27). Fun Seeking showed positive correlation with Change 1 SBP (pr = .24) and inverse correlation with Change 2 (pr = -.20) even after controlling for Baseline SBP. BAS Reward Responsiveness and BIS were not significantly associated with SBP in the SO group.

Table 6a summarizes the zero-order and partial correlations between BIS/BAS and diastolic blood pressure (DBP) for significant others. Controlling for Baseline, BAS Drive had a significant inverse relationship with Change 2 (pr = -.23) DBP. This relationship is similar to the relationship between BAS Fun Seeking and Change 2 SBP. BAS Fun Seeking showed significant correlation to Baseline (r = - .23) and High Stress (r = .26), as well as significant partial correlation for Change 2 (pr = -.27) and Change 3 (pr = -.21). As seen with SBP, DBP was not significantly related to BAS Reward Responsiveness and BIS scores among significant others.

Heart rate. Table 6a shows the correlations between BIS/BAS scores and heart rate (HR) variables for the SO group. All three BAS scales had significant inverse zero-order correlations with Baseline, High Stress, and Recovery HR (*r*s -.21 to -.28), which is consistent with hypotheses. The BIS scale was not related to the HR variables for the significant others.

Physiological reactivity summary (SO Group). Overall, there was a consistent pattern of moderate inverse relationships between the individual physiological time points and the BIS/BAS. Other than for cortisol, these inverse correlations were stronger for the BAS scales than the BIS scale. After controlling for baseline, Change 1 cortisol shows positive relation to BAS Drive and BIS. BAS Drive is also positively correlated with Change 3 cortisol. The BIS/BAS show positive relation with Change 1 SBP and DBP and inverse relation with Change 2 and 3 SBP and DBP. For HR, the absolute values at the individual time points rather than the change scores were most predictive.

Hypothesis 4(a) – Traumatic Brain Injury Group. Correlations were conducted between the BIS/BAS scales and the physiological stress measures for the TBI group. Zero-order correlations and the partial correlations adjusting for baseline measures are summarized in Table 6b.

Cortisol. Results show that BAS Drive has a significant inverse relationship with cortisol at the High Stress time point, *pr* = -.33. TBI participants who endorsed higher ratings for items related to strong pursuit of goals had lower cortisol levels at High Stress. BAS Drive was significantly correlated with Change 1 and Change 3 cortisol scores, *pr* = .39, *pr* = .20, respectively.

BAS Fun Seeking had a significant inverse relationship with High Stress cortisol, *pr* = -.25. BAS Fun Seeking showed the same pattern of relationships with Change 1 and Change 3

cortisol scores as BAS Drive, *pr* = .30, *pr* = .22, respectively. BAS Reward Responsiveness had significant positive correlations with Change 1 and Change 3 cortisol as well, *pr* = .29, *pr* = .28, respectively. After controlling for Baseline cortisol, the BIS scale was not significantly related to any cortisol variables.

Blood Pressure. As shown in Table 6b, BAS Fun Seeking had a significant positive relationship with High Stress systolic blood pressure (SBP; *pr* = .23). BAS Fun Seeking had a small but significant inverse relationship with Change 1 SBP, *pr* = -.20. BAS Reward Responsiveness was inversely related to Baseline (*r* = -.23) and High Stress SBP (*r* = -.24). BAS Drive and BIS were not significantly associated with SBP variables for individuals with TBI.

Table 6b shows that BAS Drive has a small but significant inverse relationship with diastolic blood pressure (DBP) at the High Stress time point, after controlling for Baseline DBP, *pr* = -.19. Also, BAS Drive was positively correlated with Change 1 DBP (*pr* = .20) and was inversely related to Change 2 DBP(*pr* = -.25).

BAS Reward Responsiveness showed a significant positive relationship with Recovery DBP, *pr* = .26. BAS Reward Responsiveness was inversely correlated with Change 2 and Change 3 DBP, *pr* = -.20, *pr* = -.23, respectively. BAS Fun Seeking and BIS were not significantly related to DBP in the TBI group.

Heart Rate. Table 6b shows BAS Drive had a significant positive relationship with Change 1 heart rate (HR), *pr* = .22. BAS Fun Seeking was positively correlated with Change 3 HR, *pr* = .23. BAS Reward Responsiveness had a significant inverse relationship with Recovery HR, after controlling for Baseline HR, *pr* = -.33. BAS Reward Responsiveness (*pr* = .34) and BIS (*pr* = .23) were also positively correlated with Change 3 HR.

Physiological reactivity summary (TBI Group). Several BAS scales were significantly

and inversely related to the individual physiological time points, similar to the pattern of relations seen between these variables in the SO group. Whereas all the individual cortisol time points were inversely correlated to BIS for the significant others, they were not significantly related to the BIS in the TBI group. Also, Change 1 and Change 3 cortisol show stronger correlations with the BAS scales in the TBI group compared to the SO group, after controlling for Baseline cortisol. The TBI group had few significant correlations between the BIS/BAS and the BP change scores and did not display any consistent patterns for these variables. In contrast to the SO group, the individual HR time points were not predictive of BIS/BAS scores for individuals with TBI. The majority of the HR change scores had positive relation to the BIS/BAS scales.

Hypothesis 4(b) – Unique predictive value of BIS/BAS to physiologic reactivity. Hierarchical multiple regressions were used to examine the hypothesis that BIS/BAS would be uniquely related to stress coping after TBI, beyond that explained by severity of injury and demographic characteristics. Four physiological indexes of stress (change from baseline to high stress for cortisol, SBP, DBP and HR) served as dependent variables in the analyses. For each multiple regression, age, the baseline physiological measurement, and TBI severity were entered on Step 1, and the four BIS/BAS scales were entered on Step 2. Table 7 presents the multiple regression results for Step 2.

For cortisol stress reactivity (baseline – high stress), Step 1, with age, baseline cortisol, and TBI severity entered into the model, was significant and accounted for 22% of the variance in outcome. Addition of the BIS/BAS scales on Step 2 reliably improved the model and accounted for 13% of additional variance in cortisol reactivity outcome. The total model accounted for 35% of variance in cortisol stress reactivity outcome, $F(7,66) = 5.09$, $p < .001$. The

squared semi-partial correlations (sr^2), which indicate the unique variance of each variable to the model, indicated that after baseline cortisol (sr^2 = .14), BAS Drive (sr^2 = .04) accounted for the most unique variance, followed by age (sr^2 = .02).

For systolic blood pressure (SBP) reactivity (baseline – high stress), the total model accounted for 13% of the variance but was not significant, $F(7,71) = 1.56$, $p = .16$. BAS Fun Seeking accounted for the most unique variance (sr^2 = .07), followed by age (sr^2 = .04), BAS Drive (sr^2 = .01), and BIS (sr^2 = .01).

Table 7 presents the hierarchical multiple regression results for diastolic blood pressure (DBP) reactivity (baseline – high stress). Step 1, with age, baseline DBP, and TBI severity entered into the model, was significant and accounted for 14% of the variance in outcome. Addition of the BIS/BAS scales on Step 2 reliably improved the model and accounted for 14% of additional variance in DBP reactivity outcome. The total model accounted for 28% of variance in DBP reactivity outcome, $F(7,69) = 3.78$, $p = .002$. The squared semi-partial correlations (sr^2), indicated that after age (sr^2 = .10), BAS Reward Responsiveness (sr^2 = .06) accounted for the most unique variance in DBP outcome, followed by baseline DBP (sr^2 = .05), BAS Drive (sr^2 = .04), BIS (sr^2 = .03), and BAS Fun Seeking (sr^2 = .02).

For change in heart rate from baseline to high stress, Step 1 was significant and accounted for 23% of the variance in outcome. Addition of the BIS/BAS scales on Step 2 did not significantly improve the model as it accounted for only 4% of additional variance in heart rate reactivity outcome. The total model accounted for 27% of variance in heart rate stress reactivity outcome, $F(7,71) = 3.70$, $p = .002$. Baseline heart rate accounted for the most unique variance (sr^2 = .10) and was followed by TBI severity (sr^2 = .07), BAS Drive (sr^2 = .02), BIS (sr^2 = .02), age (sr^2 = .02) and BAS Reward Responsiveness (sr^2 = .01).

CHAPTER 4

DISCUSSION

The present study indicates that personality is uniquely related to stress coping and reactivity among people with TBI, beyond that explained by demographic and injury characteristics. The present findings also indicate that individuals with moderate to severe TBI show a different pattern of relations between neurobiologically-defined personality and stress coping compared to non-brain-injured individuals. Significant others of people with TBI showed expected patterns of relation; for example, positive affect was associated with behavioral activation sensitivity (i.e., high BAS), and negative affect with behavioral inhibition sensitivity (i.e., high BIS). In contrast, among individuals with TBI, behavioral activation sensitivity was positively related to *both* positive and negative affect. Adults with TBI also endorsed higher levels of behavioral activation compared to significant others. Interestingly, severity of brain injury was positively related to behavioral activation sensitivity, but it was not related to behavioral inhibition sensitivity. Also notable were associations between BIS/BAS personality and observations of emotional expression: among significant others and brain-injured adults, behavioral activation sensitivity was positively related to expression of anxiety when discussing stressful aspects of recovery. Further, individuals with TBI showed less anxiety and more happiness than significant others during emotional disclosure. Physiological stress reactivity was better predicted by behavioral activation sensitivity than by behavioral inhibition sensitivity among both individuals with brain injury and their significant others.

Consistent with the first hypothesis, adults with TBI were more likely to endorse personality characteristics related to strong pursuit of goals and positive reactions to rewards (BAS) compared to individuals without TBI. As individuals with TBI often have impaired awareness of deficits and may not accurately appraise stressful stimuli (Prigatano & Schacter,

1991; Spikman et al., 2012), it was thought that these patients may experience an "ignorance is bliss" phenomenon, and show personality traits associated with positive affect. Although having high BAS might appear beneficial for individuals with TBI, limited awareness of impairments experienced in severe TBI that could be driving up BAS is detrimental to recovery outcomes. When an individual with TBI is not aware of or does not care about his or her deficits, compensation for the deficits is not effectively utilized (Kervick & Kaemingk, 2005; Rapport, Hanks, Millis, & Deshpande, 1998). The hypothesis that people with TBI would show lower behavioral inhibition sensitivity (BIS) compared to their significant others was not supported.

Although information about premorbid personality is not known, it can be speculated that the findings showing higher levels of behavioral activation in TBI participants compared to non-brain-injured individuals reflect personality change following TBI. Patients' significant others often describe personality changes following brain injury including emotional indifference, disinhibition, and inappropriate social behavior (Warriner, Rourke, Velikonja, & Metham, 2003). These changes can be some of the most distressing symptoms for friends and family of individuals with TBI (Ergh, Rapport, Coleman, & Hanks, 2002). Previous research has found a positive relationship between BAS and impulsivity and a negative relationship between BIS and impulsivity (Braddock et al., 2011). Gray (1990) also suggested that impulsivity is the result of reward motivation and is regulated by the BAS. Alternatively, these personality characteristics may be consistent with premorbid personality, and may not reflect an increase in behavioral activation sensitivity following brain injury. Individuals who are driven by pursuing fun (i.e., sensation seeking) and rewards may engage in high risk activities, making them more likely to have a brain injury than individuals who are not as high in these personality traits. This idea is inconsistent with research by Braddock and colleagues though, which demonstrated an inverse

relationship between BAS and risky health behavior.

BAS sensitivity increased with severity of brain injury, whereas BIS sensitivity did not. Thus, TBI appears to intensify behavior motived by pursuit of rewards and goals but does not appear to affect concern about potential punishment. A large literature indicates that individuals with severe TBI commonly perceive that they have less impairment than those with mild or moderate TBI (see Ownsworth & Clare, 2006; Prigatano, 2005b for review). It may be that low awareness of impairments facilitates focus on rewards and positive aspects of life among people with TBI. Individuals with mild-complicated or moderate brain injuries do not display as strong tendencies to be motivated by rewards. Kervick and Kaemingk (2005) found that individuals with mild to moderate brain injury actually perceived greater impairment than that reported by their significant others.

For the third hypothesis, non-brain-injured significant others showed the predicted pattern of relations between personality and self-reported affectivity. Individuals high in behavioral activation tended to experience positive affectivity and those high in behavioral inhibition experienced negative affectivity. Additionally, non-brain-injured individuals who expressed concern about negative events and had strong reactions to negative events (i.e., high BIS) endorsed low levels of positive affect. As hypothesized, the relationships between the personality and self-reported affectivity differed from this expected pattern in brain-injured adults. Inconsistent with previous research that indicates that the BAS scales are related to positive affect (Carver & White, 1994; Erdle & Rushton, 2010), TBI participants who highly endorsed behavioral activation sensitivity also reported high *negative* affect.

Demographic correlates of the BIS/BAS were also examined. Among significant others, behavioral activation sensitivity generally decreased with age. This finding is congruous with

expectations: the drive to go after a reward with a “no holds barred” approach or to seek excitement is likely to diminish with age. Also, among the significant others, education and IQ were inversely associated with BIS sensitivity. Previous research has suggested that neuroticism is adversely associated with academic performance, though findings are mixed (De Feyter, Caers, Vigna, & Berings, 2012; Furnham, Charmorro-Premuzic, & McDougall, 2003). Among adults with TBI, education and IQ were inversely associated with behavioral activation sensitivity, whereas behavioral inhibition sensitivity was not meaningfully related.

The present study was the first to examine the relationship between personality and emotional expression in TBI. A notable finding was that adults with TBI produced fewer words when describing stressful aspects of their recovery than did their non-brain-injured significant others. A reduction in the ability to produce language has obvious negative implications on social communication and emotional expression. Language impairments, reduced motivation, or executive functioning deficits that often result from TBI (Hanks, Ricker, & Millis, 2004; Hartley & Jensen, 1991) could contribute to this finding. A reduction in language production following TBI limits one’s ability to use emotional expression as a coping strategy effectively. As a result, people with TBI may not experience the same health and psychological benefits from emotional expression (Pennebaker, 1993) as non-brain injured individuals.

Although overall output differed between groups, for both groups, persons with high behavioral inhibition sensitivity used a higher *proportion* of negative words when describing stress compared to others with low BIS. Previous research supports that neuroticism (which is related to BIS) is associated with the use of negative emotion words (Holtgraves, 2011). The relationship between BIS and verbal output of negative emotion was predicted for the significant other group, but it was hypothesized that the TBI group might not show this expected pattern.

The finding that both groups showed the same pattern of relation between BIS and expression of negative emotion suggests that the association is fairly robust to brain injury. Contrary to hypotheses, behavioral activation sensitivity was not related to the proportion of positive words used by significant others. Consistent with the hypothesis that the TBI group would show an irregular pattern of relations, behavioral activation sensitivity was positively associated with the proportion of *negative* emotion words rather than positive words used when describing a stressful personal experience among individuals with TBI. It may be that differences in BAS sensitivity influence the propensity of an individual to engage in and, therefore, benefit from talking about stress and negative emotions. As BAS is related to extraversion and *approach* behavior, individuals with high behavioral activation sensitivity might be more willing to approach and confront negative emotions than individuals with low BAS. Research by Laghai and Joseph (2000) supports that the personality traits of extraversion, agreeableness, and openness are related to a positive attitude towards emotional expression. Alternatively, expression of negative emotions might bring relief only to individuals high in BAS whereas individuals with low BAS might experience anxiety and avoidance when challenged to confront their stress emotionally. Zakowski et al. (2011) found that individuals high in neuroticism did not benefit from a written emotional disclosure intervention and actually exhibited higher distress at follow-up compared to those low in neuroticism. Emotional disclosure might be a trait-congruent coping mechanism for extraverts (i.e., individuals high in BAS) but not for individuals with high levels of neuroticism (i.e., high BIS/low BAS).

The current study was also distinctive in that it examined nonverbal emotional expression in individuals with traumatic brain injury. Group differences were found on the observation of emotional expression. Participants with TBI showed more happiness and less anxiety than did

the significant others when describing stressful aspects of recovery. A trend toward more expressions of helplessness among significant others as compared to people with TBI also was observed. Research has demonstrated the adverse effects of the patient's recovery process on the significant other (Anderson, Parmenter, & Mok, 2002; Ergh, Hanks, Rapport, & Coleman, 2003). Frequently, significant others have to take on new caregiving responsibilities when their partner, child, family member or friend has a TBI. Significant others often shoulder stressors associated with recovering from a brain injury (e.g., financial burden, rehabilitation, transportation), as individuals with TBI are often unable to manage these responsibilities themselves. When talking about stressful aspects of recovery from brain injury, significant others were likely to have been more aware of the hardships and have insight into problems than individuals with TBI. Prior research suggests that individuals with impaired awareness of cognitive and behavioral deficits may be less distressed about difficulties associated with TBI than are individuals who appreciated the consequences of injury (Malec, Machulda, & Moessner, 1997). Whereas significant others generally showed increased experience of stress, patients with TBI may have decreased experience of stress due to anosognosia and anosodiaphoria.

Consistent with the third hypothesis, nonverbal expressions of sadness were inversely related to behavioral activation sensitivity among non-brain-injured adults. The tendency to be reward-focused may be protective from experiencing negative emotions during stressful situations. On the other hand, expression of negative emotion can be beneficial for coping and health (Frattaroli, 2006; Pennebaker & Beall, 1986; Petrie et al., 2004). Therefore, it could be the case that high BAS and low expression of negative emotions is detrimental to coping and health. Also as predicted, BIS sensitivity was associated with nonverbal expression of anger and helplessness in healthy-brained adults. As noted earlier, BIS is related to negative affect.

Therefore, individuals high in BIS are likely to hold overall negative worldviews and are prone to experiencing negative emotions. Contrary to predictions, behavioral activation sensitivity (specifically reward seeking) was positively related to nonverbal expression of anxiety for both people with TBI and their significant others.

Behavioral activation sensitivity also predicted physiological reactivity to stress. Of note, physiologic response among the healthy significant others and people with TBI indicated an expected pattern of stress reactivity: rises in systolic and diastolic blood pressures during stress induction followed by a return to baseline. Heart rate remained relatively steady through the experience; although average cortisol declined from baseline through high stress and recovery, the majority of participants showed increased cortisol between one or more time points. Nonetheless, for both groups, behavioral activation sensitivity was *favorably* related to acute stress reactivity (i.e., low cortisol levels at high stress). This relationship was consistently seen across all other indexes of physiological reactivity (systolic and diastolic blood pressure, heart rate) among significant others but not among persons with TBI. Additionally, behavioral activation sensitivity showed a favorable association with physiological adjustment to acute stress (i.e., reduction of cortisol from baseline to high stress and recovery) in both groups. These results suggest that individuals who are driven by appetitive stimuli do not exhibit the expected increased physiological reactivity, specifically cortisol reactivity, in response to an acute stressor. Other research (Heponiemi, Keltikangas-Jarvinen, Kettunen, Puttonen, & Ravaja, 2004) posits that participants with high BAS sensitivity would find a speech task to be rewarding, because BAS is related to extraversion, the essential feature of which is the tendency to enjoy social situations. It may be the case that persons who are sensitive to incentive signals did not experience the speech task as stressful but rather as enjoyable, resulting in reduced cortisol stress

reactivity. Additionally, it is possible that BAS reflects the predisposition to experience expression of stressful feelings as stress *relieving*, which in turn is reflected in diminished physiologic stress response (Berry & Pennebaker, 1993; Lumley et al., 2011; Pennebaker & Seagal, 1999).

Consistent with the finding that BAS was positively associated with stress reactivity, but not predicted in the hypotheses, physiological recovery from acute stress (i.e., recovery of systolic and diastolic blood pressure toward baseline) was *inversely* related to behavioral activation sensitivity among significant others. This pattern was also seen for diastolic blood pressure among individuals with TBI. On one hand, because BAS sensitivity is related to extraversion and positive affect, it might be expected that individuals with high BAS would exhibit better physiological recovery from stress than those with low BAS; however, that was not the case in the present study. If, however, people experience relief from the opportunity to express their stressful emotions, they would return to a relatively higher baseline after the experience. Thus, the combination of associations – drop in reactivity and rise in reactivity associated – depicts a consistent pattern with BAS.

Absolute values of heart rate scores at the individual time points were most predictive for non-brain injured adults. Behavioral activation sensitivity was *favorably* associated with heart rate, as hypothesized. Significant others with the tendency to be reward-driven had lower heart rates at baseline, high stress, and recovery compared to those with low BAS scores. Consistent with predictions, this expected pattern of relations was not seen in the TBI group. For individuals with TBI, both behavioral activation and behavioral inhibition sensitivity predicted decreased physiological stress reactivity (i.e., reduction of heart rate from baseline to high stress and recovery).

It was predicted that BIS would show inverse relation with physiological stress reactivity. Individuals who are highly sensitive to punishment were expected to experience greater stress during the speech task compared to individuals with low BIS. This prediction was not supported by findings for the significant other group. Behavioral inhibition sensitivity had a *favorable* association with absolute cortisol among non-brain-injured participants. Whereas this relationship was expected for BAS, it seems counterintuitive that BIS would also show the same relationship. After controlling for baseline, the only relationship between behavioral inhibition and physiological reactivity for the TBI group was seen between BIS and physiological adjustment in heart rate. High behavioral inhibition sensitivity was *favorably* associated with physiological adjustment in heart rate (i.e., reduction of heart rate from baseline to recovery). As BIS is related to negative affectivity and neuroticism, it was expected that individuals who tend to impede behavior due to risk of punishment would exhibit a strong stress response; however, this relationship was not supported by the present study. The findings related to the association between personality and physiological stress reactivity are consistent with research by Heponiemi et al. (2004), which found BAS sensitivity was related to physiological reactivity, whereas BIS sensitivity was unrelated to reactivity and baseline levels of all characteristics assessed. Notably, findings from the current study support that personality is uniquely related to stress coping, beyond that explained by demographic and injury characteristics. For cortisol and diastolic blood pressure, BIS/BAS accounted for 13-14% of variation in stress reactivity outcome beyond that explained by age, baseline, and TBI severity.

The present study allowed for preliminary examination of the validity of using the BIS/BAS personality scale among people with TBI. These adults with moderate to severe TBI endorsed the BIS/BAS reliably and at levels generally similar to those in the original normative

sample (Carver & White, 1994), supporting the validity of using the BIS/BAS with individuals with TBI. Additionally, the three BAS scales showed generally modest overlap among both people with TBI and significant others, indicating that they are related but are not measuring the same construct. This finding supports the division of the BAS scale into three specific scales (Drive, Fun Seeking, and Reward Responsiveness). However, the reliabilities of the three brief subscales, especially Fun Seeking and Reward Responsiveness, were fairly low (< .70 among people with TBI), which may partly attenuate relationships among the scales. The observation of relatively low reliabilities for Fun Seeking and Reward Responsiveness compared to Drive is consistent with those reported in prior research with other populations (Gable, Reis, & Elliot, 2000; Jorm et al., 1999; Pothress et al., 2008). Similarly, the present study replicated a common finding that the two reverse-coded BIS items showed poor fit with the total scale (Johnson, Turner, & Iwata, 2003; Pothress et al., 2008). Prior studies report that these two items have formed a separate factor, and the finding has been attributed to the observation that they are the only items that reference fear explicitly, whereas other BIS items focus on anxiety. Other theorists have attributed the finding to method artifact and rightly note that the keyed direction and the content are confounded; therefore, the BIS scale has been examined as two separate subscales in previous research (Pothress et al., 2008). Contrary to previous research (Carver & White, 1994), the BIS scale was related to BAS in both groups, though the magnitude of association was weaker than those observed between the BAS scales. Of note, Carver and White (1994) found, of the three BAS scales, BIS was most strongly related with Reward Responsiveness, which is similar to the findings of the present study.

Future research should use the BIS/BAS scales with individuals with TBI. BIS/BAS scores were well within the range observed in healthy normative samples, and expected

associations among subscales were seen for the most part. As some of the subscales had somewhat low reliabilities in the TBI group, future investigators might want to explore using a total BAS scale rather than three separate subscales with brain-injured patients. In fact, Jorm et al. (1999) observed a unitary factor of behavioral activation from a factor analysis of the three BAS subscales in a large community sample. Additionally, the BIS/BAS scales showed only small to modest overlap with trait positive and negative affectivity, supporting the notion that the BIS/BAS scale taps a distinct feature of personality.

Limitations and Future Directions

A limitation of the study was the specific nature of the sample: participants were predominantly urban dwelling adults with moderate to severe TBI, which limits generalizability to other populations. Additionally, African Americans were well represented in this sample and comprised the majority of participants. This characteristic of the sample could be viewed as both limitation and also a strength, as this group is typically underrepresented in research. No research has specifically examined potential differences on the BIS/BAS associated with self-identified race or ethnicity, and it is beyond the scope and capacity of this study to do so comprehensively. There are no formal grounds or existing empirical findings to expect that personality traits as assessed by the BIS/BAS vary systematically by self-identified race or ethnicity, but the cross-cultural generalizability of the scale should be examined in future research. Also, the majority of the TBI group was men and the majority of the significant other group was women. This gender imbalance is a natural demographic of TBI, which occurs more often in men than women (Bruns & Hauser, 2003). The disproportionate composition of genders in the groups is a statistical weakness, but it is ecologically valid and representative of individuals with TBI and their significant others.

Additionally, 83% of the TBI group was classified as having severe TBI; therefore, results may not generalize well to moderate and especially mild TBI. It may be that people with symptomatic mild TBI would produce profiles closer to those observed for healthy adults without history of brain injury; however, some research has shown that adults with lingering symptoms from uncomplicated mild TBI (concussion) report greater psychological, cognitive, and somatic symptoms than adults with moderate to severe TBI, even at 2 years post injury (Tsanadis et al., 2008). Thus, people with mild TBI might exhibit trait anxiety and other personality factors that predispose to heightened vigilance and overreaction to negative events (i.e., BIS-like qualities) and could yield more aberrant BIS/BAS profiles than those observed in the present study. Future research should replicate these findings with among participants with different proportions of race, gender, and TBI severity.

As nonverbal expression is rarely studied compared to verbal expression, a coding system for observed emotion was created. The interrater reliability for the observations of nonverbal emotional expression was classified as good to excellent for all variables included in analyses (Cicchetti & Sparrow, 1981). However, the task of creating a coding system came with several methodological challenges, such as deciding which emotions to include and operationalizing their hallmark features, as well as establishing agreement on the intensity of observed emotions. One issue that arose was that high intensities of specific emotions were not displayed. The finding that the majority of emotions were rated low on the intensity scale is consistent with real world expression of emotions: most individuals do not angrily yell or hysterically laugh when asked to discuss stressful aspects of TBI recovery for three minutes in a research setting. It was found that some emotions (i.e., fear, excitement, and guilt) were rarely observed by raters when coding videos of the speech task. The nature of the task (e.g., talking about stress to a researcher

while being videotaped) or the possibility that these emotions are difficult to distinguish from other emotions may have contributed to this result. Although nonparametric tests were employed given the limitations of the emotion observation data, restricted range and skewness due to rarity likely attenuated relationships observed among those characteristics and BIS/BAS.

Another study limitation was that it relied on self-report measures of personality. Limitations associated with self-report methodology and shared method variance are applicable (Podsakoff, MacKenzie, Lee, & Podsakoff, 2003). A strength of the study includes the multi-method measurement of emotional expression and physiological stress reactivity. The current study used a novel system for coding observations of emotional expressions for which validity and reliability were not previous establish; however, interrater reliability was good. Replication of a similar study that utilizes the coding system for observations of emotional expression will provide further information regarding test characteristics. Also, the LIWC normative data were not specific to individuals with TBI. The normative data were compiled from a large and diverse group of individuals, most of which were not individuals with moderate to severe brain injury. In terms of the BIS/BAS scale, future research should investigate the value of a BAS Total scale that combines the three separate scales, or ideally, use factor analyses and advanced item response theory (IRT) such as Rasch analyses to investigate and improve the scale. These analyses are beyond the scope of the present study because they are based on large-sample theory. Lastly, in the learning context of this thesis research, a very large number of analyses were conducted, which inflates the likelihood of Type I error.

Conclusions and Clinical Implications

In conclusion, the current study provides support for the hypothesis that patterns of relation between personality, emotional expression, and stress reactivity are affected by

traumatic brain injury. The present study offered a unique, multidimensional view of emotional processing and expression after TBI: Subjective experience of trait emotion was assessed via self-report of affectivity; objective expression of emotional processing was assessed via verbal output and observation of nonverbal behavior, which are under some conscious control, as well as through generally nonconscious expressions of emotional experience, physiological reactivity to emotional challenge. The profiles of emotional expression and experience associated with personality as reflected in BIS/BAS sensitivities depict both consistency and difference between these adults with TBI and significant others without history of brain trauma.

People with TBI and significant others showed similar patterns for BIS in terms of propensity toward subjective experience of negative affectivity, as well as concomitant verbal output of negative emotion when confronting stressful feelings about recovery from TBI. A trend toward experience of positive affectivity with increasing BIS among people with TBI is noteworthy because significant others showed an expected *inverse* pattern (i.e., low positive affect with high BIS). Significant others showed a distinctive pattern for BAS sensitivity, which was associated with subjective experience of positive affectivity and low nonverbal expressions of sadness relative to a propensity to express anxiety and anger during the emotional challenge. By comparison, people with TBI showed a global pattern for BAS sensitivity of heightened affectivity (positive *and* negative affectivity), as well as explicit verbal output reflecting negative emotionality. Like significant others, BAS was associated with the propensity toward nonverbal expression of anxiety during the emotional challenge; however, this finding should be interpreted in the context that people with TBI expressed more happiness, and less anxiety and helplessness when confronting the topic than did significant others. Impairments in awareness of deficits and impaired cognitive appraisal of stress following TBI are likely to have contributed to the finding

that adults with TBI exhibited more happiness and less anxiety than significant others. In general, TBI appears to enhance BAS but not BIS, which is supported by higher BAS sensitivity as a function of TBI severity and relative to individuals without TBI.

For both groups, BAS sensitivity was *favorably* related to acute stress reactivity. In fact, among people with TBI BAS was uniquely related to stress coping, beyond that explained by demographic and injury characteristics. Taken together, the findings generally depict a pattern in which BAS facilitates expression of emotion and may also buffer or relieve experience of stress during emotional challenge. One explanation for this pattern of findings is that BAS sensitivity relates to stress appraisal and/or the extent to which experience and expression of emotion is embraced as positive. The clinical and research implications of these findings may be that certain patients are predisposed to respond positively to immersion and encouragement of sharing stressful emotions, whereas others are not. A constitutional predisposition may help to explain mixed and null findings for some research examining benefits of emotional disclosure in psychotherapy. The BIS/BAS theory of personality and scale appear to be promising avenues for future research in these regards.

The current study contributes to the limited body of research on personality and stress in TBI. Additional knowledge about how these differences in emotional expression and physiological stress reactivity following a brain injury affect rehabilitation and quality of life outcomes is needed. The use of emotional expression is often a major component of psychotherapy. As individuals with brain injury produced fewer words compared to significant others when asked to discuss stressful aspects of recovery, the benefits from such coping techniques may be reduced. Also, as significant others endorsed lower behavioral activation sensitivity than adults with moderate to severe TBI, additional social and psychological support

for significant others may be warranted. Overall, the present study uniquely examined personality and stress coping among individuals with TBI and their significant others using a multimethod approach, and provided insight into how brain injury affects the relations between personality, stress reactivity and emotional expression. Findings also highlight the importance of considering personality traits when using or studying emotional expression. Future research investigating the utility of these associations to predict rehabilitation and quality of life outcomes among brain-injured individuals has the potential to inform recovery prognosis and treatment recommendations.

APPENDIX A

Table 1. *Descriptive Statistics for Traumatic Brain Injury (TBI) and Significant Other (SO) Groups.*

	TBI (n = 81)		SO (n = 76)		Total (N = 157)		
Variable	*M*	*(SD)*	*M*	*(SD)*	*M*	*(SD)*	*Range*
Age (years)	44.6	(12.8)	49.9	(13.8)	47.1	(13.6)	20 – 82
Education (years)	12.0	(1.6)	12.7	(2.4)	12.4	(2.1)	7 – 19
Estimated IQ (WTAR)	85.4	(9.9)	89.4	(10.3)	87.4	(10.2)	70 – 119
Days to follow commands	6.5	(8.6)					0.5 – 37
Time since injury (months)	117.4	(66.1)					19 – 223
Post-traumatic confusion (days)	26.1	(19.7)					0 – 76

Note. WTAR = Wechsler Test of Adult Reading, Predicted Full Scale IQ; Days to follow commands (≥ 6 on the Glasgow Coma Scale motor scale.

Table 2. *Descriptive Statistics and Group Comparisons of BIS/BAS, Emotional Expression, and PANAS for TBI (n = 81) and Significant Other (n = 76) Groups.*

	TBI			*Significant Other*					
Variable	*M*	*SD*	*Cronbach's Alpha*	*M*	*SD*	*Cronbach's Alpha*	*t*(155)	*d*	*95% CI of the difference*
BAS Drive	11.3	(3.1)	.80	10.1	(3.1)	.84	2.42*	0.38	[0.22, 2.15]
BAS Fun Seeking	11.6	(2.6)	.66	10.9	(2.5)	.64	1.76*	0.27	[-0.09, 1.54]
BAS Reward Responsiveness	17.5	(2.1)	.60	17.6	(2.3)	.76	-0.46	0.05	[-0.86, 0.54]
BIS Total	19.4	(3.3)	.69	19.8	(4.1)	.73	-0.69	0.11	[-1.57, 0.78]
PANAS									
Positive Affectivity	32.8	(8.4)	.87	32.3	(7.6)	.83	0.40	0.06	[-2.03, 3.05]
Negative Affectivity	15.2	(6.6)	.91	13.9	(5.9)	.89	1.37	0.22	[-0.61, 3.37]
Linguistic Analysis (LIWC)[1]									
Word Count	342.2	(101.9)	--	401.0	(94.5)	--	-3.38**	0.59	[-93.26, -24.38]
Positive Emotion	-0.5	(0.9)	--	-0.4	(0.9)	--	-0.57	0.10	[-0.41, 0.23]
Negative Emotion	1.3	(1.5)	--	1.1	(1.5)	--	0.84	0.15	[-0.30, 0.74]

Note. PANAS = Positive and Negative Affect Schedule; LIWC = Linguistic Inquiry and Word Count (gender-adjusted Z scores except Word Count); *d* = Cohen's d.

1. Group sizes for LIWC data: TBI *n* = 66, Significant Other *n* = 62.

*$p < .05$, **$p < .01$.

Table 3a. *Correlations for BIS/BAS, Demographic and Personality Characteristics: Significant Other group (n = 76).*

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. BAS Drive	--														
2. BAS Fun Seeking	.57**	--													
3. BAS Reward	.40**	.54**	--												
4. BIS Total	.08	.30**	.28**	--											
5. Age	-.29**	-.29**	-.11	.15	--										
6. Education	-.06	-.10	-.13	-.32**	.04	--									
7. FSIQ Estimate (WTAR)	-.08	-.09	-.08	-.21*	.17	.50**	--								
8. Positive Affect (PANAS)	.24*	.16	.22*	-.21*	-.07	.25*	.16	--							
9. Negative Affect (PANAS)	-.04	.04	.05	.41**	-.02	-.20*	-.25*	-.00	--						
10. Positive emotion (LIWC)	-.05	.05	.16	-.16	-.09	.08	-.12	.13	.10	--					
11. Negative emotion (LIWC)	.13	-.07	-.00	.24*	-.20	-.07	.03	-.02	.09	-.26*	--				
12. Happiness (Obs)	.08	-.07	.09	.20	-.03	-.12	-.17	.14	.14	.21*	-.09	--			
13. Anxiety (Obs)	.19	.23*	.07	-.02	-.44**	-.16	.06	-.01	.07	.02	.10	-.14	--		
14. Sadness (Obs)	-.23*	-.03	.04	.17	-.05	-.17	-.10	-.22*	.24*	.12	-.03	-.14	.05	--	
15. Anger (Obs)	.03	.19	.31**	.38**	-.01	-.20	-.05	-.10	.25*	-.25*	.23*	-.02	-.08	.03	--
16. Helplessness (Obs)	-.07	.15	.13	.22*	-.04	-.34**	.11	.11	.21*	-.09	.18	-.16	.15	.14	.26*

Note. PANAS = Positive and Negative Affect Schedule; LIWC = Linguistic Inquiry and Word Count.
Pearson correlations for variables 1 – 11; Spearman correlations are presented for Emotional Observation data (variables 12 – 16).
*$p < .05$, **$p < .01$.

Table 3b. *Correlations for BIS/BAS, Demographic, Personality, and Injury-related Characteristics: TBI group (n = 81).*

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1. BAS Drive	--																
2. BAS Fun Seeking	.58**	--															
3. BAS Reward	.44**	.40**	--														
4. BIS Total	.23*	.30**	.42**	--													
5. Age	-.04	-.06	-.19	.12	--												
6. Education	-.24*	-.27**	-.30**	-.03	.21*	--											
7. FSIQ Estimate (WTAR)	-.25*	-.17	-.19*	.10	.12	.50**	--										
8. Positive Affect (PANAS)	.19*	.08	.27**	.18	-.16	-.03	.03	--									
9. Negative Affect (PANAS)	.24*	.37**	.08	.29**	.01	-.17	-.11	.09	--								
10. Positive emotion (LIWC)	.02	-.01	.12	.14	.07	-.02	.12	.13	-.09	--							
11. Negative emotion (LIWC)	.24*	.02	.32**	.26**	-.17	-.21	-.14	.36**	.22*	.08	--						
12. Happiness (Obs)	-.02	.01	.07	-.02	-.11	.05	.11	-.17	-.07	-.05	-.07	--					
13. Anxiety (Obs)	.16	.26*	.31**	.00	-.54**	-.21*	-.31**	.03	.14	-.05	.12	.21*	--				
14. Sadness (Obs)	.02	.18	.07	.05	-.10	-.05	-.04	-.00	.13	.01	.07	.18	-.08	--			
15. Anger (Obs)	.05	.04	.12	.06	-.03	-.12	-.01	.01	-.09	-.09	.15	-.05	-.14	.02	--		
16. Helplessness (Obs)	.04	.01	.14	.11	.05	-.08	-.13	.11	.17	-.14	-.02	.26*	-.01	-.11	.13	--	
17. TBI Severity	.35**	.25*	.26**	.02	-.24*	-.20*	-.28**	.06	.08	-.02	.05	-.14	.21*	.18	-.05	.26*	--
18. Time Since Injury	.12	.07	-.03	-.01	.22	-.10	-.15	.13	.13	.09	.02	.25*	-.13	-.07	-.08	-.14	-.01

Note. WTAR = Wechsler Test of Adult Reading; PANAS = Positive and Negative Affect Schedule; LIWC = Linguistic Inquiry and Word Count; Obs = Emotional Observation Rating. Spearman correlations presented for Emotional Observation data.
*$p < .05$, **$p < .01$.

Table 4. *Descriptive Statistics and Group Comparisons of Emotional Observation Ratings for TBI (n = 66) and Significant Other (n = 62) Groups.*

	TBI			*Significant Other*					
Variable	*ICC*	*M*	*SD*	*ICC*	*M*	*SD*	*U*	*z*	*d*
Happiness	0.93	1.1	(1.1)	0.81	0.5	(0.7)	1403.0	-3.33**	0.62
Anxiety	0.91	0.8	(0.8)	0.80	1.2	(0.8)	1565.5	-2.47*	0.45
Sadness	0.90	0.5	(0.8)	0.91	0.6	(0.9)	1801.5	-1.38	0.25
Anger	0.68	0.7	(0.5)	0.64	0.8	(0.7)	1901.5	-0.79	0.14
Helplessness	0.76	0.5	(0.7)	0.69	0.7	(0.9)	1696.5	-1.88†	0.34

Note. U = Mann Whitney U; *d* = Cohen's d; *ICC* = Intraclass Correlation Coefficient.
† $p < .10$, * $p < .05$, ** $p < .01$.

Table 5. *Descriptive Statistics for Traumatic Brain Injury (TBI) and Significant Other (SO) Groups: Cortisol, Heart Rate and Blood Pressure.*

	TBI (n = 81)		SO (n = 74)		Total (N = 155)		
Variable	*M*	*(SD)*	*M*	*(SD)*	*M*	*(SD)*	*Range*
Cortisol							
Baseline	0.29	(0.16)	0.23	(0.15)	0.25	(0.16)	0.01 – 0.81
High Stress	0.26	(0.13)	0.20	(0.12)	0.23	(0.13)	0.01 – 0.70
Recovery	0.23	(0.11)	0.20	(0.11)	0.22	(0.11)	0.01 – 0.64
% Change 1	2.2	(35.3)	0.3	(35.0)	1.3	(35.0)	-90 – 74
% Change 2	7.2	(26.5)	5.3	(33.8)	6.3	(30.2)	-90 – 90
% Change 3	8.8	(36.1)	1.0	(50.0)	5.0	(43.4)	-135 – 75
Heart Rate							
Baseline	71.8	(11.1)	74.8	(12.1)	73.3	(11.6)	42 – 108
High Stress	70.0	(10.4)	74.1	(12.5)	71.9	(11.5)	41 – 111
Recovery	67.6	(10.3)	71.6	(12.0)	69.5	(11.3)	41 – 101
% Change 1	2.0	(7.1)	0.7	(6.1)	1.4	(6.6)	-21 – 17
% Change 2	3.1	(6.5)	3.0	(7.2)	3.1	(6.9)	-15 – 26
% Change 3	5.4	(5.5)	4.0	(5.6)	4.7	(5.6)	-7 – 22
Systolic Blood Pressure							
Baseline	124.8	(17.9)	128.4	(21.9)	126.5	(20.0)	88 – 182
High Stress	128.9	(20.8)	136.1	(23.3)	132.3	(22.3)	85 – 195
Recovery	124.0	(17.5)	125.7	(20.9)	124.8	(19.1)	88 – 185
% Change 1	-3.7	(7.9)	-6.8	(9.5)	-5.2	(8.8)	-32 – 21
% Change 2	3.2	(7.7)	7.1	(8.4)	5.1	(8.3)	-26 – 31
% Change 3	0.1	(7.0)	1.4	(8.2)	0.7	(7.6)	-17 – 17
Diastolic Blood Pressure							
Baseline	82.0	(13.0)	82.2	(14.9)	82.1	(13.9)	54 – 120
High Stress	84.1	(12.8)	84.9	(15.0)	84.5	(13.9)	54 – 130
Recovery	82.3	(12.4)	80.5	(14.1)	81.5	(13.2)	51 – 122
% Change 1	-3.0	(8.1)	-2.9	(6.8)	-3.0	(7.5)	-31 – 17
% Change 2	1.6	(8.8)	4.8	(8.3)	3.1	(8.7)	-21 –21
% Change 3	-0.9	(9.3)	2.3	(7.6)	0.7	(8.7)	-24 – 25

Note. Change 1 = (Baseline – High Stress); Change 2 = (High Stress – Recovery); Change 3 = (Baseline – Recovery).

Table 6a. *Significant Other Group – BIS/BAS Correlations with Cortisol, Heart Rate, and Blood Pressure Stress Reactivity: Zero-order and Partial Correlations (Controlling for Respective Baseline Physiologic Index).*

Variable	Zero-order				Partial (controlling for baseline)			
	BAS Drive	BAS Fun	BAS Reward	BIS	BAS Drive	BAS Fun	BAS Reward	BIS
Cortisol – Baseline	-.17	-.19	-.12	-.25*	--	--	--	--
Cortisol – High Stress	-.26*	-.17	-.15	-.30**	-.23*	-.04	-.08	-.16
Cortisol – Recovery	-.31**	-.11	-.17	-.34**	-.28**	.04	-.12	-.23*
Cortisol – % Change 1	.23*	-.03	-.12	.12	.31**	.05	-.08	.23*
Cortisol – % Change 2	.07	-.06	.04	-.03	.08	-.06	.04	-.03
Cortisol – % Change 3	.25*	-.09	-.11	.02	.34**	-.02	-.07	.13
Systolic – Baseline	-.15	-.22*	-.10	-.05	--	--	--	--
Systolic – High Stress	-.20*	-.27*	-.06	.01	-.14	-.16	.05	.09
Systolic – Recovery	-.03	-.16	.02	.05	.21*	.06	.21	.19
Systolic – % Change 1	.15	.19	.12	.00	.18	.24*	.14	.01
Systolic – % Change 2	-.32**	-.20*	-.14	-.08	-.32**	-.20*	-.13	-.08
Systolic – % Change 3	-.18	-.04	-.04	-.07	-.15	.01	-.02	-.06
Diastolic – Baseline	-.12	-.23*	-.05	.03	--	--	--	--
Diastolic – High Stress	-.18	-.26*	-.10	.01	-.19	-.13	-.13	-.05
Diastolic – Recovery	-.06	-.12	-.05	.07	.10	.20	-.01	.09
Diastolic – % Change 1	.11	.08	-.00	.01	.48**	.13	.01	-.00
Diastolic – % Change 2	-.23*	-.27**	-.12	-.13	-.23*	-.27*	-.12	-.13
Diastolic – % Change 3	-.15	-.26*	-.14	-.13	-.13	-.21*	-.13	-.14
Heart Rate – Baseline	-.28**	-.22*	-.25*	-.13	--	--	--	--
Heart Rate – High Stress	-.25*	-.21*	-.22*	-.09	.04	-.01	.06	.10
Heart Rate – Recovery	-.25*	-.23*	-.21*	-.10	.03	-.05	.08	.07
Heart Rate – % Change 1	-.06	.02	-.03	-.03	-.03	.04	.01	-.02
Heart Rate – % Change 2	.02	.03	-.00	-.02	.03	.03	.00	-.02
Heart Rate – % Change 3	-.02	.06	-.02	-.06	.01	.08	-.00	-.05

Note. Change 1 = (Baseline – High Stress); Change 2 = (High Stress – Recovery); Change 3 = (Baseline – Recovery).
*$p < .05$, **$p < .01$

Table 6b. *Traumatic Brain Injury Group – BIS/BAS Correlations with Cortisol, Heart Rate, and Blood Pressure Stress Reactivity: Zero-order and Partial Correlations (Controlling for Respective Baseline Physiologic Index).*

Variable	Zero-order				Partial (controlling for baseline)			
	BAS Drive	BAS Fun	BAS Reward	BIS	BAS Drive	BAS Fun	BAS Reward	BIS
Cortisol – Baseline	-.02	-.07	-.08	-.18	--	--	--	--
Cortisol – High Stress	-.25*	-.22*	-.19	-.02	-.33**	-.25	-.19	.16
Cortisol – Recovery	-.14	-.16	-.16	-.04	-.17	-.16	-.16	.12
Cortisol – % Change 1	.35**	.25*	.23*	-.12	.39**	.30**	.29**	-.06
Cortisol – % Change 2	-.14	-.10	-.15	-.05	-.14	-.09	-.15	-.04
Cortisol – % Change 3	.18	.17	.22*	-.22*	.20*	.22*	.28**	-.16
Systolic – Baseline	-.19	-.19*	-.23*	.11	--	--	--	--
Systolic – High Stress	-.13	-.06	-.24*	.08	.07	.23*	-.07	-.03
Systolic – Recovery	-.09	-.11	-.18	.15	.16	.12	.06	.11
Systolic – % Change 1	.01	-.20*	.06	.05	.01	-.20*	.07	.05
Systolic – % Change 2	-.12	.09	-.20*	-.14	-.08	.15	-.15	-.18
Systolic – % Change 3	-.11	-.10	-.12	-.08	-.06	-.04	-.05	-.12
Diastolic – Baseline	.03	.02	-.05	.14	--	--	--	--
Diastolic – High Stress	-.06	-.04	-.02	.13	-.19*	-.14	.04	.01
Diastolic – Recovery	.10	-.04	-.10	.16	.13	-.10	.26*	.09
Diastolic – % Change 1	.20*	.13	-.06	.07	.20*	.13	-.04	.03
Diastolic – % Change 2	-.25*	-.01	-.20*	-.05	-.25*	-.01	-.20*	-.07
Diastolic – % Change 3	-.09	.10	-.23*	-.02	-.11	.10	-.23*	-.07
Heart Rate – Baseline	.02	-.14	-.03	-.04	--	--	--	--
Heart Rate – High Stress	-.05	-.14	-.06	-.04	-.14	-.03	-.08	-.01
Heart Rate – Recovery	-.01	-.21*	-.15	-.11	-.05	-.19	-.33**	-.18
Heart Rate – % Change 1	.21*	.03	.07	.02	.22*	.07	.09	.03
Heart Rate – % Change 2	-.11	.11	.17	.20*	-.11	.11	.17	.20*
Heart Rate – % Change 3	.11	.17	.27*	.32**	.11	.22*	.30*	.34**

Note. Change 1 = (Baseline – High Stress); Change 2 = (High Stress – Recovery); Change 3 = (Baseline – Recovery).
*$p < .05$, **$p < .01$.

Table 7. Regression to physiological stress reactivity outcomes: Step 2 includes BIS/BAS scales.

Variables	R^2	Beta	sr^2	*F*	*df*	*p*	R^2 Change	Sig *F* Change
Model 2 (Cortisol)	.35			5.09	7,66	< .001	.13	.016
Baseline Cortisol		.39	.14***					
Age		-.16	.02					
TBI Severity		-.06	.00					
BAS Drive		.27	.04*					
BAS Fun Seeking		.08	.00					
BAS Reward Responsiveness		.12	.01					
BIS		-.09	.01					
Model 2 (Systolic)	.13			1.56	7,71	.161	.08	.165
Baseline Systolic		.06	.00					
Age		-.22	.02					
TBI Severity		.08	.00					
BAS Drive		.16	.01					
BAS Fun Seeking		-.34	.02					
BAS Reward Responsiveness		.04	.09**					
BIS		.11	.01					
Model 2 (Diastolic)	.28			3.78	7,69	.002	.14	.015
Baseline Diastolic		.23	.05*					
Age		-.34	.10**					
TBI Severity		-.05	.00					
BAS Drive		.27	.04*					
BAS Fun Seeking		.18	.02					
BAS Reward Responsiveness		-.31	.06*					
BIS		.20	.03					
Model 2 (Heart Rate)	.25			3.46	7,72	.003	.05	.340
Baseline Heart Rate		.30	.08**					
Age		-.22	.04					
TBI Severity		.25	.05*					
BAS Drive		.23	.03					
BAS Fun Seeking		-.10	.01					
BAS Reward Responsiveness		-.15	.01					
BIS		.17	.02					

***$p < .001$. **$p < .01$, *$p < .05$.

APPENDIX B

WAYNE STATE UNIVERSITY

IRB Administration Office
87 East Canfield, Second Floor
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http://irb.wayne.edu

CONCURRENCE OF EXEMPTION

To: Christina Wong
Psychology
5057 Woodward, 7th Floor Suite

From: Dr. Scott Millis _____
Chairperson, Behavioral Institutional Review Board (B3)

Date: May 16, 2013

RE: IRB #: 025413B3X

Protocol Title: Neurobiological Correlates of Personality and Emotional Expression in Traumatic Brain Injury

Sponsor:

Protocol #: 1302011734

The above-referenced protocol has been reviewed and found to qualify for **Exemption** according to paragraph #4 of the Department of Health and Human Services Code of Federal Regulations [45 CFR 46.101(b)].

- Revised Protocol Summary Form (received in the IRB Office 5/16/2013)
- Protocol (received in the IRB Office 4/15/2013)

This proposal has not been evaluated for scientific merit, except to weigh the risk to the human subjects in relation to the potential benefits.

° Exempt protocols do not require annual review by the IRB.

° All changes or amendments to the above-referenced protocol require review and approval by the IRB **BEFORE** implementation.

° Adverse Reactions/Unexpected Events (AR/UE) must be submitted on the appropriate form within the timeframe specified in the IRB Administration Office Policy (http://irb.wayne.edu/policies-human-research.php).

NOTE: Forms should be downloaded from the IRB Administration Office website http://irb.wayne.edu at each use.

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ABSTRACT

NEUROBIOLOGICAL CORRELATES OF PERSONALITY AND EMOTIONAL EXPRESSION IN TRAUMATIC BRAIN INJURY

by

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December 2013

Advisor: Dr. Lisa J. Rapport

Major: Psychology (Clinical)

Degree: Master of Arts

Many individuals with traumatic brain injury (TBI) experience cognitive, emotional, and functional deficits, all of which can contribute to chronic stress. Unfortunately, individuals with TBI often engage in less effective coping than non-brain-injured individuals, which has negative implications for rehabilitation. Differences in personality traits have been linked to individual differences in coping styles, physiological stress reactivity, and emotional disclosure. Research on personality and coping after TBI has been sparse. Thus, the present study examined the influence of TBI on the pattern of the relationships between personality, emotional expression, and stress reactivity. Eighty-one adults who sustained moderate to severe TBI and 76 significant others of individuals with TBI participated. Personality was assessed using the Behavioral Inhibition System/Behavioral Activation System (BIS/BAS) scale, and self-report of affectivity was measured with the Positive and Negative Affect Schedule (PANAS). Verbal and nonverbal emotional expression were gleaned from a 3-minute videotaped speech task for which participants were asked to talk about stressful aspects of recovery from brain injury.

Physiological measures of stress were also collected during the speech task. Results indicate that the pattern of relations between personality, emotional expression, and stress reactivity are affected by TBI; however, consistencies between the groups were also found. Both groups showed similar patterns for BIS in terms of propensity toward negative affectivity, as well as concomitant verbal output of negative emotion. Significant others showed a distinctive pattern for BAS sensitivity, which was associated with positive affectivity and low nonverbal expressions of sadness relative to a propensity to express anxiety and anger during the emotional challenge. By comparison, people with TBI showed a global pattern for BAS sensitivity of heightened affectivity (positive *and* negative affectivity), as well as explicit verbal output reflecting negative emotionality. Like significant others, BAS was associated with the propensity toward nonverbal expression of anxiety during the emotional challenge; however, people with TBI expressed more happiness, and less anxiety and helplessness than did significant others. Impairments in awareness of deficits and impaired cognitive appraisal of stress following TBI are likely to have contributed to the finding that adults with TBI exhibited more happiness and less anxiety than significant others. In general, TBI appears to enhance BAS but not BIS, which is supported by higher BAS sensitivity as a function of TBI severity and relative to individuals without TBI. For both groups, BAS sensitivity was *favorably* related to acute stress reactivity. In fact, among people with TBI BAS was uniquely related to stress coping, beyond that explained by demographic and injury characteristics. Taken together, the findings generally depict a pattern in which BAS facilitates expression of emotion and may also buffer or relieve experience of stress during emotional challenge. The BIS/BAS theory of personality and scale appear to be promising avenues for future research in these regards. The present study provides insight into how brain injury affects the relations between personality, stress reactivity, and emotional

expression. Findings also highlight the importance of considering personality traits when studying emotional expression. Future research investigating the utility of these associations to predict rehabilitation and quality of life outcomes among brain-injured individuals has the potential to inform recovery prognosis and treatment recommendations.

AUTOBIOGRAPHICAL STATEMENT

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Education

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2007 – 2009	Mortar Board National Honor Society