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Measuring Affective Processes In Traumatic Brain Injury

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MEASURING AFFECTIVE PROCESSES IN TRAUMATIC BRAIN INJURY

by

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ABSTRACT

Changes to emotional functioning are difficult to measure after traumatic brain injury (TBI). This study examines how TBI impacts emotional functioning using self-report measures of psychological symptoms, affect, and social participation as well as objective measures of affective processes. The first experiment consists of the development of a novel measure of facial affect recognition that is validated in a sample of 78 non-clinical participants. The second experiment is an exploratory study examining group differences between 50 individuals with mild complicated, moderate, or severe TBI and 32 demographically similar controls. Correlations between self-reported psychological symptoms, affect, and social participation and performance on measures of affective processes are reported. Finally, moderation analyses are used to examine if the relationship between self-reported measures and affective processes changes in the presence of TBI. Results indicated that those with TBI showed different patterns of affective processing as compared to controls. Specifically, TBI participants demonstrated a positive bias when interpreting facial expressions and a negative bias when recalling emotion words. Self-reported measures were also associated with overall performance on measures of affective processing. Findings indicated that the effect of valence appears to be domain specific (e.g. faces versus words) and research within one domain (e.g. affective language) may not generalize to other cognitive-affective processes (e.g. facial affect recognition). Further research on affective processing after TBI is warranted with particular attention given to negatively arousing stimuli.

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LIST OF ABBREVIATIONS

AFT	Ambiguous Faces Test
BSI	Brief Symptom Inventory
C-AVLT	Cognitive-Affective Verbal Learning Test
C-DRS	Connor-Davidson Resilience Scale
EWFT	Emotion Word Fluency Test
PANAS	Positive and Negative Affect Schedule
POC	Person of Color
TBI	Traumatic Brain Injury
VF	Valence Factor
RT	Reaction Time

MEASURING AFFECTIVE PROCESSES IN TRAUMATIC BRAIN INJURY

Introduction

Epidemiological studies of TBI estimate that each year 1.1 million Americans are treated for traumatic brain injury (TBI) in emergency departments and that about 3.2 million US civilians were living with disability following TBI at the time of the study (Corrigan, Selassie, & Orman, 2010). The consequences of TBI include a variety of cognitive, physical, emotional, and social problems that negatively impact quality of life and long-term adjustment (Hawthorne, Gruen, & Kaye, 2009; Hoofien, Gilboa, Vakil, & Donovick, 2001; Langlois, Rutland-Brown, & Thomas, 2006). While cognitive and physical changes are important, research has indicated that changes to emotional and social functioning pose some of the greatest barriers to adjustment after TBI (Williamson et al., 2013; Yates, 2003).

Changes to emotional and social functioning after TBI are difficult to measure. Historically, scientists have relied on self-report ratings of emotional and social functioning to study TBI outcomes (Wilde et al., 2010). However, there is growing interest in the use of objective measures of affective processes to study emotional and social outcomes of TBI (Babbage et al., 2011; McDonald, 2013; McDonald, 2017). These studies have identified deficits in emotion perception and expression after TBI (Babbage et al., 2011; Neumann & Zupan, 2019; Rosenberg, McDonald, Rosenberg, & Westbrook, 2019; Spikman et al., 2013). It is suspected that such affective processing deficits may underly common problems in social and emotional functioning (Knox & Douglas, 2009; Milders, Ietswaart, Crawford, & Currie, 2008; Spikman et al., 2013). In turn this may lead to social isolation and loss of friends (Knox & Douglas, 2009).

Yet, this is an emerging field and more research is needed to identify how emotional processes are impacted by TBI.

This study aims to measure changes in emotional functioning after TBI through a combination of self-report measures of psychological symptoms, affect, and social participation as well as objective measures of affective processes. As such, the following sections will review the literature on TBI including measurement of affect (i.e. mood) and measurement of affective processes (i.e. the ability to perceive and interpret emotions). It will also present a theoretical framework used in the development and selection of measures used in this study.

Background

Traumatic brain injury (TBI) refers to damage sustained to the brain as a result of an external mechanical force. The principle mechanisms of injury for TBI are focal brain damage due to contusions, lacerations, intracranial hemorrhages, and diffuse axonal injury caused by acceleration and deceleration forces (Werner & Engelhard, 2007). While pathophysiology of TBI may involve axonal damage, vascular injury, and hemorrhage, secondary damage can also arise from cellular damage or systemic processes such as hypoxia (Kochanek et al., 2008). Incidence rates for TBI are highest in young and older adults and are much more common among men than women (Corrigan et al., 2010).

There are considerable differences across severity groups regarding outcome, particularly between mild and moderate to severe TBI. The cognitive consequences of mild TBIs typically resolve within the first few months after injury, while the cognitive consequences of moderate to severe TBIs are more prolonged (Schretlen & Shapiro, 2003). A common classification system to determine TBI severity uses duration of unconsciousness, Glasgow Coma Scale, and/or

duration of posttraumatic amnesia (Ponsford, Draper, & Schonberger, 2008; Teasdale & Jennett, 1974). In addition, mild TBIs that have positive neuroimaging findings (i.e., evidence of a traumatic bleed) are referred to as mild complicated TBIs and have outcomes similar to moderate TBIs (Carroll et al., 2004; Kashluba, Hanks, Casey, & Millis, 2008).

Evidence of emotional problems following TBI comes from a wealth of research demonstrating that affective disorders, including depression and anxiety, are commonly diagnosed following TBI. Psychiatric problems are associated with functional disability, poorer recovery, and lower quality of life (Fann et al., 2004; Rapoport, McCauley, Levin, Song, & Feinstein, 2002; Williamson et al., 2013). Gould et al. (2011) found that 60.8% of individuals with TBI were diagnosed with at least one psychiatric disorder in the first year after injury. The most commonly diagnosed disorders were anxiety (44.1%) and depressive disorders (31.4%), with a 72% comorbidity rate. The rates of affective disorders vary significantly across studies. For instance, a meta-analysis reported rates of depression after TBI between 9% and 67% depending on the study (Osborn, Mathias, & Fairweather-Schmidt, 2014). At a rehabilitation center, Bombardier et al. (2010), found that of a sample of persons with complicated mild to severe TBI, 53% met criteria for depression at least once during the first year following TBI, but they found that point prevalence rates ranged from 21% to 31%. In another longitudinal study of depression following TBI, Hart et al. (2012) found that 26% of mild complicated to severe TBI participants met the clinical cut-off for major depressive disorder in the first year. They also found that 21% of individuals' depressive symptoms improved and 20% of individuals' depressive symptoms worsened from their first to second year after injury. In a large-scale TBI study, Fann et al., (2004) found that the incidence of depression in the first-year post-injury was 49% in moderate to severe TBI as compared to 34% in mild TBI and 18% in a control group. In

contrast, recent epidemiological data estimate that lifetime prevalence rates of depression in the community are about 18% while the 12-month prevalence rates are around 7% (Kessler et al., 2012).

Prevalence of mood disorders following TBI varies significantly across studies in part because of the significant overlap between psychiatric symptoms and sequelae of TBI. Several researchers have argued that a lack of depression symptom specificity leads to an attribution problem (Barker-Collo et al., 2015; Kim et al., 2007; Osborn et al., 2014; Seel et al., 2003). For instance, symptoms of depression such as lack of energy, fatigue, sleep disturbance, difficulty concentrating, and apathy are common in individuals with TBI with or without a mood disturbance (Andersson, Krogstad, & Finset, 1999; Kim et al., 2007). Depressive symptoms commonly endorsed in a TBI sample such as feeling slowed down, may be caused by many factors including medications, recovery from injuries, or functional weakness (Barker-Collo et al., 2015). In addition, neurological consequences of TBI (e.g., flat affect, poor initiation) may be misinterpreted as mood symptoms.

Current standards of clinical assessment of emotional functioning rely on self-report measures, which can be problematic in a TBI population. There is speculation that some persons with TBI cannot accurately recognize, reflect and communicate their emotional and behavioral experiences because of cognitive deficits (Kreutzer, Seel, & Gourley, 2001; McKinlay & Brooks, 1984). Supporting evidence comes from research that shows self and family reports of mood and behavior are often in disagreement (Hart, Seignourel, & Sherer, 2009). In addition, TBI has been associated with alexithymia, which is characterized by difficulties in identifying and describing emotions as well as reduced introspection (Henry, Phillips, Crawford, Ietswaart, & Summers, 2006a). While capturing subjective experiences is an essential component of any assessment, and

a vast body of research has confirmed its utility, a growing body of research is demonstrating the usefulness of objective measurement of affective processes.

"Affective processes" refers to the brain's ability to identify, learn, interpret, and communicate internal and external information that is affectively valenced. These processes are thought to underlie many of the deficits related to emotional and social functioning (McDonald, 2017). The term affective processes is also known as cognitive-affective processes.

Measuring affective processes following TBI has gained increasing attention in recent years (McDonald, 2013; McDonald, 2017). The majority of this research has demonstrated that TBI leads to deficits in emotion perception (Dethier, Blairy, Rosenberg, & McDonald, 2012; Zupan, Babbage, Neumann, & Willer 2014; Spikman, Timmerman, Milders, Veenstra, & van der Naalt, 2012; de Sousa, McDonald, Rushby, Dimoska, & James, 2010a). It is suspected that these deficits underlie problems in social and emotional functioning after TBI such as difficulty managing relationships (Knox & Douglas, 2009).

The most widely studied affective process following TBI is emotion recognition. Emotion recognition refers to the accurate recognition of nonverbal cues (e.g., facial or vocal expressions) portrayed by others and is thus an important element in effective interpersonal interactions and relationships (Marsh, Kozak, & Ambady, 2007; Zhang & Parmley, 2015). One meta-analysis demonstrated that those with TBI perform 1.1 standard deviations below controls (Babbage et al., 2011). These deficits in emotion recognition also extend to video and audio clips (McDonald, Flanagan, Rollings, and Kinch, 2003; Rosenberg, Dethier, Kessels, Westbrook, & McDonald, 2015). That said, studies have found that the recognition of emotional facial expressions appears to be significantly more impaired after TBI than recognition of emotional vocal expressions (Drapeau, Gosselin, Peretz, & McKerral, 2017; Ietswaart, Milders, Crawford,

Currie, & Scott, 2008; Zupan et al., 2014). Furthermore, research has demonstrated that there is a dose-response relationship between affect recognition deficits and TBI severity (Drapeau et al., 2017; Spikman et al., 2012) and that these deficits are stable over time (Ietswaart et al., 2008).

This research has pointed to an important finding; TBI results in brain changes that cause deficits in perceiving emotions. Research has largely investigated the impact of TBI on discrete emotion perception accuracy (e.g., fear, sadness, anger), and demonstrates a general deficit in accurate emotion recognition (Rosenberg et al., 2019). However, there have been no consistent findings regarding which specific basic emotions are impacted (Milders et al., 2008; Spikman et al., 2013; Rosenberg et al., 2019). For instance, one study found an effect of TBI on recognition of anger, fear and sadness (Spikman et al., 2013) while another found only deficits recognizing disgust (Rosenberg et al., 2019). The underlying theory of these studies is that of discrete basic emotions (Eckman, 1972), which proposes a limited set of basic emotions such as happiness, anger, and fear that are characterized by unique physiological and neural profiles (Vytal & Hamann, 2010). Although this theory was essential for propelling emotion research forward, many studies in affective neuroscience have moved away from discrete emotion research (Lindquist, Barrett, Bliss-Moreau, & Russel, 2006; Lindquist, Satpute, Wager, Weber, & Barrett, 2016). Instead, they emphasize dimensional theories of emotion that conceptualize emotions using a framework in which affective states can be represented in terms of underlying factors such as emotional arousal and emotional valence (degree of pleasantness or unpleasantness).

Researchers generally agree that valence is a basic psychological process and a fundamental, universal property of the human experience (Posner, Russel, & Peterson, 2005). Valence contributes to the experience of positive and negative feelings as well as processing

emotionally laden information. Although valence is widely recognized as a fundamental element of emotional processes, debate continues about how to best conceptualize the nature of valence.

There exist two prevailing theories of valence that hypothesize about positive and negative affect. First, the bipolar theory of valence states that positivity and negativity constitute opposite ends of a single dimension (Wundt & Judd, 1897). Second, the bivalence theory of valence hypothesizes that positive and negative affect are represented by distinct physical systems and are measured on two dimensions, positivity to neutral and negativity to neutral (Watson & Tellegen, 1985). Behavioral and neuroimaging studies have yet to show unequivocal evidence for one theory over the other (Lindquist et al., 2016). That said, there is evidence that certain brain structures are more likely to be involved in processing emotional information (e.g., dorsal anterior insula, dorsal anterior cingulate cortex) with some having a preference for negatively valenced information (e.g., left amygdala, left anterior insula; Lindquist et al., 2016). Given that these structures are also vulnerable to injury by TBI (Ariza et al., 2004), it is reasonable to suspect that regions involved in processing valenced information are disrupted in individuals with TBI. This study aims to build on existing research by measuring changes to valence systems following TBI instead of processes involved in recognizing discrete emotions.

Rationale.

Evidence from self-report rating studies have demonstrated that positive and negative affect underly emotional and social adjustment after TBI. (Meachen, Hanks, Millis, & Rapport, 2008; Williams, Rapport, Millis, & Hanks, 2014; Juengst, Arenth, Whyte, & Skidmore, 2014; Juengst et al., 2015). In this context, positive and negative affect refer to the experience of positive feelings (e.g., interest, excitement, and pride) or negative feelings (e.g., guilt, hostility,

and shame). High negative affect is correlated with greater emotional distress (Meachen et al. 2008; Williams et al., 2014), and is higher among TBI patients with depression (Juengst et al., 2014; Juengst et al., 2015). In addition, high negative affect is associated with less desirable outcomes post-TBI including worse perceived quality of community integration (Hanks, Rapport, Waldron-Perrine, & Millis, 2016; Meachen et al., 2008; Williams et al., 2014). On the other hand, higher positive affect is associated with greater resilience, greater social participation, increased life satisfaction, and greater perceived quality of community integration (Hanks et al., 2016; Juengst et al., 2014; Williams et al., 2014).

Studies on emotion perception after TBI also point to a valence effect. On emotion recognition tasks, individuals with TBI are less accurate at identifying negatively valenced stimuli as compared to positively valenced stimuli (Drapeau et al., 2017; Genova et al., 2017; Neumann & Zupan, 2019; Spikman et al., 2013; Zupan et al., 2014). For instance, TBI participants were worse at recognizing sad and fearful video clips but not happy video clips (Neumann & Zupan, 2019) and they were worse at recognizing anger, fearful, and sad facial expressions but not surprise or happy facial expressions (Genova et al., 2017). While the specific emotions impacted (e.g. fear, sadness, anger) vary across studies, the finding that TBI selectively impedes recognition of negatively valenced faces is robust (Rosenberg, McDonald, Dethier, Kessels, & Westbrook, 2014).

When discussing the evidence of changes to affective processes after TBI, the role of mood disorders (e.g. depression and anxiety) must be considered. Depression and anxiety are commonly diagnosed following TBI (Bombardier, Hoekstra, Dikmen, & Fann, 2016; Hart et al., 2014), and depression and anxiety can alter perception and interpretation of emotional stimuli (Dalili, Penton-Voak, Harmer, & Munafo, 2015).

In non-brain injured populations numerous studies have shown that depression and anxiety lead to deficits in emotion recognition (Demenescu, Kortekaas, den Boer & Aleman, 2010; Hattingh et al., 2013; Langenecker et al., 2005; Surcinelli, Codispoti, Montebarocci, & Baldaro, 2006). One meta-analysis found that emotion recognition was impaired in individuals with major depression across all emotions except sadness (Dalili et al., 2015). Another meta-analysis found that adults with anxiety disorders also have deficits in emotion recognition, and that these deficits are more pronounced among those with comorbid major depression as compared to anxiety alone (Demenescu et al., 2010). Depression is particularly associated with poor recognition of neutral expressions as depressed individuals often misattribute negative valence to these expressions (Leppanen, Milders, Bell, Terriere, & Hietanen, 2004).

The influence of mood on affective processing after TBI is poorly understood. While some studies have found that mood symptoms are not associated with emotion perception following TBI (Ietswaart et al., 2008; Milders et al., 2008) others have statistically controlled for mood to reduce its influence on results (Rosenberg et al., 2019) or omitted mood measures in their procedures (Henry et al., 2006a). Even so, deficits in emotion processes after TBI, like emotion recognition, are likely to represent a complex mixture of impairments arising from structural lesions underpinning emotion processes, mood disorders, and cognitive deficits (McDonald, 2013). Given the high rates of depression and anxiety after TBI (Bombardier et al., 2010; Bombardier et al., 2016; Hart et al., 2012), it is reasonable to suspect that mood symptoms may account for and/or exacerbate facial affect recognition deficits in TBI.

The current study.

This study is the first to examine if TBI has an impact on a variety of cognitive-affective processes involving the negative and positive valence systems. It uses a combination of subjective rating scales and performance-based measures of affective processes to study how TBI influences emotional functioning, in an exploratory fashion. It also explored the relationship between rating scales and performance-based measures. To sample a breadth of performance-based affective processing, in addition to administering some previously established measures, a novel task was developed and is presented in Chapter 1. This affective facial recognition task was developed to mirror standard measures of emotion recognition but with some important differences including use of ambiguous stimuli and a measure of valence biases. Chapter 2 describes exploratory research aimed at investigating affective processes in a sample of individuals with mild complicated, moderate, and severe TBI and a demographically similar control group. Together these studies aim to (1) examine how individuals with TBI perform on measures of affective processes (i.e., affect recognition, verbal fluency, and emotion word learning and memory) compared to demographically similar controls and (2) examine the relationships between self-rated measures of mood and performance-based measures of affect.

CHAPTER 1

DEVELOPMENT OF THE AMBIGUOUS FACES TEST

Rationale, Objectives, & Hypotheses

The purpose of this study was to develop a novel test of facial affect recognition to be used in the second study. It is designed to mirror the characteristics of measures of affective processing used in the second study (see Chapter 2). Namely, it produces scores regarding accuracy and valence biases. It is also designed to address some of the limitations of existing emotion recognition tasks. For instance, studies measuring facial emotion recognition in TBI typically ask participants to identify which of several basic emotion words match the emotion expressed on a static image of a face (Allerdings & Alfano, 2006; Bland et al., 2016; Henry et al., 2006a; Ietswaart et al., 2008; Knox et al., 2009; Milders et al., 2003; Rosenberg et al., 2014). These images typically consist of actors displaying expressions of the six basic emotions, including fear, anger, sadness, disgust, happiness, and surprise which are predominantly selected from the Pictures of Facial Affect (Ekman & Friesen, 1976).

These stimulus sets are used to draw inferences about whether people with TBI display an overall impairment in emotion recognition (Bland et al., 2016; Henry et al., 2006a; Ietswaart et al., 2008; Milders et al., 2003; Rosenberg et al., 2014). They are also used to show selective impairments for specific emotions compared to others as well as differential impairment in negative versus positive emotions (Rosenberg, 2014). To examine a valence effect, researchers typically compare accuracy at recognizing happiness and surprise, both conventionally categorized as positively valenced faces (e.g., Babbage et al., 2011) to four negatively valenced faces (sad, angry, disgust, and fear). This design has been subject to several critiques. For one,

the Ekman and Friesen dataset includes only a small number of faces and has several limitations, including restriction in ethnicity and age. There is also an imbalance with regard to the number of positively and negatively valenced emotions available. The mean valence scores produced by these measures result in differential reliability and sensitivity (Croker & McDonald, 2005). In addition, there is evidence for differences in difficulty across emotions that can lead to different floor and ceiling effects across positively and negatively valenced stimuli (Rosenberg et al., 2014). For instance, while surprise is typically categorized as a positively valenced emotion in studies, its true valence has been debated in the literature with some arguing that it has no clear valence connotation (Kreibig, 2010). On the other hand, fear is often reported to be the most difficult negatively valenced facial expression to recognize and is typically confused with surprise (Rapcsak et al., 2000; Tottenham et al., 2009).

The widely recognized limitations of these emotion recognition tasks that are used with TBI participants have resulted in development of variations of this standard measure. Several have used dynamic images of faces that may have more ecological validity than static images (Drapeau, 2017; McDonald et al., 2003; Rosenberg et al., 2014; Rosenberg et al., 2019). One study allowed for free form descriptions of facial expressions instead of providing a forced-choice paradigm (Turkstra et al., 2017). Another compared the use of a visual analogue scale of valence and arousal to emotion words (Drapeau et al., 2017). Interestingly, Drapeau et al. (2017) found that there were no significant group differences when participants responded to facial expressions with an analog scale, but there was a difference in accuracy when responding with emotion words. This finding, along with a body of literature on emotion processing (Gendron, Lindquist, Barsalou, & Barrett, 2012), points to the importance of including emotion words in

facial affect recognition tasks. Emotion words likely contribute to the construction and interpretation of facial affect (Lindquist et al., 2006).

The current study aims to add to the growing body of literature on facial affect recognition in TBI by presenting the development of a novel measure. This measure varies from standard facial affect recognition tasks in two important ways. First, the task moves away from use of discrete categories of emotion (e.g., sad, happy, neutral) and instead categorizes stimuli (e.g. faces and words) along the dimension of valence including intensity of positive and negative affect. As previously discussed, positive and negative valence are proposed to underly most emotional processes (Posner, 2005; Russel, 1980) and this framework is widely used in affective neuroscience research (Lindquist et al., 2016). For this task, emotion words are randomly selected based on their affective valence and they are not exact matches to the facial expressions provided. As such, the participant is forced to match the word and facial expression based on the valences of the words and faces. The participant is unaware that there is no correct answer and chooses the word based on their interpretation of the perceived valence of the facial expression. By using this design, the measure generates a continuous valence score that can then be compared across groups and analyzed in a continuous manner with self-reported symptom scores.

The second important difference is inclusion of ambiguously valenced facial expressions in the stimulus set. The literature indicates that individuals with major depression tend to misclassify neutral and ambiguously valenced facial expressions, often with a negative bias (Bourke, Douglas, & Porter, 2010). Interpretation biases of neutral or ambiguous facial expressions has yet to be examined in those with TBI.

The current study aimed to examine how non-clinical participants perform on the AFT and to explore the relationships between self-reported psychological symptoms, affect, and social participation and performance on the AFT. We hypothesized that (1) participants would match the valence of faces to the valence of words, (2) percent agreement (i.e., agreement of word-face match) would be lowest among the ambiguously valenced faces, and (3) that self-report measures (e.g., depression, anxiety, negative affect, resilience) would be reflected by mood congruent interpretation biases (e.g. more depressed symptoms would be associated with a negative interpretation bias). Below is an examination of how a non-clinical sample of participants responded to this novel measure of facial affect recognition. Results from administration with a TBI sample are presented in a subsequent chapter.

Methods

Participants.

Participants consisted of 78 undergraduate students who were recruited through the psychology participant pool. The majority of participants were female (n=65, 83.3%) and all were between the ages of 17 and 30 (*M*=21.24, *SD*=3.15). Participants identified as White/Caucasian (n= 37, 47.4%), Black/African American (n= 9, 11.5%), Hispanic/Latinx (n=2, 2.6%, mixed race/ethnicity (n= 4, 5.1%), or Asian (n=26, 33.3%). Regarding mental health history, 30% reported being diagnosed or treated for a mental health disorder. These were all described as depression, anxiety, and sleep difficulties. No participant endorsed a history of a psychotic disorder. Half of these participants were randomly selected to complete the AFT twice to evaluate test-retest reliability and 32 attended their follow-up sessions. There were no

significant differences in age or gender between those included in the second part of the study and those who only completed one day of the testing.

Measures.

Participants completed a questionnaire that included questions about demographics and mental health history (see Appendix A). They also completed the AFT and self-report questionnaires regarding mood.

The AFT is a novel measure that intends to capture appraisal biases in the interpretation of emotionally valenced faces. The participant is presented with a facial expression displayed on a screen and is forced to choose one of five words that best describes the facial expression.

The objective of the measure is twofold. It first acts as a measure of emotion recognition as previous research has demonstrated that emotion recognition is often disrupted after traumatic brain injury (Babbage et al., 2011). In addition, the measure generates a valence factor that provides information regarding an interpretation bias towards negatively or positively valenced emotions. Previous research has demonstrated that depressed individuals tend to interpret facial expressions with a greater negative valence as compared to normal controls (for a review see Bourke et al., 2010).

The stimuli consist of facial expressions taken from the NimStim stimulus set, which is a set of 43 male and female actors of various ethnicities, each making eight different expressions (angry, sad, fear, disgust, happy, surprise, neutral, and calm). The total number of pictures in the stimulus set is 672. The faces have shown to have good validity based on level of between-subject agreement between the intended expression and participants' ratings, with Cohen's kappa values ranging from .60 to .94 for each of the eight expressions (Tottenham et al., 2009).

For the AFT, 40 faces were selected from the NimStim facial expression database. For the purposes of this study, faces were selected and categorized into three hypothesized categories: Negatively valenced emotional expressions, ambiguous emotional expressions, and positively valenced facial expressions. The study stimuli consisted of 10 positively valenced faces, 10 negatively valenced faces, and 20 ambiguous faces. Among the 10 positively valenced faces selected, all were depicting the emotion 'happy' as labeled by the NimStim dataset. Among the 10 negatively valenced faces 3 depicted 'anger', 2 'disgust', 3 'fear', and 2 'sadness' as determined by the NimStim dataset. Among the ambiguous faces, 7 were depicting 'neutral', 10 were 'calm', and 3 depicted 'surprise' as determined by the NimStim dataset. Surprise was considered an ambiguous facial expression because surprise was often confused for fear and demonstrated to have poor reliability in the validation study of the NimStim dataset (Tottenham et al., 2009). The images were selected based on the emotion being expressed as well as the gender and race of the actor in order to ensure diversity in the demographics of the actors. As such, 22 (55%) of the images presented were of women. With regard to race, 22 (55%) were of White/Caucasian race, 13 were of Black/African-American race, 4 were of Asian descent, and one was Latinx/Hispanic race. Due to lack of availability in the database, individuals of Latinx/Hispanic descent were underrepresented in the stimuli.

For each face, five emotion words are provided to select from. Two of the words are positively valenced (one high intensity and one low) and two of the words are negatively valenced (one high intensity and one low). In addition, the word 'neutral' is always presented as an option. The words were selected from a dataset of words created by Warriner, Kuperman, and Brysbaert (2013) that provides valence values based on a large normative sample. These norms were established by taking the mean of participant ratings for valence on scales ranging from 1

(unhappy) to 9 (happy) such that scores below 5 (neutral) are indication of negative affect, and scores greater than 5 are indicative of positive affect. The words for the AFT were selected such that there was a high negative valence word (valence score between 1 and 2), a low negative valence word (valence score between 3 and 4), a low positive valence word (valence score between 6 and 7), and a high positive valence word (valence score between 8 and 9). The emotion word with which the faces were created (e.g., happy, surprise, sad, or fear) were not be included in the emotion word options to increase task difficulty and require interpretation of valences. Words from each category were randomly assigned to each facial expression (see Figure 1). For the purposes of this study, each word was assigned a value based on its valence category (see Table 1.01).

Figure 1. Example stimuli from the Ambiguous Faces Test.

Table 1.01

Assigned Values for Word Options on the AFT

Word Valence	Example Word	Value

HIGH Positive valence	Confident	2
LOW Positive valence	Intrigued	1
Neutral	Neutral	0
LOW Negative valence	Resentful	-1
HIGH Negative valence	Hateful	-2

In addition to the AFT, self-report measures of social and emotional functioning were selected to examine the relationship between affective biases and self-reported affective functioning:

Positive and Negative Affect Schedule (PANAS; Watson, Clark, & Tellegen, 1988). The PANAS is a 20-item self-report measure that generates two subscales of positive and negative affect. Each item consists of a word that describes a feeling, which is then rated for relevance to the participant on a scale of 1 ("very slightly or not at all") to 5 ("extremely"). Participants were asked to reflect on their experiences over the last week. Total scores for the positive and negative affect subscales can range from 10 to 50, with higher scores reflecting a higher level of positive or negative affect, respectively. The scale generates separate Positive Affect (PA) and Negative Affect (NA) scores.

Brief Symptom Inventory-18 (BSI; Derogatis, 2001). The BSI is a measure of emotional distress that generates three subscales: Somatization, Depression, and Anxiety. The total raw score ranges from 0 to 24 on each domain with higher scores indicating greater distress. A global distress total score is also generated. The BSI has been validated for use with TBI populations (Meachen et al., 2008).

Connor-Davidson Resilience Scale (CD-RISC; Connor & Davidson, 2003). The CD-RISC consists of 25 items assessed using a 5-point Guttmann-type scale ranging from 0 (not true at all) to 4 (true nearly all of the time). Total scores range from 0 to 100, with higher scores indicating greater resilience. Research has demonstrated that the scale has good psychometric properties in a traumatic brain injury population (Hanks et al., 2016).

Neuro-QOL. The National Institutes of Neurological Disorders developed this patient-reported outcome measurement system that consists of separate item banks covering several domains important for outcome (Perez et al., 2007; Miller, Nowinski, Victorson, Peterman, & Perez, 2005). For this study, the item banks 'satisfaction with social roles and activities' and 'ability to participate in social roles and activities' short-forms were administered.

Procedure.

The tests and questionnaires in this study were all administered on individual computers, by a trained research assistant. The study was approved by the University of Windsor Research Ethics Board and participants underwent the informed consent processes with the research assistant who was available to answer questions. Seventy-eight participants completed just one study session and 32 returned for a one-week follow-up to complete a second version of the task where the words and faces were presented in a different randomly assigned order.

A computer interface was created in Java to present the digitized test stimuli to the participants on a computer screen. The 40 test stimuli were presented in two different fixed random orders. The two different sequences were created in order to reduce potential order effects on the level of group analysis. The two versions were also used for the test-retest reliability assessment. Responses and reaction time were recorded by a computer interface,

which also presented the 5 affective word options in the form of buttons to click on the screen. Each participant was required to give an answer to proceed to the next stimulus. There was no time restriction on the test stimuli and the computer would move on to the next stimulus as soon as a word was selected. This allowed for participants to elaborate on the faces for as long as they wanted. Instructions to participants were also presented on the screen; the participants read, "Please look at the faces on the screen and select the word that you think best describes the emotion expressed on the face." The self-report questionnaires were administered on the computer upon completion of the AFT at each visit.

Data Analyses.

Valence Factors (VF*)* were calculated for each participant by averaging the valences of each word that was selected for the 40 trials (range -2 to 2). In addition, valence factors were calculated for each group of facial expressions (i.e., Negative, Ambiguous, Positive). Reactions times, or response times, were also averaged. A percent agreement value was calculated for each item presented to determine how consistent participants were when selecting a word choice in response to a facial expression. Scores are presented in percentages, such that a score of 60% indicates that 60% of participants chose the same word response. Finally, an accuracy score was generated indicating the number of faces correctly identified as negatively valenced or positively valenced.

Descriptives for each item included in the measure are provided in Table 1.2 including the average valence and percent agreement. Items were grouped into three categories: positively valenced faces (n=10 faces), negatively valenced faces (n=10 faces), or ambiguously valenced faces (n=20 faces). One-way ANOVAs were used to compare the three categories of items with

regard to average valence of responses, percent agreement of responses, and time to respond. Independent t-tests were used to compare accuracy for positive versus negatively valenced faces. The relationship between self-reported mood symptoms and performance on the AFT was examined using Spearman's rho correlations. Finally, test-retest reliability was measured by calculating Pearson's correlations among the two time points as well as intraclass correlations. There was less than 5% missing data and cases with missing data were excluded pairwise in the analyses.

Results

All items are presented in Table 1.02 indicating the assigned valence category (i.e., Ambiguous, Positive Valence, Negative Valence), the average valence response for that item, and how consistent responses were for each item.

One-way ANOVA was conducted to determine if the average valence (i.e., valence factor score) was different for items from different categories. As previously discussed, all items were classified into three categories: positive (n = 10), negative (n = 10), and ambiguous (n = 20). There were no outliers, as assessed by boxplot; data were normally distributed for each category, as assessed by Shapiro-Wilk test ($p > .05$); and there was homogeneity of variances, as assessed by Levene's test of homogeneity of variances. The average valence for item categories was lowest for the negatively valenced faces (M = -1.22, SD = .71), followed by the ambiguously valenced faces (M = -.14, SD =.62), and highest among the positively valenced faces (M = 1.68, SD =.20). The differences in average valences between these item categories was statistically significant, $F(2, 39) = 70.54$, $p < .01$. Post-hoc analyses demonstrated that all conditions were significantly different from each other.

Another one-way ANOVA was conducted to determine if the percent agreement (i.e., percentage of participants that responded the same way on an item) was different for items from different valence categories. There were no outliers, as assessed by boxplot; data were normally distributed for each category, as assessed by Shapiro-Wilk test ($p > .05$); and there was homogeneity of variances, as assessed by Levene's test of homogeneity of variances. The average percent agreement was lowest among the ambiguous items (M =.58 ± .16), followed by negative items (M =.67, SD = .22) and positive items (M =.74, SD = .15). However, the differences in average percent agreement between these three categories were not statistically significant, $F(2, 39) = 2.84$, $p = .07$. Post-hoc analyses demonstrated that percent agreement among the ambiguous category was significantly lower than among the positive category ($t(37)=2.32$, $p <.05$).

Response time was also examined for each item category using a one-way ANOVA. There was one outlier identified by assessment of boxplots that was removed from analyses; data were normally distributed for each category, as assessed by Shapiro-Wilk test ($p > .05$); and there was homogeneity of variances, as assessed by Levene's test of homogeneity of variances. The mean time to respond (seconds) was highest among the ambiguous items (M = 6.00, SD = 1.37), followed by negative items (M = 4.98, SD = 1.21) and positive items (M = 4.70, SD = .89). The differences in average time to respond between these three categories was statistically significant, $F(2, 39) = 5.09$, $p = .01$, and post-hoc analyses demonstrated that time to respond to ambiguous items was significantly greater than negative items ($t(37)=2.25$, $p <.05$) and positive items ($t(37)=2.88$, $p<.05$). There was no significant difference in time to respond between the positive and negative items.

As an additional measurement of task difficulty, the standard deviation of response times within a face category was calculated to compare intraindividual variability in response time. Results demonstrated that ambiguous faces generated the most variability in response times (M = 5.61, SD = 3.10) as compared to positively valenced faces (M = 2.97, SD = 1.08) and negatively valenced faces (M = 2.48, SD = 1.51), $F(2, 231) = 40.91$, $p < .01$.

Finally, accuracy scores were examined. On average, participants matched 18 of the 20 positively and negatively valenced faces with positive and negative words, respectively (M = 18.00, SD = 1.51). Accuracy was significantly lower for the negatively valenced faces (M = 8.55, SD = 1.27) as compared to the positively valenced faces (M = 9.49, SD = .71; $t(154)=5.42$, $p<.01$).

Table 1.02

Item Specifications for the AFT

Item #	NimStim Emotion	Assigned Item Category	Average Valence	Percent Agreement
1	Surprise	Ambiguous	.89	62%
2	Neutral	Ambiguous	-.07	74%
3	Happy	Positive	1.34	75%
4	Angry	Negative	-1.04	48%
5	Calm	Ambiguous	-.11	40%
6	Disgusted	Negative	-1.94	98%
7	Neutral	Ambiguous	-.53	54%
8	Neutral	Ambiguous	-.23	80%
9	Happy	Positive	1.57	60%
10	Neutral	Ambiguous	-.2	77%
11	Calm	Ambiguous	-.70	38%
12	Happy	Positive	1.57	60%
13	Neutral	Ambiguous	-.46	57%
14	Calm	Ambiguous	-.11	68%
15	Happy	Positive	1.81	77%
16	Happy	Positive	1.43	53%
17	Calm	Ambiguous	-1.11	47%
18	sad	Negative	-1.81	96%
19	fear	Negative	-1.71	87%
20	calm	Ambiguous	-.38	44%
21	sad	Negative	-.76	59%
22	happy	Positive	1.59	80%
23	surprise	Ambiguous	-.31	30%
24	surprise	Ambiguous	.90	49%
25	happy	Positive	1.38	57%
26	calm	Ambiguous	.66	43%
27	disgusted	Negative	-1.27	64%
28	calm	Ambiguous	0.43	47%
29	neutral	Ambiguous	-0.32	39%
30	angry	Negative	-1.73	70%
31	neutral	Ambiguous	-0.35	70%
32	happy	Positive	1.89	93%
33	neutral	Ambiguous	-0.32	77%
34	calm	Ambiguous	-0.54	55%
35	happy	Positive	1.95	98%
36	fear	Negative	-.90	47%
37	sad	Negative	-1.23	59%
38	neutral	Ambiguous	-.67	54%
39	fear	Negative	.21	57%
40	happy	Positive	1.83	86%

The influence of age and gender on AFT index scores was examined using Pearson's correlation and independent sample t-tests, respectively. There were no significant differences in

performances between men and women on the AFT valence factor or time to respond. There was no significant correlation between age and AFT valence or time.

The influence of age and gender on self-report measure scores was examined using Pearson's correlations and independent sample t-tests, respectively. Age was not significantly correlated with any self-report scores. Some scores did vary by gender (see Table 1.03). The influence of race/ethnicity was also examined using the person of color as a dichotomous variable; findings indicated that there were no differences with regard to overall time to respond or valence of responses between those who identified as White/Caucasians (55%) and those who identified as not White/Caucasian (45%; $p>.05$).

Table 1.03

Gender Differences on Symptom Reporting

Self-report Questionnaires	Female *M* (*SD*)	Male *M* (*SD*)	*t*	*df*	*p*	95% Confidence Interval	
						Lower	Upper
BSI GSI	15.83 (13.94)	7.08 (4.63)	-4.01	58.11	**<.01**	-13.11	-4.38
BSI Depression	5.91 (5.72)	4.00 (3.53)	-1.57	63.35	**<.01**	-4.40	0.58
BSI Anxiety	5.66 (5.02)	2.15 (1.82)	-4.35	27.69	.10	-5.12	-1.89
BSI Somatic	4.02 (4.72)	0.92 (1.45)	-4.47	52.76	**<.01**	-4.64	-1.77
PANAS NA	23.24 (7.15)	20.15 (7.01)	-1.42	76	.16	-7.42	1.24
PANAS PA	25.67 (7.41)	31.08 (7.47)	2.37	76	**.02**	0.86	9.95
CDRISC	64.46 (15.78)	66.75 (17.83)	.45	76	.65	-7.86	12.43
NeuroQOL Ability	24.17 (5.59)	24.46 (5.78)	.17	76	.87	-3.14	3.72
NeuroQOL Satisfaction	23.96 (5.38)	25.77 (6.88)	1.05	76	.30	-1.63	5.26

Note. GSI = Global Severity Index

Correlations between measures were also examined (Table 1.04). Non-parametric correlations were used to account for the non-normal distribution of the measures. No outliers were identified or removed after reviewing box plots. Notably, positive affect was not significantly correlated with any BSI measures but it was positively correlated with CD-RISC and the NeuroQOL measures. BSI scores were significantly positively correlated with the PANAS NA scale. According to these correlations, the measures cluster into two groups, the measures of negative valence (BSI subscales and PANAS NA) and the measures of positive valence (PANAS PA, CD-RISC, NeuroQOL scales).

Table 1.04

Inter-correlations Between Self-Report Measures

Self-report Questionnaires	BSI GSI	BSI Dep.	BSI Anxiety	BSI Somatic	PANAS NA	PANAS PA	CD-RISC	NeuroQOL Ability	NeuroQOL Satisfaction
BSI GSI	1.00	**.85****	**.86****	**.74****	**.72****	-.03	**-.41****	-.04	-.09
BSI Dep.		1.00	**.58****	**.44****	**.58****	-.14	**-.55****	-.06	-.04
BSI Anxiety			1.00	**.60****	**.74****	.08	**-.25***	.02	-.01
BSI Somatic				1.00	**.52****	.14	-.19	.02	-.14
PANAS NA					1.00	.11	**-.27***	-.22	-.19
PANAS PA						1.00	**.39****	**.32****	**.37****
CDRISC							1.00	.19	**.25***
NeuroQOL Ability								1.00	**.60****
NeuroQOL Satisfaction									1.00

*p<.05, **p<.01; *Note*. GSI = Global Severity Index

Normality of the self-report measures was evaluated using Shapiro-Wilk and by examining normality plots, which demonstrated that the symptom scores were not normally

distributed. For instance, the BSI data were highly positively skewed. As such, Spearman's rho correlates were calculated between the AFT scores and the mood symptom scores. Outliers were examined using scatter plots, and one outlier was removed for the analyses involving time to respond.

Table 1.05 presents the correlations between self-report measures and valence factors from the AFT including the overall valence factor and the valence factors or the negative, positive, and ambiguously categorized items, separately. The results demonstrated that a negative bias on the AFT Valence Factor was associated with greater BSI somatic symptoms. This was primarily driven by a negative bias when interpreting ambiguously valenced faces. A negative bias on the AFT Valence Factor was also associated with higher NeuroQOL ability scores, again primarily driven by the interpretation of ambiguously valenced faces.

Table 1.05

Correlations Between AFT Valence Factors and Mood Symptoms

AFT Scores	BSI GSI	BSI Depression	BSI Anxiety	BSI Somatic	PANAS NA	PANAS PA	CDRISC	NeuroQOL Ability	NeuroQOL Satisfaction
Overall VF	-.06	-.01	-.11	**-.24***	-.02	-.13	-.07	**-.27***	-.17
Negative VF	.07	.15	-.01	-.05	.05	-.07	-.21	-.04	.02
Ambiguous VF	-.11	-.06	-.12	**-.27***	-.08	-.22	-.01	**-.32****	-.20
Positive VF	-.04	-.14	.01	.04	.04	.20	.12	.01	-.12

* $p<.05$, ** $p<.01$, *Note*. Spearman's rho coefficients are presented; VF = Valence Factor; GSI = Global Severity Index.

Table 1.06 presents the correlations between self-report measures and time to respond on the AFT. The results demonstrated that higher scores on the BSI depression subscale were associated with an overall faster response time, primarily driven by faster response times to

negatively valenced and ambiguously valenced items. Faster response times for negatively valenced faces were also associated with higher scores on the BSI GSI and the BSI Anxiety subscales. Conversely, higher scores on the CD-RISC were associated with slower response times to the negatively and ambiguously valenced faces.

Table 1.06

Correlations Between AFT Response Times and Mood Symptoms

AFT Scores	BSI GSI	BSI Dep.	BSI Anxiety	BSI Somatic	PANAS NA	PANAS PA	CDRISC	NeuroQOL Ability	NeuroQOL Satisfaction
Overall RT	-.22	**-.31****	-.16	-.07	-.15	.04	.30	.07	.07
Negative RT	**-.27***	**-.30***	**-.24***	-.18	-.18	.03	**.40****	.06	.04
Ambiguous RT	-.21	**-.32****	-.14	-.07	-.14	.07	**.31***	.09	.06
Positive RT	-.13	-.23	-.09	.00	-.12	<.01	.22	.13	.16

* $p<.05$, ** $p<.01$, *Note*. Spearman's rho coefficients are presented; RT= Reaction Time, GSI = Global Severity Index.

Given the influence of gender on the symptom scores, the same analyses were re-run while controlling for the influence of gender on the variables. Pearson's partial correlations were used to analyze these differences. The BSI scores were transformed with a log linear transformation to account for the positive skew of the data. Findings revealed that BSI Somatic scores were still negatively correlated with valence factor of ambivalent faces and faster reaction times to negative and ambivalent faces. PANAS PA was associated with more negative interpretation of ambiguous faces and positive faces. NeuroQOL scores were associated with a more negative interpretation bias overall and specifically on ambiguous faces.

Table 1.07

Correlations between AFT Scores and Mood Symptoms While Controlling for Gender

AFT scores	BSI GSI	BSI Depression	BSI Anxiety	BSI Somatic	PANAS NA	PANAS PA	CD-RISC	NeuroQOL Ability	Neuro QOL Satisfaction
Overall VF	-.09	-.01	-.05	-.18	-.04	-.19	-.03	**-.28***	-.23
Negative VF	.02	.16	.02	-.03	.02	-.14	-.18	-.06	-.02
Ambiguous VF	-.11	-.05	-.07	**-.24***	-.07	**-.31***	-.02	**-.35****	**-.28***
Positive VF	-.06	-.14	-.02	<.01	-.02	**.28***	.21	.01	-.09
Overall RT	**-.31***	**-.37***	**.24***	-.20	-.16	.10	**.31***	.14	.09
Negative RT	**-.27***	**-.34***	-.22	-.21	-.12	.06	**.33***	.06	.01
Ambiguous RT	**-.32***	**-.39****	**-.26***	-.23	-.19	.15	**.32***	.15	.09
Positive RT	-.20	**-.27***	-.14	-.08	-.09	.08	.23	.20	.14

* $p<.05$, ** $p<.01$; *Note.* VF= Valence factor; RT=Reaction time

Thirty-two participants completed the AFT on two successive occasions with 1 week between test sessions and a different order of items on both occasions. Pearson's correlations of scores between the first and the second test were calculated; the measures were normally distributed as determined using Shapiro Wilk's ($p>.05$) and outliers were checked by reviewing box plots. Correlations coefficients were calculated for the AFT measures and are presented in Table 1.08. Intraclass correlation (ICCs) estimates and their 95% confident intervals were calculated based on a mean-rating, absolute-agreement, and 2-way mixed-effects model (see Table 1.08). Results indicate that response times at time 1 and 2 are similar. There is lower test-retest reliability among the valence factors, compared to response times, with negatively valenced items having the lowest test-retest reliability.

Table 1.08

AFT Test-retest Reliability

AFT Scores	Pearson Correlations	Intraclass correlation	95% CI		F Test with True Value		
			Lower Bound	Upper Bound	*df*1	*df*2	*p*
Overall VF	**.45***	.45	.12	.69	31	31	<.01
Negative VF	.05	.04	-,24	.34	31	31	.40
Ambiguous VF	.24	.24	-.11	.54	31	31	.09
Positive VF	**.44***	.45	.10	.69	29	29	.01
AFT RT	**.85****	.64	.05	.86	31	31	<.01
Negative RT	**.75****	.60	.26	.80	31	31	<.01
Ambiguous RT	**.81****	.63	.12	.84	31	31	<.01
Positive RT	**.60****	.56	.28	.76	31	31	<.01

* $p<.05$, ** $p<.01$, *Note*: VF= Valence factor; RT=Reaction time

Discussion

In this study, we examined how a non-clinical sample of undergraduate participants responded to a novel task designed to measure interpretation biases in facial expressions. The measure presented 40 faces to participants that were divided into three groups: negatively valenced faces, positively valenced faces, and ambiguously valenced faces. Average valence scores were generated for each group of items based on how individuals responded to the task. Our first aim was to test if participants would match faces and words based on valence. Findings from the study indicated that as hypothesized, participants matched the valence of faces to the valence of words such that negatively and positively valenced faces were responded to with negatively and positively valenced words, respectively. While accuracy for identifying negative and positive faces was high, accuracy for negative faces was significantly lower than that for positive faces.

Our second aim was to measure responses to ambiguous facial expressions to generate variability in responses. Percent agreement of word-face matches were lowest among the ambiguously valenced faces and participants took a significantly longer time responding to these faces. These findings indicate that the ambiguous faces were the most difficult to interpret and produced the most variability in responses.

This task design addressed some important limitations to standard facial affect recognition tasks. For one, the paradigm included a similar number of positive and negative facial expressions with a similar number of positively valenced and negative valenced word options. This differs from typical facial affect recognition tasks that typically have a greater number of negatively than positively valenced faces and words in their stimulus set (Rosenberg et al., 2014; Kessels, Montagne, Hendriks, Perrett, & de Haan, 2014). Such imbalance can lead to floor and ceiling effects that impact statistical analyses, particularly when examining the effect of valence (Rosenberg et al., 2014). The inclusion and analysis of an ambiguously valenced group of faces is also an uncommon contribution to this body of literature. Findings indicate it produces the most variance in responses, which may mean it is the most vulnerable to interpretation biases.

In addition, the AFT included a multi-ethnic set of actors, which is different from most facial affect recognition tasks that typically use Caucasian actors (e.g., Kessels et al., 2014; McDonald et al., 2003). Literature has indicated that emotions may be more accurately judged when done so by members of the same ethnic and cultural groups (Elfenbein & Ambady, 2002; Matsumoto, 2002; Hart et al 2000). The majority of participants in this sample did not identify as White or Caucasian. As such, the inclusion of multiple ethnicities among the facial affect stimuli may have minimized the in-group advantage that would have benefited Caucasian participants if

a standard facial affect recognition task had been used. This study did not directly examine the influence of race/ethnicity on performance due small sample sizes for each racial/ethnic group. Future research studying this topic is warranted and Matsumoto (2002) outlines recommendations for studying this important topic.

Our third aim was to examine if self-rated mood was associated with affective biases. Analyses demonstrated that somatic symptoms were associated with a more negative bias when responding to ambiguous faces. This finding is consistent with previous research that demonstrated individuals with somatoform disorders exhibit general deficits in facial affect recognition accuracy (Pedrosa et al., 2009; Buhlmann, McNally, Etcoff, Tuschen-Caffier, & Wilhem, 2004). In addition, the negative interpretation bias when confronted with ambiguous information is consistent with cognitive models of somatization. These propose that people with somatization tendencies are more prone to catastrophic thinking and negative interpretation biases (Woud, Zhang, Becker, Zlomuzica, & Margraf, 2016). This finding suggests that interpretation of ambiguous facial expressions may be a sensitive measure to underlying cognitive-appraisal biases of somatization.

Other findings on the AFT and self-report symptoms were mixed. It is difficult to explain why a more negative bias in the interpretation of ambiguous faces would be associated with more positive self-reported affect and ability to participate in social roles. Notably, the literature consistently reports relationships between depression and anxiety symptoms and negative interpretation biases of ambiguous information (Bourke et al., 2010). However, studies do not typically include any measure of positive affect. The bivalence theory of affect proposes that positive and negative affective systems are independent of one another (Watson & Tellegen, 1985). Using this framework, it is reasonable to suspect that self-rated positive affect may have

an independent contribution to interpretation biases when compared to self-rated negative affect. To speculate, positive affect may lead to a contrast effect when interpreting ambiguous stimuli. In other words, if a person typically experiences high levels of positive affect they may perceive the absence of positive affect (including ambiguous or neutral stimuli) as negative.

In addition, there was no relationship between depression and anxiety and interpretation of faces as demonstrated in previous research in individuals with mood disorders (Bourke et al., 2010; Dalili et al., 2015). It should be noted that this is not a clinical a sample and thus the relationship between symptom scores and affective biases should be interpreted with caution, as no diagnostic criteria were examined. That said, it should also be noted that the ambiguous faces index was the most frequent measure to be associated with mood. This may indicate that it is particularly sensitive to mood states.

Analysis of correlations between response times on the AFT and self-reported symptoms revealed some interesting findings. Higher psychological symptoms scores were associated with faster response times, particularly to negative and ambiguously valenced faces. Higher resiliency scores were associated with slower response times, particularly to negative and ambiguously valenced faces. These findings are consistent with the theory of mood congruent processing. Mood congruent processing theory states that there is preferential processing for valenced information that matches mood (Bower, 1981). Supporting this theory, research has demonstrated that depressed individuals have an attentional bias to sad faces as compared to controls (Gotlib, Krasnoperova, Yue, & Joorman, 2004). Most studies on facial affect recognition do not report response times (Kessels et al., 2014; Surcinelli et al., 2006; Dalili et al., 2015). That said, the existing research on facial affect recognition response times has demonstrated that when compared to controls, depressed participants are typically slower to

respond to emotional expressions (Langenecker et al., 2005; Leppanen et al., 2004). Leppanen et al. (2004) found this slowed effect held true when depressed participants responded to neutral faces as well. In contrast, Langenecker et al. (2005) found that the slowed effect among depressed participants was only true when faces were emotionally valenced (sad and happy) but not for neutral faces. Notably, these studies had important differences to the study presented here. Namely, they asked participants to rapidly classify faces as happy, sad, or neutral and they compared clinical to non-clinical groups. As such, test anxiety, hesitancy, and general slowed processing could contribute to findings. It may be that when not concerned about time, individuals suffering from psychological distress are faster and feel more certain when recognizing psychological distress on another's expression. Conversely, those who are more resilient have greater difficulty recognizing and interpreting these expressions.

Test-retest reliability was low among the valence factors but adequate among response time measures. Intraclass correlation coefficients were particularly low for the negative and ambiguous valence factors. One reason for this low test-retest reliability is likely due to changing the word options that were presented with each face. For instance, word options presented at time 1 with Face item #2 were different than the word options presented with Face item #2 at time 2. This suggests that the word list available with each face likely influences how participants respond. This is consistent with theory that emotion words likely contribute to the interpretation of facial affect (Lindquist et al., 2006). In addition, it is possible that this measure is sensitive to mood states and is subject to changes in interpretation biases depending on the mood state.

Limitations

This study has important limitations. For one, the sex distribution is imbalanced toward females. Due to the imbalance of cell sizes, the effect of gender on performance was not investigated. However, partial correlations were used to control for the effect of gender when examining the relationships between self-reported mood and performances. Future research is warranted to investigate the effect of gender on performance on the AFT. In addition, the AFT deviates from standard protocols of facial affect recognition making direct comparisons to previous research difficult. Although the stimuli used include a variety of facial expressions and word options, making it difficult to isolate effects by emotion, the overall interpretation biases of participants were the primary interest, regardless of the emotion expressed in the stimuli. It should also be noted that correlations between mood measures and performance on the AFT are from a non-clinical sample. Due to range restriction on symptoms measures, relationships between symptoms and AFT performance should be interpreted with caution. However, 30% of the sample reported a history of depression, anxiety, and/or sleep disturbance. As such, the sample may include participants that meet diagnostic criteria for a mood disorder. This study examines the relationship of current mood symptoms on performance on the AFT and was not designed to look diagnostic groups.

In sum, this chapter presents the development and examination of the AFT, which is a novel task designed to measure affective biases in the interpretation of emotional expressions. The task demonstrated that even when no exact word-to-facial expression matches are available, participants chose emotion words that match facial expressions based on valence with a high degree of consistency. It also demonstrated that interpretation of ambiguous stimuli may be more sensitive to interpretation biases caused by mood as compared to negative or positive faces.

CHAPTER 2

MEASURING AFFECTIVE PROCESSES IN TBI

Rationale, Objectives, & Hypotheses

Affective processes refer to the brain's ability to identify, learn, interpret, and communicate emotional information. These are essential for healthy functioning and social interactions (McDonald, 2017). Previous research has demonstrated that some aspects of affective processes are disrupted following TBI, particularly emotion recognition (Babbage et al., 2011; Neumann & Zupan, 2019; Rosenberg et al., 2019; Spikman et al., 2013). Additional research in the field is now needed to examine how other types of affective processes, such as affective learning and memory, and affective language, are impacted by TBI. Better understanding of the breadth of affective processes disrupted by TBI will help researchers and clinicians understand the underlying mechanisms behind common social and emotional problems.

Although research regarding emotion recognition after TBI has been reviewed (see Background), a review of other affective processes in healthy participants is warranted here to justify use of measures that examine verbal learning and memory of emotion words and verbal fluency of emotion words.

Affective learning and memory.

To date, there has been no research regarding the impact of TBI on learning and memory of affectively valenced information.

Among non-clinical populations, verbal learning and recall of emotion words is enhanced as compared to neutral words (see Hamann, 2001 for review). This enhancement is likely due to the fact that emotional stimuli recruit activity in a broader network of brain regions than does neutral content (Straube, Sauer, & Miltner, 2011). The enhanced emotional processing effect is also attributed to increased amygdala activity in response to emotionally valenced stimuli (Hamann & Mao, 2002). In fact, patients with amygdala lesions and Alzheimer's related amygdalar atrophy do not show this memory enhancement effect for emotional stimuli (Adolphs, Tranel, & Denburg, 2000; Chan et al., 2001; Hamann, Monarh, & Goldstein, 2000; Kensinger, Brierley, Medford, Growdon, & Corkin, 2002). Based on neuroimaging and behavioral research, Kensinger and Schacter (2006) proposed that two distinct mechanisms to support memory enhancement for emotional information. One mechanism is via the arousal systems; memory enhancement for arousing words is mediated by an amygdalar-hippocampal network, which may reflect relatively automatic effects of emotion on memory. The second mechanism is a valence specific system; the enhancement for negative non-arousing items is due to self-generated encoding processes, such as elaboration or rehearsal of information, which involves the PFC-hippocampal network (Kensinger & Corkin, 2003). These mechanisms may be differentially impacted by TBI.

Although frontal and temporal areas have been considered the most susceptible to focal injury from TBI, a growing body of literature points to damage to deep brain structures including the amygdala (Ariza et al., 2004; Wilde et al., 2007). In addition, neurological substrates involved in memory for emotional stimuli are vulnerable to damage by TBI including the prefrontal cortex and orbital frontal cortex (Rolls, 2013; Straube et al., 2011). As such, it is reasonable to suspect that TBI may be associated with changes to emotional learning and recall.

It is also widely accepted that mood disorders influence learning and remembering of emotionally valenced information in non-brain injured individuals. Results of a meta-analysis demonstrated that those with depressed mood exhibited preferential recall of negative information and nondepressed groups exhibited preferential recall of positive information (Gaddy & Ingram, 2014). The prevailing theory for this pattern of findings is that individuals have enhanced attention and memory for mood congruent information (e.g., negatively valenced) when compared to information that it is not mood congruent (e.g., positively valenced; Bower, 1981; Matt, Vazquez, & Campbell, 1992). The mechanism for this mood congruent cognition is described by the Network Theory of Affect (Bower, 1981), which states that mood-congruent information receives superior processing for both encoding and retrieval. At encoding, mood-congruent information is connected to already activated related nodes and it is therefore more richly interconnected and processing is more elaborate. Mood incongruent information is less represented in the network and therefore is less elaborated. At retrieval, mood congruent information is more easily accessed because related nodes are already activated (see Singer & Salovey, 1988). Evidence for mood congruent cognition in individuals with mood disorders has grown in the last few decades as studies have continued to demonstrate that depressed individuals allocate greater attentional resources to negatively valenced information (Koster, Raedt, Leyman, & Lissnyder, 2010; Sanchez, Vazquez, Marker, LeMoult, & Joormann, 2013). In addition, biases towards recalling negative words has predicted onset of symptoms (Jensen et al., 2016). Investigations into the neural correlates of these findings have implicated the hippocampus, insula, amygdala, anterior cingulate and prefrontal cortex (Elliott, Rubinsztein, Sahakian, & Dolan, 2002; Van Tol et al. 2012).

Although there is evidence for a negative bias in learning and memory among depressed individuals, memory for positively valenced information is examined less often. However, existing literature points to a robust finding that healthy controls (i.e., no mood disorder) have enhanced memory for positively valenced words as compared to neutral or negatively valenced words and this enhancement is absent in persons with depression (Altgassen et al., 2011; Considine et al., 2017; Gaddy & Ingram, 2004; Jensen et al., 2016; Matt et al., 1992). For instance, Altgassen et al. (2011) found that healthy controls had enhanced accuracy on a prospective memory task when positive cues were given, but the depressed group did not. There were no group differences when negative cues were given. On an affective verbal list learning task, Considine et al. (2017) found no group differences in the recall of negative words, but they did find that healthy individuals showed an enhanced recall for positively valenced words that was absent among those with sleep disorders. Jensen et al. (2016) had similar findings on their affective verbal list learning task. They found that individuals with a depressive disorder did not show an enhancement for recall of positive words that was evident among the healthy controls. These findings suggest that a lack of positive bias, rather than the presence of a negative bias, is important to the evaluation of learning and memory of emotion words.

Affective language.

Affective language broadly refers to the production and comprehension of affectively valenced words and phrases as well as emotional intonation and prosody. Affective neuroscience research has demonstrated that affectively valenced words are processed in distinct ways from non-affectively valenced words (Cato et al., 2004). In short, similar to affective memory, affective word processing recruits more diverse networks of cognitive affective brain regions

than nonaffective words (Kissler Herbert, Peyk, & Junghofer, 2007; Scott, O'Donnell, Leuthold, & Sereno, 2009). To date, research on affective language has shown that TBI leads to deficits in recognizing intonation and prosody (McDonald et al., 2003; Zupan et al., 2014). It has also demonstrated that TBI is associated with alexithymia (Henry, Phillips, Crawford, Theodorou, & Summers, 2006b; Williams & Wood, 2010), which is characterized by the ability to identify and describe emotions (Sifneos, 1973). This has been attributed in part to damage in the anterior insula (Hogeveen, Bird, Chau, Krueger, & Grafman, 2016). Henry et al. (2006), found that among individuals with TBI, measures of alexithymia were associated with verbal fluency deficits. These authors suggest that the underlying cause of alexithymia and verbal fluency may be difficulties symbolizing language, and particularly emotion words. While it is commonly accepted that TBI is associated with deficits in verbal fluency of neutral words (Henry & Crawford, 2004), its effect on emotion verbal fluency has yet to be investigated.

Emotion verbal fluency tasks aim to measure affective processing deficits that impair rapid retrieval of emotion words (Abeare, Freund, Kaploun, McAuley, & Dumistrescu, 2016; Sass, Fetz, Oetken, Habel, & Heim, 2013). To date, few studies have examined the behavioral and neural correlates of emotion verbal fluency (Abeare, 2016; Gawda & Szepietowska, 2013; Gawda, Szepietowska, Soluch & Wolak, 2017; Sass et al., 2013). Existing studies have been limited to healthy non-clinical samples. Abeare et al. (2016) demonstrated that in a non-clinical group, generating emotion words was associated with physiological measures of arousal. They found that the number of galvanic skin responses were positively correlated with the number of emotion words generated but not the number of non-emotion words on a complimentary task. These authors hypothesized that emotion verbal fluency is uniquely associated with sympathetic arousal (an core component of emotions) as well as the neural networks involved in verbal

fluency. When examining the effect of valence, Sass et al. (2013) found that healthy participants produced more words in response to positive cues than negative cues and postulated this was due to a positive bias commonly seen in healthy controls. Gawda et al. (2017) extended this finding by demonstrating that emotion verbal fluency was associated with a different distribution of neural activity than verbal fluency of neutral words. They also found that there were differences in brain activation when participants were cued to generate positively valenced words (frontal-cingulate activation) as compared to negatively valenced words (right parietal, temporal and cingulate).

The impact of mood disorder on emotion verbal fluency has not been studied. The impact of depression on verbal fluency of neutral words has been widely studied with mixed results. In a review by Henry & Crawford (2004), they found depression had a small to medium negative effect on verbal fluency. In a more recent review, Klumpp & Deldin (2010) concluded that while there may be slowed processing in general, there was no evidence of specific semantic language deficits in persons with depression. They did report an enhanced processing of negatively valenced information as demonstrated by faster processing speed when responding to negatively valenced stimuli. This is consistent with evidence of a broad cognitive-affective bias towards negatively valenced information in depression (Gaddy & Ingram, 2014). For instance, in one study individuals with depression were found to be more accurate at rapidly judging the valence of negative words (but not neutral or happy words) as compared to controls (Atchley, Stringer, Mathias, Ilardi, & Minatrea, 2007). In addition, depression has also been associated with attenuated responses to positively valenced prosody expressed in speech (Koch et al., 2018). Thus, it is reasonable to suspect that mood may influence the number and valence of words produced on a rapid emotion verbal fluency task. Supporting this notion is evidence from one

study of a non-clinical sample that showed stress and anxiety were associated with greater emotion word production and greater production of negatively valenced words (Abeare et al., 2016).

The current study.

Affective processes have been shown to be impacted by TBI and affective disorders. This study is the first to measure the distinct types of affective processes in TBI that include facial affect recognition, learning and memory of emotion words, and verbal fluency of emotion words. It is also the first to explicitly study if TBI has an impact across a range of cognitive-affective processes involving the negative and positive valence systems. This exploratory study aims to (1) examine how individuals with TBI perform on measures of affective processes (i.e., facial affect recognition, verbal fluency, and emotion word learning and memory) compared to demographically similar controls and (2) examine the relationship between self-report measures of psychological symptoms, affect, and social participation and objective measures of affective processes. Finally, we explored how self-reported mood and TBI interacts to influence performance on affective processes. Preliminary hypotheses are presented in the results section for each task included in the study: Emotion Word Fluency Test (EWFT; Abeare, Freund, Kaploun, McAuley, & Dumitrescu, 2016), the Cognitive-Affective Verbal Learning Test (CAVLT; Considine, Keatley, & Abeare, 2017), and the Ambiguous Faces Test (AFT).

Methods

Recruitment.

This is a cross-sectional study that recruited from a rehabilitation hospital in Detroit, Michigan. The study population consists of community dwelling adults with a mild complicated, moderate, or severe TBI who received services at a rehabilitation center for their injuries. It included a control group recruited through snowball sampling, as well as from a database of research volunteers affiliated with the rehabilitation center in Detroit, Michigan, and a database of volunteers affiliated with the Wayne State University Primary Health Clinic.

To be eligible to participate in this study, an individual had to be between the ages of 18 and 65 years old. For the TBI group, the participants had to have a history of a mild complicated, moderate, or severe TBI. Participants were excluded from either the TBI or control group if they had a diagnosed neurological condition (i.e., dementia, anoxic injury, stroke, brain tumor, seizure disorder, or encephalopathy), or a neurodevelopmental disorder other than Attention Deficit/Hyperactivity Disorder (e.g., autism spectrum disorder, intellectual disability). Participants were excluded from the control group if they had a history of mild complicated, moderate, or severe TBI.

Participants with a mild complicated, moderate, or severe TBI were recruited from a database developed by the Psychology & Neuropsychology Department at the Rehabilitation Institute of Michigan (RIM). This database includes the contact information and injury characteristics of persons who had sustained a mild complicated, moderate, or severe TBI, were treated at the RIM for their TBI, and provided informed consent to have their information stored in a TBI research database to be contacted about future research studies. Informed consent and information were obtained by a research assistant while the patient was receiving services at

RIM; only those who had capacity to give consent, as determined by a neuropsychologist, were approached. Patients that consented had the following information recorded in the database: name, date of birth, gender, race/ethnicity, phone number, address, type of injury, Glasgow Coma Scale score as determined by the medical professionals and recorded in medical records, and if there were positive neuroimaging findings. Eligible patients that met the inclusion criteria were identified and contacted by the research coordinator at the RIM. Interested participants were then scheduled to participate in the research study. The participants were encouraged to recruit friends and family members with no history of TBI to participate in the study as controls. Interested controls were screened on the phone and invited to participate if they met eligibility criteria. In addition, controls were recruited from a database of individuals interested in engaging in research from RIM as well as a database of research volunteers who were recruited through a primary care clinic as an initiative designed by Wayne State University. IRB approval was obtained for Wayne State, RIM, and the University of Windsor.

Measures.

Demographics questionnaire and injury characteristics. Participants completed a demographics questionnaire that included questions regarding age, gender, and education history. It also asked about psychiatric history. Injury information, including date of injury and GCS scores, were obtained from the recruitment database.

Ambiguous Faces Test (AFT). The development and test characteristics of the AFT are presented in Chapter 1 of this document. In brief, the AFT is a novel measure that intends to capture appraisal biases in the interpretation of emotionally valenced faces. The participant is presented with a facial expression displayed on a screen and is forced to choose one of five

words that best describes the facial expression. The results of the AFT generate several scores for each item category: 1) an accuracy score based on whether the participant accurately identified the face as positive or negative, 2) average valence scores, and 3) time to respond.

Cognitive-Affective Verbal Learning Test (C-AVLT; Considine et al., 2017). The C-AVLT consists of 16 words and an exposure/recall protocol that mirrors the structure of the CVLT-II (Delis et al., 2000). By mirroring the protocol and stimuli characteristics of the CVLT-II. The words are semantically divided into four categories, positively-valenced words ("positive emotion words"), negatively-valenced words ("negative emotion words"), neutral-abstract words ("units or measures of time"), and neutral-concrete words ("parts of the body"). Lexical and valence characteristics of the words were carefully controlled within and between lists and categories (for more details on measure construction please refer to Considine, Keatley, & Abeare, 2016). The C-AVLT protocol capitalizes on the clinical and practical utility of using the CVLT-II structure. The distraction list (Trial B) contains distractor positive and negative emotion word categories, along with a distractor neutral-abstract category (academic topics of study) and a distractor neutral-concrete category (items found in a refrigerator). Additional semantically-related and non-semantically related distractor targets used in the recognition trial mirror the distribution used in the CVLT-II. Several indices can be generated from the C-AVLT. The primary indices consist of a Total Learning Trials scores (sum of words learned in the five learning trials), Short-Delay Free Recall total score (number of words recalled after a brief delay), and Long-Delay Free Recall score (number of words recalled after a 20-minute delay). Proportions of words recalled from each semantic category may be generated for each trial.

In addition, a valence factor can be generated for the learning trials, short-delay free recall, and long-delay free recall trials. The valence factor is calculated by subtracting the

number of negative words recalled from the number of positive words recalled. The resulting C-AVLT Valence Factor is only generated if emotion words are recalled (i.e., at least one emotion word must be recalled). A score ranging from -4 to 4 is generated with negative scores indicating greater negative bias (-4 strongest negative bias), and positive numbers indicating a positive bias (4 represents the strongest negative bias). The valence factor accounts for overall recall because a bias can be represented with combinations regardless of the total emotion words recalled (i.e., 2-0=2, 4-2=2).

Emotion Word Fluency Test (EWFT; Abeare et al., 2016). The EWFT is a measure of emotion word generation. Like other word generation tasks, the participant is asked to generate as many words as they can from the semantic category, emotion words, in one minute. A total words generated score is used as the main outcome measure. Scoring is done based on a scoring program developed by the Abeare lab that has parameters for identifying emotion versus non-emotion words. An inclusive approach is used allowing a range of responses that can refer to an emotional state including words such as, "smiling." In addition, response valence values are generated for each word provided based on a lexical norms database compile by Warriner et al., (2013). These norms were established by taking the mean of participant ratings for valence on scales ranging from 1 (unhappy) to 9 (happy) such that scores below 5 (neutral) are indication of negative affect, and scores greater than 5 are indicative of positive affect. Using these normative values a valence score for each word generated on the EWFT is given, an average valence score for the EWFT is calculated to create a valence factor with 1-4 representing negatively biased scores (with 1 representing the strongest negative bias), 5 representing neutral score/no valence bias, and scores from 6-9 representing a positive valence bias (9 representing the strongest positive valence bias).

Positive and Negative Affect Schedule (PANAS; Watson, Clark, & Tellegen, 1988). The PANAS is a 20-item self-report measure that generates two subscales of positive and negative affect. Each item consists of a word that describes a feeling, which is then rated for relevance to the participant on a scale of 1 ("very slightly or not at all") to 5 ("extremely"). Total scores for the positive and negative affect subscales can range from 10 to 50, with higher scores reflecting a higher level of positive or negative affect, respectively. The scale generates separate Positive Affect (PA) and Negative Affect (NA) scores.

Brief Symptom Inventory-18 (BSI; Derogatis, 2001). The BSI is a measure of emotional distress that generates three subscales: Somatization, Depression, and Anxiety. The total raw score ranges from 0 to 24 on each domain with higher scores indicating greater distress. A global distress total score is also generated. The BSI has been validated for use with TBI populations (Meachen et al., 2008). The developers of the BSI-18 use the term caseness to identify individuals with clinically significant emotional distress levels. Specifically, caseness refers to having either a GSI T score greater than 62, or having 2 or more symptom dimension T scores greater than 60. For the 3 symptom dimensions and the GSI, internal consistency is in the acceptable range, with alpha coefficients ranging from .74 to .89. Test-retest reliability is .90 for the GSI and ranges from .68 to .84 for the symptom dimensions.

Connor-Davidson Resilience Scale (CD-RISC; Connor & Davidson, 2003). The CD-RISC consists of 25 items assessed using a 5-point Guttmann-type scale ranging from 0 (not true at all) to 4 (true nearly all of the time). Total scores range from 0 to 100, with higher scores indicating greater resilience. Research has demonstrated that the scale has good psychometric properties in a traumatic brain injury population (Hanks et al., 2016).

Neuro-QOL. The National Institutes of Neurological Disorders developed this patient-reported outcome measurement system that consists of separate item banks covering several domains important for outcome (Perez et al., 2007; Miller, Nowinski, Victorson, Peterman, & Perez, 2005). For this study, the short forms for 'satisfaction with social roles and activities' and 'ability to participate in social roles and activities' were administered.

Procedures.

Participants met with the researcher and underwent the informed consent process. The consent form was read and reviewed with the participant, with the researcher answering questions. All participants were their own legal guardians. Signed copies of the consent forms were provided to the participant. Following the consent process, the participant completed the demographic questionnaire with assistance from the researcher. The researcher then administered the cognitive-affective measures. Finally, the participant completed self-report measures regarding mood symptoms.

Upon completion of the study, the participant was provided with a $20 cash reimbursement for their participation. The compensation was calculated to provide funds for transportation and reimbursement for their time.

Data Analyses.

Descriptive data is presented as means and standards deviations or frequencies and percentages. As a first analysis, correlations were primarily used to examine the relationship between demographic variables, self-report measures, and performance on the measures of affective processes in the TBI and Control groups separately. Outliers and adjustments for

violations of assumptions were made for different measures and are discussed within the text. Independent sample t-tests were used to examine group differences on self-report measures and performance on measures of affective processes. Although the data were not always normally distributed, the data between groups were always skewed in a similar direction and t-tests are robust to this type of violation (Field, 2009). Finally, when indicated, an interaction term was computed between the TBI and self-report measure scores to determine if mood moderated the relationship between TBI and performance on measures of affective processes. Assumptions of the regression models were analyzed including linearity, multicollinearity (VIF<10), homoscedasticity, and normality as well as testing for outliers, leverage points and influential cases. Any adjustments made for violations of these assumptions are discussed in the results section. Notably, significance was held at $p<.05$ and no corrections for multiple comparisons were made given the exploratory nature of the study.

Results

Participants.

Participants consisted of 50 individuals with mild complicated, moderate or severe TBI and 32 demographically similar controls. Participant demographic characteristics are presented in Table 2.01. The groups were not significantly different with regard to age ($t(44.21)=-.08$, $p=.94$), years of education ($t(80)=-.52$, $p=.60$), race (Pearson's $X^2=3.19$, $p=.67$), or marital status (Pearson's $X^2=3.12$, $p=.37$). The TBI group did have a significantly higher proportion of men ($X^2= 23.67$, $p<.01$). Notably, 30% of the TBI group self-reported a history of psychiatric problems and 50% of the control sample reported a history of psychiatric problems, which included depression, anxiety, substance use disorders, bipolar disorder and/or schizophrenia.

Table 2.01

Participant Characteristics

Variables	TBI *M* (*SD*)	Controls *M* (*SD*)
Age	46.80 (9.11)	46.56 (15.87)
Gender (male; n, %)	43 (86.00)	10 (31.25)
Years of education	16.05 (21.09)	14.09 (2.35)
Race (n, %)		
Black/African-American	30 (60.00)	20 (62.50)
White/Caucasian	13 (26.00)	8 (25.00)
Hispanic/Latino	1 (2.00)	0
Mixed Race	2 (4.00)	2 (6.25)
Native American	0	1 (3.13)
Other	4 (8.00)	1 (3.13)
Marital Status (n, %)		
Single	34 (69.39)	18 (54.55)
Married	8 (16.00)	10 (31.25)
Divorced	6 (12.00)	4 (12.50)
Separated	1 (2.00)	0
Missing	1 (2.00)	0
History of psychiatric d/o (n, %)	15 (30)	16 (50)
Depression	7 (14)	13 (40.6)
Anxiety	4 (8)	8 (25)
Substance use disorder	10 (20)	0
Bipolar disorder	4 (8)	2 (6.3)
Schizophrenia	0	1 (3.1)
Injury severity (n, %)		
Mild complicated	9 (18.00)	-
Moderate	20 (40.00)	-
Severe	21 (42.00)	-
Years since injury	15.30 (8.40)	-

This is a predominantly African-American sample, which is not representative of the population in the United States but is representative of Detroit, MI, where these data were collected. All participants spoke English as their primary language. Cultural variables to consider include race. Participants were divided into White/Caucasian and Persons of Color (POC), which is predominantly, but not exclusively, represented by African-Americans. Using a

POC variable is consistent with previous literature (Rothenberg, 2004) and may act as a proxy for a multitude of different life experiences that persons of color may experience in the United States. Notably, there was a significant difference in years of education between POC (M = 12.89, SD = 2.29) and the White/Caucasians (M = 15.36, SD = 2.72, $t(80)=4.07$, $p<.01$). Relationships between demographic variables for the groups combined are presented in Table 2.02.

Table 2.02

Intercorrelations Between Participant Demographic Variables

Demographic Variables	Age	Gender	Years of Education	POC
Age	1	.07	.02	.11
Gender		1	.07	.08
Years of Education			1	**-.41****

*$p<.05$, **$p<.01$. Note: POC= person of color

Self-Report Measures.

We examined group differences on the self-report measures and if demographic variables influenced symptom reporting. The assumptions of Pearson correlations were evaluated by examining scatter plots for linear relationships and outliers. The assumptions for normality were examined using Shapiro Wilk test for normality and by examining the histogram charts. Many of the self-report questionnaires were not normally distributed and log transformation did not significantly improve the problem of normality. As such, Pearson's correlations and Spearman's correlations were analyzed. For simplicity, Pearson's correlations are presented here and when

there was a significant deviation between Pearson and Spearman's correlation coefficient it is noted in the text. There were no outliers identified or removed.

Among those with TBI, results indicated that more years of education was related to fewer BSI symptoms, and higher scores on the CD-RISC and the NeuroQOL Ability scale (Table 2.03). No significant correlations were found in the control group (Table 2.04).

Table 2.03

Correlation Between Demographic and Injury Characteristic and Symptom Scores for those with TBI

Demographic Variables	BSI GSI	BSI Dep	BSI Anx	BSI Som	PANAS NA	PANAS PA	CD-RISC	NeuroQOL Ability	NeuroQOL Satisfaction
Age	.04	.11	-.12	.05	-.03	.03	.11	-.08	-.08
Gender	-.04	-.04	-.03	.01	.13	-.14	-.13	-.05	-.06
Years of Education	**-.19***	-.10	-.14	-.18	-.16	.21	**.37****	**.41****	.09
POC	.14	.10	.14	.19	.22	.02	-.23	**-.32***	-.09
GCS	<.01	.03	-.09	.07	.08	<.01	.01	-.10	-.14
Days since Injury	-.01	-.09	-.06	.12	-.11	.15	.07	-.17	.04

*p<.05, **p<.01; *Note*: POC=Person of color, GCS=Glasgow Coma Scale, GSI= Global Severity Index

Table 2.04

Correlation Between Demographic and Symptom Scores for the Control Group

Demographic Variables	BSI GSI	BSI Dep	BSI Anx	BSI Som	PANAS NA	PANAS PA	CD-RISC	NeuroQOL Ability	NeuroQOL Satisfaction
Age	-.29	-.18	-.34	-.10	-.29	.13	.18	.18	.09
Gender	.04	-.08	-.13	.22	-.07	.03	.07	.13	.16
Years of Education	-.32	-.12	-.31	-.26	-.31	.13	.33	.34	.20
POC	-.07	-.06	-.07	.01	-.09	.17	.06	.07	-.07

*p<.05, **p<.01; *Note*: POC=Person of color, GCS=Glasgow Coma Scale, GSI= Global Severity Index

The correlation coefficients between measures were analyzed using Spearman's rho correlations for both the TBI and control groups. Generally, the PANAS NA was positively correlated with the BSI scales and negatively correlated with the PANAS PA, CD-RISC, and NeuroQOL measures (Table 2.05). Conversely, PANAS PA was negatively correlated with the BSI subscales and positively correlated with the CD-RISC and NeuroQOL measures. The directions of the correlations were similar across groups with some differences in coefficient sizes.

Table 2.05

Intercorrelations of Symptom Scores for those with TBI (below the diagonal) and Controls (above the diagonal)

Self-report Measures	BSI GSI	BSI Dep	BSI Anx	BSI Som	PANAS NA	PANAS PA	CD-RISC	NeuroQOL Ability	NeuroQOL Satisfaction
BSI GSI	1	**.86****	**.84****	**.76****	**.75****	**-.47****	**-.56****	**-.53****	**-.63****
BSI Dep	**.89****	1	**.75****	**.52****	**.73****	**-.37***	**-.37***	**-.30**	**-.39***
BSI Anx	**.83****	**.71****	1	**.39***	**.75****	-.33	**-.54****	**-.56****	**-.64****
BSI Som	**.80****	**.60****	**.55****	1	**.58****	**-.51****	**-.37***	-.34	**-.47****[*]
PANAS NA	**.56****	**.54****	**.60****	**.47****	1	-.28	-.29	-.26	**-.36***
PANAS PA	**-.35***	**-.40****	-.30	**-.28****	-.26	1	**.54****	**.58****	**.57****
CD-RISC	**-.46****	**-.46****	**-.45****	**-.38****	**-.36***	**.56****	1	**.58****	**.45****
NeuroQOL Ability	**-.53****	**-.39****	**-.41****	**-.54****	**-.36****	**.43****	**.57****	1	**.75****
NeuroQOL Satisfaction	**-.62****	**-.54****	**-.45****	**-.54****	**-.55****	**.47****	**.36***	**.75****	1

*p<.05, **p<.01. *Note*: GSI= Global Severity Index

Independent sample t-tests were conducted to compare symptom reporting between the two groups (see Table 2.06). Results indicated that the TBI group endorsed more depression symptoms as compared to controls; although not statistically significant, scores indicated that there was a trend towards significance with a small effect size for this difference. In contrast, the control group endorsed higher scores on the CDRISC and PANAS PA; although not statistically significantly different, there were small to medium effect sizes. Notably, there were no significant differences between the Neuro QOL scales.

Table 2.06

Group Differences on Self-report Measures

Self-report Measures	TBI M (SD)	Control M (SD)	*t*	*df*	*p*	Cohen's d
BSI GSI	57.82 (13.67)	54.97 (12.67)	-.98	80	.33	.21
BSI Depression	59.44 (12.55)	54.94 (9.29)	-1.86	78.21	.07	**.41**
BSI Anxiety	55.16 (12.89)	51.69 (11.03)	-1.26	80	.21	.29
BSI Somatic	54.12 (10.80)	55.38 (10.56)	.52	80	.61	.10
PANAS NA	17.66 (6.74)	17.50 (5.65)	-.11	78	.91	.03
PANAS PA	33.06 (9.58)	36.30 (7.75)	1.57	78	.12	**.37**
CD-RISC	70.08 (16.96)	76.70 (13.57)	1.92	78	.06	**.43**
Neuro QOL Ability	30.40 (7.71)	31.53 (4.86)	.80	77.77	.42	.18
Neuro QOL Satisfaction	29.33 (8.13)	31.20 (5.23)	1.25	76.76	.22	.27

Note: GSI= Global Severity Index

The proportion of clinically elevated scores on the BSI was compared between the two groups using a T cut-off score of 60. T-scores for the BSI were calculated using community-based norms correcting for gender (Table 2.07). Notably, 52% of participants from the TBI group met criteria for clinically significant depression while 31% of the control group met

criteria for clinically significant depression and there was a trend toward this being a statistically significant difference.

Table 2.07

Group Differences Between Frequency of Clinically Elevated Scores (T scores >60)

BSI Scores	TBI n (%)	Control n (%)	X^2	p	Ψ
BSI GSI	25 (50.0)	11 (34.4)	1.93	.16	.15
BSI Depression	26 (52.0)	10 (31.3)	3.41	.07	.20
BSI Anxiety	17 (34.0)	7 (21.9)	1.39	.24	.13
BSI Somatization	16 (32.0)	10 (31.3)	.01	.94	.01

Note. GSI= Global Severity Index

To examine how group membership might influence symptom scores after controlling for demographic variables, regression models were run for each self-report scale with age, gender, years of education, POC and Group as predictors (Table 2.8). Only the models predicting CDRISC and NeuroQOL Ability scores were significant. In both models, only years of education was a significant predictor.

Table 2.8

Regression models examining the association between demographics and group membership on symptom reporting

Self-report Measures	*F*	df	*p*	Adj.R^2
BSI GSI	1.19	80	.32	.05
BSI Depression	1.04	80	.39	.01
BSI Anxiety	1.77	80	.14	.04
BSI Somatization	.95	80	.44	<-.01
CDRISC	4.89	80	**<.01**	.17
PANAS PA	1.76	80	.17	.04
PANAS NA	.98	80	.42	<-.01
Neuro QOL Ability	3.69	80	**.01**	.12
Neuro QOL Satisfaction	.90	80	.47	-.01

Note. GSI = Global Severity Index

Emotion word fluency test.

Objective 1. Examining group differences.

The control group was expected to produce more words than the TBI group on the EWFT, given documented group differences in verbal fluency generally, but that there would be no significant differences between the EWFT valence factors. One outlier was removed from the TBI group for having an EWFT Total Score 3 standard deviations above the mean. This case was only removed for the EWFT Total score analyses and not the Valence Factor score analyses.

The influence of demographic variables and injury characteristics on the EWFT scores were first examined in both the TBI and control groups (Table 2.09). Age and gender did not impact scores in either group. Years of education was significantly associated with more words

generated on the EWFT in the TBI group but not the control group. Injury characteristics were not significantly associated with EWFT scores.

Table 2.09

Correlations Between Demographic and Injury Characteristic and EWFT Scores

Demographic Variables	TBI		Controls	
	EWFT Total	EWFT VF	EWFT Total	EWFT VF
Age	.09	.17	-.09	.20
Gender	-.14	-.13	-.11	-.04
Years of Education	**.35***	.27	.30	.08
POC	-.17	-.08	-.14	.08
GCS	.07	.02	-	-
Days since Injury	.01	-.12	-	-

*p<.05, **p<.01. *Note*: Pearson's correlations presented; similar findings with Spearman's rho, POC= Person of color, GCS = Glasgow Coma Scale, VF=Valence Factor

Group differences in EWFT performance between the TBI and Control group were examined using independent sample t-tests; there were no group differences (Table 2.10).

Table 2.10

Group differences on the EWFT

EWFT Scores	TBI M (SD)	Control M (SD)	*t*	*df*	*p*	Cohen's d
EWFT Total	10.26 (4.14)	9.96 (3.59)	.09	79	.93	.08
EWFT VF	4.62 (.85)	4.76 (.91)	.72	80	.48	.16

Note. VF = Valence Factor.

In a regression model controlling for education level, there remained no significant group difference on EWFT total scores and education accounted for most of the variance in performance ($F(80)=9.02$, $p<.01$, Adj. $R^2=.17$; Table 2.11).

Table 2.11

Relationship between TBI and EWFT Total Score after controlling for education

Predictors	*B*	*SE B*	β	*t*	*p*	95% Confidence Interval	
						Lower Bound	Upper Bound
Years of education	.60	.14	.44	4.25	**<.01**	.32	.88
Group	.45	.75	.06	.61	.55	-1.04	1.95

Objective 2. Examining effect of mood on performance.

Increased self-report mood symptoms were expected to be associated with a negative valence bias and worse overall performance in both groups. Pearson's correlations are presented. Data were also checked against Spearman's rho correlations and there were no differences among the significance tests.

The PANAS PA Scale and CD-RISC were positively correlated with greater word production on the EWFT in the TBI group (Table 2.12). The CD-RISC was also positively correlated with greater word production in the Control group. In the control group, greater negative affect was also associated with a more negative valence bias. When the groups were combined, BSI symptoms scales were associated with fewer words produced on the EWFT and the PANAS PA and CD-RISC were associated with greater word production.

Table 2.12

Correlations between self-reported symptoms and EWFT scores

Self-report Measures	TBI		Controls		Combined	
	EWFT Total	EWFT VF	EWFT Total	EWFT VF	EWFT Total	EWFT VF
BSI GSI	-.21	-.17	-.30	-.24	**-.27***	-.20
BSI Depression	**-.28***	-.05	-.23	-.10	**-.28***	-.08
BSI Anxiety	-.17	-.13	-.21	-.16	**-.24***	-.15
BSI Somatic	-.24	-.24	-.23	-.17	**-.24***	-.21
PANAS NA	-.19	-.13	-.14	**-.38***	-.18	-.20
PANAS PA	**.32***	-.17	.23	-.06	**.30****	-.12
CD-RISC	**.30***	-.18	**.44***	.08	**.38****	-.08
NeuroQOL Ability	.14	.15	.33	.24	.19	.09
NeuroQOL Satisfaction	<.01	.09	.17	.29	.08	.12

*p<.05, **p<.01. *Note*: EWFT=Emotion Word Fluency Test, VF= Valence Factor, GSI= Global Severity Index

Objective 3. Moderation analyses.

TBI was expected to moderate the relationship between self-report symptoms and performance on the EWFT. To examine how symptoms scores may impact emotional semantic fluency in those with and without TBI differently, we completed moderation analyses that also controlled for education level. All assumptions of the regression models were adequately met. The BSI Depression subscale, PANAS PA, and PANAS NA were selected for the analyses as they were significantly associated with EWFT performances at the univariate level. BSI Depression in particular was selected as this disorder is most commonly represented in the literature regarding the effects of mood on verbal fluency and cognitive-affective biases.

The first step of the model included years of education, group, and BSI Depression scores and this model was significant ($F(80)=7.65$, $p<.001$, Adj. $R^2 = .20$) with more years of education and lower BSI Depression scores predicting better performance on the EWFT (Table 2.13). Since TBI was not a significant independent predictor, there was no cause to pursue a moderation analysis.

Table 2.13

Associations of Depression, TBI, and EWFT Total Scores

Predictors	*B*	*SE B*	β	*t*	*p*	95% Confidence Interval
Years of education	.55	.14	.40	3.89	**<.01**	.26 to .83
Group	.71	.74	.10	.95	.35	-.78 to 2.19
BSI Depression	-.07	.03	-.21	-2.05	**.04**	-.13 to -.01

The effect of positive affect on word production was tested using a multiple regression model followed by a moderation analysis to examine how this effect might change in the presence of TBI (Table 2.14). The first step of the model included years of education, group, and PANAS PA scores and this model was significant ($F(80)=8.02$, $p<.001$, Adj. $R^2=.20$) with greater years of education and higher PANAS PA scores predicting better performance on the EWFT. Since TBI was not a significant independent predictor, there was no cause to pursue a moderation analysis.

Table 2.14

Associations of PANAS PA, TBI, and EWFT Total Scores

Predictors	*B*	*SE B*	β	*t*	*p*	Confidence Interval
Years of education	.54	.14	.40	3.84	**<.01**	.26 to .82
Group	.66	.74	.09	.89	.37	-.81 to 2.12
PANAS PA	.09	.04	.23	2.26	**.03**	.01 to 1.7

Finally, the effect of negative affect on EWFT Valence Factor was tested using a multiple regression model followed by a moderation analysis to examine how this effect might change in the presence of TBI (Table 2.15). The first step of the model included years of education, group, and PANAS NA scores and this model was not significant ($F(81)=2.08$, $p=.11$, Adj $R^2=.04$) and so no further analyses were indicated.

Table 2.15

Associations of PANAS NA, TBI, and EWFT Total Scores

Predictors	*B*	*SE B*	β	*t*	*p*	95% Confidence Interval	
						Lower Bound	Upper Bound
Years of education	.06	.04	.17	1.49	.14	-.02	.13
Group	-.11	.20	-.06	-.57	.57	-.51	.28
PANAS NA	-.02	.01	-.17	-1.56	.12	-.05	.01

Cognitive-Affective Verbal Learning Test.

Objective 1. Examining group differences.

The TBI group was expected to learn and recall significantly fewer words on the CAVLT compared to the controls. We also hypothesized that the control group would have a significantly better score on positive-word learning and a more positive recall bias as compared to the TBI group. Normality plots were examined and CAVLT scores were generally normally distributed. No outliers were identified. The influence of demographics and injury characteristics on the CAVLT scores were examined using Pearson's correlations. Independent sample t-tests were used to compare group differences.

Younger age, female gender and more years of education were associated with better performance on the CAVLT learning and recall trials (Table 2.16). Days since injury was not associated with CAVLT scores. Higher GCS scores (i.e., less severe TBI) was associated with a more positive valence bias on the long delay free recall trial. There were no significant associations between valence factors and demographic variables.

Table 2.16

Demographic and Injury Characteristic Influences on CAVLT Scores

CAVLT Scores	Controls				TBI					
	Age	Gender	Years of Edu	POC	Age	Gender	Years of Edu	POC	GCS	Days since Injury
CAVLT T1-5	**-.47****	.16	**.53****	-.06	-.26	.03	.18	-.13	-.13	-.05
CAVLT SDFR	**-.39***	.23	**.45***	-.14	**-.37****	-.05	.20	-.16	-.11	-.10
CAVLT LDFR	**-.37***	.15	**.46****	-.09	**-.29***	.08	**.34***	-.23	-.08	-.10
CAVLT T1-5 VF	-.24	-.20	-.10	-.13	-.08	-.09	.09	-.19	.26	<.01
CAVLT SDFR VF	.21	.01	.06	.21	-.22	-.21	.14	-.12	.10	-.19
CAVLT LDFR VF	-.01	-.18	.10	-.11	-.17	-.14	.06	-.14	**.34***	-.04

*p<.05, **p<.001, SDFR= Short Delay Free Recall, LDFR= Long Delay Free Recall, VF=Valence Factor, POC=Persons of Color, GCS=Glasgow Coma Scale

Independent sample t-tests were used to compare performances across groups. Results indicated that the TBI group performed worse on the learning trials, short-delay free recall, long-delay free recall, and recognition trials with more false positive errors (Table 2.17). The TBI group also had a more negative learning and recall bias and this was particularly pronounced on the short-delay free recall trial.

Table 2.17

Differences Between TBI and Controls on CAVLT scores

CAVLT Scores	TBI *M* (*SD*)	Control *M* (*SD*)	*t*	*df*	*p*	Cohen's *d*
CAVLT T1-5	40.48 (11.24)	50.97(12.15)	4.29	80	**<.01**	**.86**
CAVLT SDFR	6.64 (3.18)	9.59 (3.22)	4.08	80	**<.01**	**.92**
CAVLT LDFR	6.66 (3.15)	9.94 (3.01)	4.63	80	**<.01**	**1.06**
CAVLT Recognition	13.36 (2.29)	14.56 (1.54)	2.61	80	**.01**	**.61**
CAVLT false positive	4.72 (4.42)	2.69 (3.60)	-2.19	80	**.03**	**.50**
CAVLT Intrusions & Repetitions	18.60 (17.98)	18.06 (11.87)	-.15	80	.88	.04
CAVLT Overall VF	-.49 (2.73)	.43 (1.33)	2.05	75.62	**.04**	**.42**
CAVLT T1-5 VF	-.52 (4.76)	.69 (3.19)	1.27	79.78	.17	.30
CAVLT SDFR VF	-1.63 (6.36)	2.21 (4.14)	3.21	74.50	**<.01**	**.72**
CAVLT LDFR VF	-1.79 (7.31)	.36 (4.84)	14.46	77.00	.12	.35

Note. SDFR=Short Delay Free Recall, LDFR=Long Delay Free Recall, VF=Valence Factor

To examine the negative bias finding more closely, t-tests were used to compare number of words recalled by semantic category (Table 2.18). Findings indicated that the TBI group recalled fewer words across all semantic categories but that this effect was smallest for negative words and measurements of time.

Table 2.18

Group Differences on CAVLT Overall Word Recall by Semantic Category

Semantic Categories	TBI *M* (*SD*)	Control *M* (*SD*)	*t*	*df*	*p*	Cohen's d
Positive Words	11.60 (5.30)	16.90 (5.60)	4.33	80	**<.01**	.97
Negative Words	12.44 (4.19)	15.34 (4.40)	3.00	80	**<.01**	.68
Body Parts	18.10 (4.19)	22.09 (4.14)	4.23	80	**<.01**	.93
Measurements of Time	11.64 (6.74)	15.97 (6.77)	2.83	80	**<.01**	.64

Note: Values are total number of words recalled across learning and recall trials

An ANOVA was used to examine how CAVLT recall varied by different levels of semantic category between those with TBI and Controls. The assumptions of the model were investigated and the assumptions of normality were adequately met and no outliers were identified. Findings revealed a significant within subjects main effect for semantic category ($F(3, 240)=49.91$, $p<.01$) indicating that number of words recalled varied by semantic category. There was also a significant between group effect ($F(1, 80)=1128.56$, $p<.01$) such that overall, those with TBI recalled fewer words than controls. There was no significant interaction between Group and Semantic category ($F(3, 240)=19.16$, $p=.27$). Post-hoc analyses revealed that the difference between number of positive and negative words recalled was significantly different between the TBI and control group ($F(1,80)=4.07$, $p=.05$); the controls recalled significantly fewer negative words as compared to positive words, while the TBI group recalled more negative words than positive words (see Figure 2).

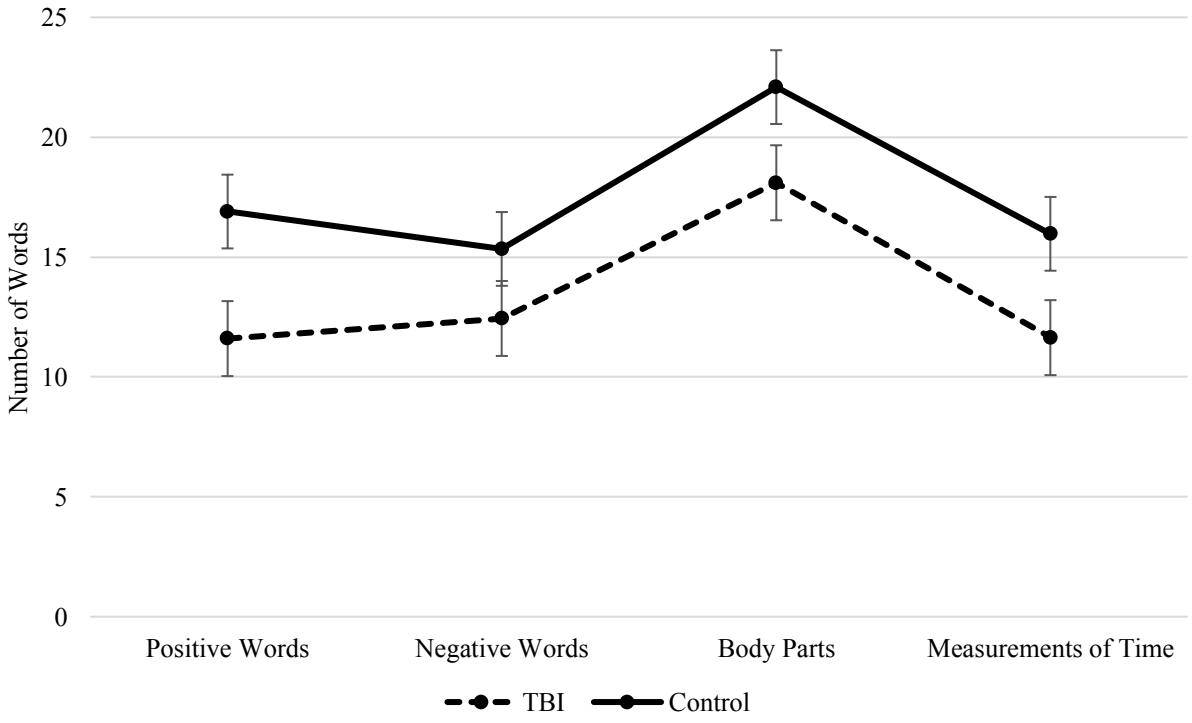


Figure 2. CAVLT word recall by semantic categories.

Objective 2. Examining effect of mood on performance.

Greater emotional distress and negative affect were expected to be associated with a negative valence bias and worse overall performance in both groups. Conversely, greater positive affect and resilience would be associated with better performance overall and a bias for positively valenced words in both groups. Pearson's correlations are presented. Data were also checked against Spearman's rho correlations and there were no differences in the pattern of findings.

Among those with TBI, higher scores on the CD-RISC, PANAS PA, and NeuroQOL Ability were associated with better performance on the learning trials (Table 2.19). CD-RISC was also positively correlated with LDFR. There was a trend toward more symptoms on the BSI being associated with worse performance on the learning trials, but these coefficients were not

statistically significant. There was no statistically significant relationship between the Valence Factors and self-report symptoms.

Table 2.19

Correlations between CAVLT Performance and Self-reported Symptoms Among those with TBI

CAVLT Subscales	BSI Total	BSI Dep	BSI Anx	BSI Som	PANAS NA	PANAS PA	CD-RISC	NeuroQOL Ability	NeuroQOL Satisfaction
T1 – T5	-.22	-.22	-.21	-.21	-.29	**.30***	**.40****	**.31***	.19
SDFR	-.08	-.15	.03	-.08	-.18	.25	.25	.22	.11
LDFR	-.18	-.26	-.14	-.13	-.22	.24	**.36***	.28	.07
T1 – T5 VF	-.03	-.01	-.07	.05	-.02	.25	.19	.14	-.02
SDFR VF	-.03	.05	-.04	-.14	-.04	.13	.18	.24	.02
LDFR VF	.04	.02	-.04	.11	.05	-.15	-.03	-.01	-.19
Overall VF	.01	.04	-.07	.07	.06	.06	.04	.01	-.15

*p<.05, **p<.01; *Note:* SDFR=Short Delay Free Recall, LDFR=Long Delay Free Recall, VF=Valence Factor

The same analyses were conducted with the Control group (Table 2.20). Again, the PANAS Positive Affect Scale and CD-RISC were associated with better performance on the learning trials. Higher CD-RISC scores were also associated with better performance on the SDFR trial. Again, there were no significant associations between the VFs and the self-report measures.

Table 2.20

Correlations between CAVLT Performance and Self-reported Symptoms Among Controls

CAVLT Subscales	BSI Total	BSI Dep	BSI Anx	BSI Som	PANAS NA	PANAS PA	CD-RISC	NeuroQOL Ability	NeuroQOL Satisfaction
T1 – T5	-.30	-.30	-.29	-.20	-.29	**.37***	**.56****	.25	.28
SDFR	-.15	-.24	-.23	.03	-.12	.13	**.41***	.12	.20
LDFR	-.17	-.27	-.25	.02	-.11	.05	.32	.14	.19
T1 – T5 VF	-.26	-.22	-.13	-.21	-.20	-.01	-.09	-.01	.20
SDFR VF	-.15	-.06	-.16	-.13	-.05	.07	.01	-.02	.01
LDFR VF	.16	.30	.33	-.11	.22	.11	-.24	.02	.01
Overall VF	-.07	-.02	.03	-.14	-.03	.03	-.24	-.06	.14

*p<.05, **p<.01; *Note*. T1-T5 = Learning Trials 1 through 5; SDFR = Short Delay Free Recall; LDFR = Long Delay Free Recall; VF=Valence Factor.

When the groups were combined, the BSI GSI and Depression scales were associated with worse performance on the learning trials while PANAS PA, CDRISC, NeuroQOL Ability and NeuroQOL Satisfaction were associated with better performance (Table 2.21). CDRISC and NeuroQOL Ability were also positively correlated with SDFR and LDFR.

Table 2.21

CAVLT Score Associations with Self-Reported Symptoms – Groups Combined

CAVLT Subscales	BSI GSI	BSI Dep	BSI Anx	BSI Som	PANAS NA	PANAS PA	CD-RISC	Neuro QOL Ability	Neuro QOL Satisfaction
T1 – T5	**-.28***	**-.25***	-.20	-.17	-.16	**.31****	**.41****	**.29****	**.23****
SDFR	-.13	-.18	-.11	-.04	-.06	.21	**.28***	**.23***	-.13
LDFR	-.16	-.22	-.14	-.02	-.08	.20	**.33****	**.26****	.14
T1 – T5 VF	-.16	-.14	-.13	.01	-.07	.19	.14	.12	-.16
SDFR VF	-.14	-.13	-.10	-.15	-.01	.09	.14	.17	.05
LDFR VF	.01	-.04	<.01	.02	.19	-.03	-.08	-.07	.01
Overall VF	.01	.01	-.06	.08	.05	.08	.02	.01	-.08

*p<.05, **p<.01; *Note*. T1-T5 = Learning Trials 1 through 5; SDFR = Short Delay Free Recall; LDFR = Long Delay Free Recall; VF=Valence Factor.

Objective 3. Moderation Analyses

We examined if the relationships between self-reported symptoms and performance on the CAVLT were moderated by the presence of TBI. The relationship between self-report symptoms and CAVLT Total word production was expected to be significantly moderated by TBI. We completed multiple regression analyses examining the effect of self-report measures and TBI on CAVLT performance after controlling for demographic variables. We included an interaction variable accounting for the presence of TBI to determine if TBI moderated the relationship between affective symptoms and performance on the CAVLT when appropriate. BSI depression, PANAS PA, and CD-RISC were chosen as measures of interest based on their significant relationships with CAVLT trials at the univariate level. CAVLT learning trials were selected as the dependent variable as it was impacted by both mood and TBI. All assumptions of

the regression models were adequately met. Multicollinearity was high (VIF>10) between group and the interaction variable in the second step of each model, which is generally considered acceptable in such analyses (Sheih, 2010).

The first step of the model included years of education, age, gender, group, and BSI Depression scores and this model was significant ($F(81)=11.28$, $p<.01$, Adj $R^2=.39$) with younger age, more years of education, absence of TBI, and lower depression scores predicting better performance (Table 2.22). When the interaction variable was included in the second step, there was not a significant change in R ($F(1)=2.09$, $p=.15$, R^2 Change=.02) and the interaction term was not significant.

Table 2.22

Moderation Analysis Examining Effect of BSI Depression Scale and TBI on CAVLT Learning

Predictors	*B*	*SD B*	β	*t*	*p*	95% Confidence Interval	
						Lower Bound	Upper Bound
Step 1:							
Age	-.36	.09	-.36	-4.13	**<.01**	-.53	-.18
Gender	3.74	2.61	.15	1.43	.16	-1.46	8.93
Years of edu	1.22	.41	.27	2.99	**<.01**	.41	2.03
Group	-6.42	2.60	-.26	-2.46	**.02**	-11.60	-1.23
BSI Depression T score	-.18	.09	-.17	-1.90	.06	-.36	.01
Step 2:							
Age	-.38	.09	-.39	-4.36	**<.01**	-.55	-.21
Gender	3.67	2.59	.15	1.42	.16	-1.49	8.83
Years of edu	1.23	.40	.27	3.04	**<.01**	.42	2.04
Group	-23.56	12.16	-.97	-1.94	.06	-47.80	.67
BSI Depression T score	-.40	.18	-.39	-2.21	**.03**	-.77	-.04
TBI x BSI Depression	.31	.21	.79	1.44	.15	-.12	.73

Next, the relationship between positive affect and CAVLT learning trials was examined while controlling for demographic variables (Table 2.23). The effect of TBI on this relationship was also examined with an interaction variable. The first step of the model included years of education, age, gender, group, and PANAS PA scores. This model was statistically significant ($F(81)=12.55$, $p<.01$, Adj $R^2=.42$) with younger age, more years of education, absence of TBI, and greater PANAS PA scores predicting better performance. When the interaction variable was included in the second step, there was not a significant change in R ($F(1)=.65$, $p=.42$, R^2 Change<.01) and the interaction term was not significant.

Table 2.23

Moderation Analysis Examining Effect of PANAS PA and TBI on CAVLT Learning

Predictors	*B*	*SD B*	β	*t*	*p*	95% Confidence Interval	
						Lower Bound	Upper Bound
Step 1:							
Age	-.37	.08	-.37	-4.34	**<.01**	-.53	-.20
Gender	4.51	2.56	.18	1.76	.08	-.59	9.60
Years of education	1.15	.40	.25	2.87	**.01**	.35	1.94
Group	-5.96	2.55	-.25	-2.33	**.02**	-11.04	-.87
PANAS PA	.31	.11	.24	2.73	**.01**	.08	.54
Step 2:							
Age	-.37	.08	-.37	-4.35	**<.01**	-.53	-.20
Gender	4.47	2.56	.18	1.74	.09	-.64	9.57
Years of education	1.16	.40	.26	2.90	**<.01**	.36	1.96
Group	.75	8.73	.03	.09	.93	-16.64	18.15
PANAS PA	.44	.20	.34	2.24	**.03**	.05	.83
TBI x PANAS PA	-.19	.24	-.29	-.80	.42	-.67	.28

The relationship between CD-RISC and CAVLT learning trials was also examined while controlling for demographic variables (Table 2.24). The effect of TBI on this relationship was examined with an interaction term. The first step of the model included years of education, age, gender, group, and CD-RISC scores and this model was statistically significant ($F(81)=14.38$, $p<.01$, Adj $R^2=.45$) with younger age, more years of education, absence of TBI, and greater CD-RISC scores predicting better performance. When the interaction term was included in the

second step, there was not a significant change in R ($F(1)=1.82$, $p=.18$, R^2 Change=.01) and the interaction term was not significant.

Table 2.24

Moderation Analysis Examining Effect of CDRISC and TBI on CAVLT Learning

Predictors	*B*	*SD B*	β	t	*p*	95% Confidence Interval	
						Lower Bound	Upper Bound
Step 1:							
Age	-.39	.08	-.40	-4.75	**<.01**	-.55	-.23
Gender	4.04	2.47	.16	1.64	.11	-.88	8.95
Years of education	.79	.41	.17	1.91	.06	-.03	1.60
Group	-5.89	2.47	-.24	-2.39	**.02**	-10.80	-.98
CD-RISC	.25	.07	.33	3.60	**.00**	.11	.38
Step 2:							
Age	-.40	.08	-.41	-4.88	**<.01**	-.56	-.24
Gender	3.72	2.47	.15	1.51	.14	-1.19	8.63
Years of education	.77	.41	.17	1.88	.06	-.05	1.58
Group	7.90	10.52	.33	.75	.46	-13.06	28.87
CD-RISC	.38	.12	.51	3.14	**<.01**	.14	.62
TBI x CD-RISC	-.19	.14	-.58	-1.35	.18	-.46	.09

Ambiguous Faces Test.

Objective 1. Examining group differences.

The control group was predicted to have better affective facial recognition than those with TBI. No outliers were removed from these analyses. Pearson's correlations were used to examine the influence of demographic variables and independent t-tests were used to examine group differences.

The relationship between demographic variables and injury characteristics on the AFT scores were examined using Pearson's correlations (Table 2.25). Greater years of education was correlated with better emotion recognition accuracy on the AFT and persons of color had worse valence accuracy.

Table 2.25

Demographic and Injury Characteristic Influences on AFT scores

AFT Subscales	GCS	Days Since Injury[a]	Age	Gender	Years of Education	POC
AFT Valence Accuracy	<.01	-.13	.19	.04	**.35****	**-.30***
AFT VF	-.04	-.11	.20	-.07	-.06	-.07
AFT Time	.13	.21	.13	.05	-.13	.12

*p<.05, **p<.01. *Note*. GCS and Days since injury only apply to the TBI group, all other variables include both the TBI and Control Group data; GCS=Glasgow Comas Scale; POC= Person of color; VF= Valence Factor.

The AFT Valence Accuracy scores for positive and negatively valenced faces are presented in Table 2.26. The greatest difference between groups was among the negatively valenced faces. Although this difference was not significant, there was a small to medium effect

size indicating that controls were better at correctly identifying negative faces than those with TBI.

Table 2.26

AFT Accuracy Scores for Positively and Negatively Valenced Faces

AFT Accuracy Scores	TBI *M* (*SD*)	Control *M* (*SD*)	*t*	*df*	*p*	Cohen's d
AFT Neg Val Accuracy	8.54 (1.29)	8.97 (.76)	1.83	75.86	.07	.41
AFT Pos Val Accuracy	8.88 (1.62)	8.80 (1.54)	-.20	76	.84	.05

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

A factorial ANOVA was run to determine if valence factor scores varied by type of face and group. Findings revealed a significant main effect for group (F(1, 228) = 5.52, p = .02, Ω = .2%) and category of faces (F(2,228) = 992.68, p <.01, Ω = 89.3%). There was no significant interaction (F(2, 228) = .31, p = .73). Simple effects contrasts comparing TBI to controls by type of face revealed that those with TBI responded in a significantly more positive way than controls when responding to negatively valenced faces (see Table 2.27).

Table 2.27

Group Differences Between AFT Valence Factors

AFT Valence Factors	TBI *M* (*SD*)	Control *M* (*SD*)	*t*	*df*	*p*	Cohen's *d*
Negative VF	-1.16 (.37)	-1.32 (.24)	-2.27	75.63	**.03**	**.51**
Ambiguous VF	-.11 (.39)	-.26 (.39)	-1.57	76	.12	.39
Positive VF	1.51 (.44)	1.45 (.43)	-.63	76	.53	.14

*p<.05, **p<.01; *Note*. VF = Valence Factor.

A factorial ANOVA was run to determine if time to respond varied by type of face and group. Findings revealed no significant main effect for group or valence. Planned contrasts also revealed no group differences (Table 2.28).

Table 2.28

Group Differences in Time to Respond on the AFT

AFT Reaction Times	TBI *M* (*SD*)	Control *M* (*SD*)	*t*	*df*	*p*	Cohen's d
Overall RT	11.24 (4.7)	11.05 (4.93)	.79	76	.88	.04
RT for Negative Faces	9.71 (5.14)	8.96 (4.83)	-.64	76	.52	.15
RT for Ambiguous Faces	13.17 (5.51)	12.96 (5.28)	-.16	76	.87	.04
RT for Positive Faces	8.72 (3.98)	9.17 (5.66)	.42	76	.68	.09

Note. RT = Reaction Time

Objective 2. Examining effect of mood on performance.

Greater self-reported negative affect was predicted to be associated with a more negative interpretation bias on the AFT. Conversely, positive affective states would be associated with a more positive interpretation bias. In addition, social functioning as measured by the NeuroQOL was predicted to be positively associated with VF accuracy and positive affective biases among those with TBI. Spearman's rho correlations were used to examine the relationships between the AFT and self-report measures as the AFT scores were not normally distributed as indicated by examining normality plots and Shapiro Wilk's test for normality ($p<.05$). No outliers were identified or removed.

Findings indicated that among those with TBI, VF Accuracy scores for positive faces were positively correlated with NeuroQOL Ability scores (Table 2.29). A more positive bias on

the VF for ambiguous and positive faces was also associated with better performance on the NeuroQOL ability scores. A positive bias when interpreting positively valenced faces was associated with higher NeuroQOL ability and satisfaction scores.

Table 2.29

Correlations Between the AFT and Symptom Scores for the TBI Group

AFT Scores	BSI GSI	BSI Dep	BSI Anx	BSI Som	PANAS NA	PANAS PA	CDRSI SC	Neuro QOL Ability	Neuro QOL Satisfaction
Negative Faces Accuracy	.16	.13	.26	.02	.12	.11	-.01	-.01	-.12
Positive Faces Accuracy	-.05	.00	-.12	.02	-.09	.06	.15	**.42****	.26
Overall VF	-.13	-.05	-.20	-.12	-.16	-.14	-.12	.25	.19
Negative Faces VF	.07	.08	-.06	.17	-.01	-.09	-.03	-.23	-.04
Ambiguous Faces VF	-.18	-.12	-.16	-.25	-.19	-.12	.15	**.32***	.20
Positive Faces VF	-.18	-.11	-.20	-.15	-.17	.09	.15	**.43****	**.32***

*p<.05, **p<.01. *Note.* VF = Valence Factor, GSI = Global Severity Index.

Among the controls, accuracy at identifying positively valenced faces was negatively correlated with BSI GSI scores and BSI Anxiety scores (Table 2.30). A more negative interpretation bias on the AFT VF for positive faces was also associated with greater BSI Anxiety scores. No other correlation coefficients were statistically significant.

Table 2.30

Correlations Between the AFT and Symptom Scores for the Control Group

AFT Scores	BSI GSI	BSI Dep	BSI Anx	BSI Som	PANAS NA	PANAS PA	CDRIS C	Neuro QOL Ability	Neuro QOL Satisfaction
Negative Faces Accuracy	.07	.14	.10	.01	.19	-.02	.07	.06	.03
Positive Faces Accuracy	**-.37***	-.30	**-.41***	-.15	-.21	-.02	.13	.09	.20
Overall VF	-.23	-.24	-.26	-.08	-.10	.21	-.14	-.04	.30
Negative Faces VF	-.03	-.04	-.02	.01	.10	-.11	-.20	-.06	.03
Ambiguous Faces VF	-.16	-.12	-.11	-.06	.18	.05	-.23	-.10	.25
Positive Faces VF	-.34	-.31	**-.39***	-.17	.04	-.24	.13	.06	.26

*p<.05, **p<.01. *Note.* VF = Valence Factor, GSI = Global Severity Index.

When the groups were combined, AFT VF Accuracy at identifying positively valenced faces was positively correlated with NeuroQOL scores (Table 2.31). In addition, a more negative bias when interpreting positively valenced faces was significantly associated with higher scores on the BSI GSI and BSI Anxiety subscale. In addition, a more positive bias when interpreting positively valenced faces was associated with higher scores on the NeuroQOL measures.

Table 2.31

Correlations Between the AFT and Symptom Scores for Combined Groups

AFT Scores	BSI GSI	BSI Dep	BSI Anx	BSI Som	PANAS NA	PANAS PA	CD-RISC	Neuro QOL Ability	Neuro QOL Satisfaction
Negative Faces Accuracy	.13	.13	.21	.04	.16	.07	.01	-.01	-.07
Positive Faces Accuracy	-.16	-.08	-.22	-.05	-.14	.03	.14	**.31****	**.25***
Overall VF	-.15	-.06	-.17	-.13	-.16	-.01	-.02	.15	.20
Negative Faces VF	.04	.03	-.05	.09	-.06	-.03	-.08	-.15	-.02
Ambiguous Faces VF	-.15	-.07	-.09	-.20	-.14	.01	-.01	.17	.19
Positive Faces VF	**-.23***	-.13	**-.24***	-.15	-.19	.05	.11	**.31****	**.29***

*p<.05, **p<.01. *Note.* VF = Valence Factor, GSI = Global Severity Index.

Objective 3. Moderation analyses.

In order to examine whether relationships between self-reported symptoms and performances on the AFT were moderated by the presence of TBI, we examined the univariate correlations to select the measures that would most likely produce moderation effects. TBI and NeuroQOL Ability scores were predicted to be independent predictors of AFT VF Accuracy for positively valenced faces after controlling for demographic influences. It was further predicted that TBI would moderate the relationship between NeuroQOL ability and AFT VF Accuracy. In addition, we hypothesized that TBI and BSI Anxiety would independently predict AFT VF for positive faces and that TBI would moderate the relationship between BSI Anxiety and AFT VF. We conducted moderation analyses that also controlled for education level. Variables included in the analyses were selected based on findings from the univariate analyses. As such, AFT VF for positive faces was selected as an outcome measure of interest as was AFT VF for positive faces. NeuroQOL and BSI measures were included as predictors. All assumptions of the regression

models were adequately met. Multicollinearity was high (VIF>10) between group and the interaction variable in the second step, which is generally considered acceptable in such analyses (Shieh, 2010).

A regression model with NeuroQOL Ability scores as the dependent variable was run that included years of education, group, AFT Accuracy for negative faces, and an interaction variable (Table 2.32). Results produced a significant model ($F(77)=3.29$, $p=.016$, Adj. $R^2=.11$). After controlling for education, TBI and NeuroQOL scores were no longer associated with AFT Accuracy of positively valenced faces.

Table 2.32

Effect of TBI and NeuroQOL Ability on AFT VF Accuracy for Positive Faces

Predictors	*B*	*SD B*	β	*t*	*p*	95% Confidence Interval	
						Lower Bound	Upper Bound
Years of edu.	.26	.10	.30	2.55	**.01**	.06	.46
Group	-.06	.50	-.01	-.12	.91	-1.05	.94
NeuroQOL	.04	.04	.12	1.02	.31	-.04	.12

We also examined the relationship between the BSI Anxiety and TBI on AFT VF for positively valenced faces (Table 2.33). A regression model with AFT VF for Positive faces as the dependent variable was run that included years of education, group, and BSI Anxiety. The model was not significant ($F(77)=1.84$, $p=.15$, Adj. $R^2 = .03$).

Table 2.33

Effect of TBI and BSI Anxiety on AFT VF of Positively Valenced Faces

Predictors	*B*	*SD B*	β	*t*	*p*	95% Confidence Interval	
						Lower Bound	Upper Bound
Years of edu.	.04	.02	.23	1.98	**.05**	<.01	.08
Group	.10	.10	.12	1.02	.31	-.10	.31
BSI Anxiety	-.01	.01	-.06	-.54	.59	-.01	.01

Discussion

This study is the first to examine if TBI has an impact on a variety of cognitive-affective processes involving the negative and positive valence systems. This research question was examined using self-report measures of psychological symptoms, affect, and social participation as well as objective measures of affective processes. The affective processes measured in this study were facial affect recognition, learning and recall of emotion words, and verbal fluency of emotion words. Each measure generated scores regarding overall performance (e.g. accuracy, number of words recalled, number of words produced) and valence biases (e.g. tendency to prefer positive versus negative information). The findings from these measures are reviewed below.

Self-report Measures.

There were no significant differences on self-report measures among those with and without TBI. That said, interpretation of effect sizes revealed some important trends. The TBI group reported more depression symptoms than the controls with a trend toward significance and a medium effect size, which is consistent with the literature (Kreutzer et al., 2001). The

prevalence rates of clinically elevated symptoms of depression among those with TBI was 52%, which is higher than some studies reported (Bombardier et al., 2010; Hart et al., 2012) but consistent with the overall literature on depression and TBI (Osborn et al., 2014). After controlling for demographic factors, TBI was not a significant predictor for differences in symptom reporting for any self-report measure included in this study.

That there were no significant differences in self-report symptoms among those with and without TBI, after controlling for demographic factors, speaks to an interesting finding in this sample. The groups were matched on most demographic variables except gender, however, in a regression model, gender was not associated with symptom reporting and thus these findings are not likely attributed to gender differences. Instead, the control group endorsed a higher rate of symptomatology compared to population estimates (Kroenke et al., 2009). For instance, 34% of the control group scored in the clinically elevated range on the BSI global symptom index and more than 31% reported clinically elevated symptoms of depression. This high rate of symptoms among the control group may be a consequence of sampling biases; e.g., those motivated to participate in the study may also be those more likely to benefit from the relatively small monetary compensation and therefore may be impacted by high rates of psychosocial stressors.

When examining the influence of demographics on self-report measures, we found that among those with TBI, more years of education was associated with greater resilience and greater social participation ability. This finding is consistent with previous literature on resilience in TBI (Hanks et al., 2016). Notably, there were no significant associations between injury severity or time since injury and self-report measures. This finding is consistent with reports that injury severity and time since injury in the chronic phase among those with moderate and severe TBI does not predict psychiatric symptoms (Hart et al., 2016; Jeungst et al., 2014). Among the

controls, there were no significant associations between demographic variables and self-report symptoms.

Emotion Word Fluency Test.

With regard to demographic variables, only years of education was associated with a greater number of words generated on the EWFT. This is consistent with other measures of verbal fluency using neutral words (Henry & Crawford, 2004). Notably, this finding was only significant among those with TBI and it supports the theory that cognitive reserve is a protective factor against cognitive deficits in those with TBI (Salmond et al., 2006). Education may allow for more efficient processing or reliance on compensatory mechanisms.

There was no significant difference regarding the number of words produced on the EWFT between the TBI and control groups. This finding is notable given that a meta-analysis on verbal fluency comparing TBI to healthy controls found that there is a medium effect size for verbal fluency deficits in those with TBI (Henry & Crawford, 2004). While it is reasonable to suspect this is a finding unique to this sample, it may also be that emotion word generation taps into neural networks distinct from, and perhaps more distributed or robust than, other verbal fluency tasks. This interpretation is supported by neuroimaging research that demonstrates emotion words are processed in distinct ways from non-emotion words (Cato et al., 2004) and involve distributed bilateral regions (Kissler et al., 2009; Scott et al., 2009). In addition, previous research has found that on timed tasks, healthy participants' physiological arousal is elevated when generating emotion words as compared to other verbal fluency tasks (Abeare et al., 2016). In this study, we found that individuals with TBI produced a similar number of

emotion words as compared to controls indicating that this cognitive-affective process may be preserved following TBI.

Performance on the EWFT was associated with self-report symptoms. Overall, negative affect and psychological distress were associated with less word production while positive affect and resilience with greater word production. These relationships were not significantly different between groups and remained significant after controlling for education level. These findings are consistent with the literature that depression is thought to negatively impact verbal fluency through problems with initiation, which slows down word production (Henry & Crawford, 2005). No studies to date have examined emotion verbal fluency in depression (see Klumpp & Deldin, 2010) but these data indicate that the emotion verbal fluency test may be an especially sensitive measure to the determinantal effects of depression on verbal fluency.

We also found that positive affect was an independent predictor of greater word production. Positive affect has been implicated in neuropsychological performance such that a more positive mood is thought be associated with better performance on some tasks. Ashby, Isen and Turken (1999) proposed that enhanced performance is due to increased dopamine levels in the brain, particularly in the prefrontal cortex and anterior cingulate. Others have proposed that happy mood states increase left frontal lobe activity (Davidson, Ekman, Saron, Senukis & Friesen, 1990). In addition, positive affect has been demonstrated to be associated with improvements in other types of cognition following TBI including problem solving and abstract reasoning (Kim et al., 2018).

The EWFT Valence Factor, which averaged the valence values of all the words generated, was not significantly different across the TBI and control groups. This finding suggests that type of emotion words produced is not influenced by the presence of TBI. In

addition, the EWFT Valence Factor was also not strongly associated with self-report measures in either group with one exception: greater negative affect was associated with generating more negative emotion words among the controls. In other words, among controls, those who endorsed more negative affect also had a negative word bias on the word generation task. This is consistent with the mood congruent theory of cognition and research that has demonstrated negative biases in depression (Gaddy & Ingram, 2014). It is also similar to findings from Abeare et al. (2016), which found that trait anxiety was associated with a bias toward negative word generation on the EWFT. Notably, this finding was not present in the TBI group, and further investigation revealed that after controlling for education, neither group nor negative affect was significantly associated with the EWFT Valence Factor.

In summary, performance on the EWFT appears to be a sensitive measure to mood states such that negative affective states including depression are associated with worse performance, and positive affective states including self-reported resilience are associated with better performance. Surprisingly, there was no difference in performance between the TBI and control group. This finding is in contrast to a wealth of literature that provides evidence that TBI negatively impacts verbal fluency (Klumpp & Deldin, 2010). The EWFT may be a unique verbal fluency task that measures a cognitive-affective process preserved following TBI.

Cognitive Affective Verbal Learning Task.

On the affective verbal learning and recall task, younger age and more years of education were significantly associated with better performance in both groups, which is consistent with studies using other verbal learning and recall measures with TBI (Norman, Evans, Miller, & Heaton, 2000).

Participants with TBI performed significantly worse on the learning and recall trials of the CAVLT as compared to controls. The TBI group also made more recognition errors and had more false positive errors. This is consistent with the literature on learning and recall of neutrally valenced words (Wiegner & Donders, 1999).

Results indicated that those with TBI had an overall more negative valence bias on learning and recall trials as compared to controls. In addition, lower GCS scores (i.e., more severe injury) were associated with a greater negative bias on learning and memory of emotion words. Further analysis revealed that while controls recalled more positive words as compared to negative words, those with TBI recalled more negative words than positive. That controls showed a bias for positive words is consistent with the existing literature on affective word learning and memory (Considine et al., 2017; Jensen et al., 2016). The finding that the TBI group did not show this bias is novel. Although attentional biases for negative words are common in depression (Gaddy & Ingram, 2014), there was no relationship between depression and negative affective biases in these analyses. As such, it appears that TBI leads to a bias towards learning and recalling negative words through alternative mechanisms not explained by depression. Since positive and negative word recall might involve different neural regions, it is possible that TBI selectively disrupts networks involved in learning and memory of positive words (Kensinger et al., 2006). Another explanatory model for this positive bias in healthy controls is the "positivity offset" theory which states that in low-threat contexts, individuals approach positively valenced or pleasing stimuli while avoiding negatively valenced stimuli (Capcioppo et al., 1999). Results of this study suggest that the "positivity offset" may be disrupted in TBI. To speculate, the muted physiological arousal in response to negatively valenced information that has been demonstrated in previous studies (de Sousa et al., 2010, 2012) may account for this difference. In other words,

if those with TBI are not physiologically aroused by negatively valenced information, there is no need to avoid it.

The absence of relationships between the valence factors and mood is notable as this is inconsistent with the literature on depression (see Gaddy & Ingram, 2014). Previous research has indicated that persons with depression have an enhanced attentional bias or faster processing for negatively valenced words (Klumpp & Deldin, 2010). Other studies have found that persons with depression lacked the attentional bias for positive words that were seen in non-depressed controls (Jensen et al., 2016). In this study we did not find any effect of depression, affect, or resilience on learning and recall of positively and negatively valenced words. Limited power and restricted range of affective words used in this measure must be considered as probable limitations in detecting this effect.

Findings revealed that depressive symptoms were significantly associated with worse performance on the CAVLT learning trials. Although there was a similar trend in the recall trials, these correlations were not significant. These findings fit the literature that indicates depression negatively impacts ability to learn and recall information (Dillon & Pizzagali, 2018). Since both TBI and depression negatively impact performance, it was reasonable to suspect that a combination of TBI and depressive symptoms would result in an exacerbation of poor performance. However, moderation analyses did not reveal any moderating effect of depression and TBI on learning or recall.

Conversely, higher positive affect, resiliency, and perceived ability and satisfaction with social participation was associated with better performance on the CAVLT. This is consistent with research that has postulated that positive affect is associated with greater performance across cognitive tasks (Ashby et al., 1999). Positive affect and resilience independently

predicted CAVLT learning scores after controlling for demographic variables and presence of TBI. While the role of negative affect on learning and memory performance has been previously investigated (Dillon et al., 2018; Dux et al., 2008), no studies could be found that directly investigated how positive affect is related to verbal learning and memory. These findings suggest it could be a useful endeavor to investigate the role of positive affect on cognition further.

In summary, the CAVLT effectively differentiated individuals with and without TBI. It demonstrated that those with TBI had worse overall verbal learning and recall. It was also sensitive to the effects of positive affect and resiliency on verbal learning and memory. In addition, it added to the literature by demonstrating that those with TBI have a bias for negatively valenced words as compared to controls, and that this bias was not attributable to depression or negative affect.

Ambiguous Faces Test.

On the AFT, years of education was associated with better performance on accurate affect recognition. This is likely in part related to level of vocabulary knowledge and therefore better recognition of words included in the stimulus set among those with higher education levels. However, since groups were matched on education level, this should not have an impact on group comparisons. Age and gender were not associated with performance, and injury severity and days since injury were not associated with performance.

Persons of color had lower valence recognition accuracy on the AFT as compared to White/Caucasians. This may be attributable to a lower education level in the POC group. However, the influence of race and culture on facial affect recognition is also implicated in this

finding. Previous research has demonstrated that there is an in-group advantage in facial affect recognition, whereby recognition is generally more accurate for perceivers from the same cultural group as emotional expressors (Elfenbein & Ambady, 2002; Hart et al., 2000; Matsumoto, 2002). Although the AFT included images of persons of color, images of White/Caucasians were the most frequently represented racial group, placing persons of color at a disadvantage. Although we did not design the measure to test for racial differences, these findings point to the importance of research that examines the influence of race, education, and culture on measurement on emotion recognition of facial expressions (see Matsumoto, 2002 for a review).

The TBI group was less accurate at identifying negatively valenced faces as negative. This was not true for positively valenced faces where accuracy rates were similarly high in both groups. Furthermore, those with TBI interpreted faces with a more positive bias. This effect was greatest among the negatively valenced faces, but was also present among the ambiguous faces. Consistent with previous research, this finding indicates that those with TBI have selective difficulty correctly identifying negatively valenced facial expressions (Drapeua et al., 2017; Genova et al., 2017; Neumann & Zupan, 2019; Spikman et al., 2013; Zupan et al., 2014). It furthers the literature by demonstrating that this valence effect is present even when there are no demands to match a specific emotion word to a facial expression as in traditional emotion recognition tasks (e.g., Kessels et al., 2014). This finding directly supports the theory that those with TBI have selective difficulty recognizing the affect of negatively valenced faces and is inconsistent with research that suggests the valence effect is solely due to limitations of task stimuli (Rosenberg et al., 2014). Since ambiguous faces also tended to be interpreted with a more

positive bias, these findings suggest that low accuracy to negatively valenced faces might be due to a positive interpretation bias. This hypothesis warrants additional investigation.

An explanation for why individuals with TBI would have a positive interpretation bias when viewing facial expressions is speculative at this time. It's possible that TBI selectively disrupts negative affective processing pathways and so the negative tone of a face is not processed as effectively after TBI. There is also a potential role of disrupted arousal processes. Research has shown that TBI results in an attenuated arousal response to negatively valenced stimuli (de Sousa et al., 2010b; de Sousa et al., 2012; Fisher et al., 2014). A lack of arousal in response to negatively valenced images may lead to a lack of sensitivity to negative cues. As such, negative faces may be misinterpreted are more neutral or pleasant. It should also be noted that on the AFT, to make an error on recognition of negative affect inherently means it was identified as neutral or positive. This in turn results in a more positive interpretation bias. As such, it is possible that the more positive bias is a function of errors recognizing negative faces rather than a true positive bias. That said, in interpersonal interactions, not recognizing negative facial expressions would typically mean they were misinterpreted as neutral or positive (i.e., non-negative). As such, this design is still relevant for studying disrupted affective processes underlying social and emotional functioning problems.

Performance on the AFT was examined in relationship to self-reported measures of psychological symptoms, affect, and social participation. These findings indicated that among those with TBI, better self-reported social participation was associated with greater accuracy at recognizing positive facial affect. It was also associated with a positive interpretation bias of ambiguous and positive faces. These findings indicate a more positive bias when interpreting facial expressions is also associated with better perceived social participation. This finding is

consistent with Genova et al. (2017). These authors found that better performance on facial affect recognition of negatively valenced faces was associated with worse self-reported quality of life. It is reasonable to suspect that deficits in identifying negative facial affect and a positive interpretation bias of ambiguous faces may be protective. As such, these individuals may have a more positive interpretation of their social participation and perhaps their quality of life. Informant reports would be useful to determine if these interpretations are accurate or a function of limited awareness. That these associations were absent from the control group indicates these associations are important in the context of TBI. Among the control group, higher anxiety was associated with a more negative interpretation bias of positively valenced faces, which is consistent with previous research (Hattingh et al., 2013).

This is the first study to examine how persons with TBI recognize valence in facial expressions instead of specific emotions. These findings indicate that persons with TBI have difficulty accurately identifying the valence of negatively valenced faces but not positively valenced faces. As such, these findings are consistent with theories that TBI disrupts interpretation of recognition of negative affect. In addition, AFT performance was associated with social functioning such that those with TBI who had a more positive interpretation bias also reported better social participation.

GENERAL DISCUSSION

In these two studies, we first developed a novel measure of affective processing and used it, along with two other measures, to examine how TBI impacted emotional functioning. Performance on three measures of affective processes were analyzed including verbal fluency of emotion words, learning and memory of emotion words, and facial affect recognition. These measures generated overall performance scores (e.g. number of words recalled) as well as valence bias scores (e.g. preference for negative v. positive words). Self-report measures of mood and social functioning were also examined in relation to performances on measures of affective processes. Findings are summarized in Tables 2.34. In short, results indicated that those with TBI showed different patterns of affective processing when compared to controls. These included differences in overall performance and valence biases on two of the three measures used (i.e., CAVLT and AFT). We also found that mood impacted overall performance on measures, but there was limited evidence of mood congruent affective biases (i.e., valence factors were not sensitive to mood). Contrary to our expectations, the negative impact of mood on affective processing was not exaggerated in those with TBI.

Table 2.34

Effect of TBI on Performance and Valence Biases Across Measures

Affective Processing Measures	Performance	Valence Biases
EWFT	No Effect	No Effect
CAVLT	Lower recall	Negative word recall bias
AFT	Lower accuracy	Positive interpretation bias

Note. Results reflect differences between those with TBI and demographically similar controls

Findings indicated that valence biases varied depending on type of task: affect recognition versus word recall. For instance, those with TBI were less accurate at perceiving negatively valenced facial expressions and thus they had a generally more positive affective bias, suggesting disruption to a negative valence system. On the other hand, those with TBI had a bias for recalling negative words as compared to positive words suggesting a preference for the negative valence system. These findings indicate that valence effects may be domain specific. Facial affect recognition involves regions of the brain (Neumann, McDonald, West, Keiski, & Wang, 2016) that are distinct from those involved in learning and recalling emotion words (Lindquist et al., 2006; Cato et al., 2004). Consistent with leading theories on how valence is represented in the brain (Lindquist et al., 2016), it is likely that positive and negative valence systems do not represent distinct neural networks but are instead integrated within domain specific cognitive-affective neural networks. As such, future research is encouraged to be mindful about making generalizations about affective processing when measuring only one type of cognitive-affective domain (e.g. affective faces vs. affective words).

One possible mechanism contributing to these findings, that was not directly measured in this study, is the influence of arousal. Studies have shown that those with TBI have lower levels

of arousal in response to negatively valenced emotional faces (de Sousa et al., 2012; Fisher et al., 2014). This is believed to be associated with neuronal loss in the amygdala and insula (Fisher et al., 2014). We suspect that a muted arousal response to negative stimuli among those with TBI may underlie some of this study's findings.

With regard to the CAVLT, we discussed how the bias for positive words among controls may be explained by the "positivity offset", which is the tendency to approach positively valenced or pleasing stimuli while avoiding non-threatening negatively valenced stimuli (Capcioppo & Bernston, 1999). This model states that in non-threatening situations, negatively valenced arousing stimuli cause unconscious avoidance. This theory is supported by behavioral studies that show preference for recall of positively valenced words among healthy controls (Considine et al., 2017; Gaddy & Ingram, 2014; Jensen et al., 2016). In contrast to the control group, the TBI group in this study showed a slight preference for negatively valenced words. The lack of a positivity bias among those with TBI may be explained by muted arousal. In other words, if those with TBI are not physiologically aroused by negatively valenced information, there is no need to avoid it.

Finally, the AFT demonstrated that those with TBI tended to interpret negative and ambiguous faces with a positive bias. Previous research has shown that those with moderate to severe TBI have muted physiological arousal in response to negatively valenced faces (de Sousa et al., 2010; de Sousa et al., 2012; Fisher et al., 2014). This muted response to typically negatively arousing stimuli, may explain the misinterpretation of valence on the faces. If negative facial expressions do not induce a typical arousal response in the subject perceiving them, they are more likely to be misinterpreted as neutral or pleasant.

Neuroimaging data points to amygdalar involvement in the responsivity to negatively arousing words and faces (Kesinger et al., 2004; Hart et al., 2000). There is also evidence of damage to the amygdala in the chronic phase of TBI (Wilde et al., 2007) as well as evidence of muted arousal (de Sousa et al., 2010; de Sousa et al., 2012; Fisher et al., 2014). Taken together these data might point to an underlying cognitive-affective process disrupted by TBI specifically related to negative arousal. This in turn may present in different ways on behavioral tasks depending on the characteristics of the stimuli. Future research could investigate this hypothesis by recording physiological responses to negatively arousing words and faces between those with and without chronic TBI. Physiological response may in turn be compared to performance on facial affect recognition and emotion word memory tasks.

Finally, there was no strong evidence that mood impacted affective processing in the context of TBI in a way that was distinct from controls. As such, this study supports prior research showing that self-rated mood can be addressed as a confound and controlled for either statistically or by using well matched comparison groups (Ietswaart et al., 2008; Milders et al., 2008; Rosenberg et al., 2019). In addition, there were no consistent relationships between mood and affective biases. However, mood did significantly influence overall performance on measures of affective processing such that, in general, positive moods were related to better performance and negative moods related to worse performances. As such, these measures may prove useful when measuring the influence of mood on cognition.

Limitations.

There are important study limitations. For one, the demographically similar control group had a high rate of depression, anxiety, and somatic complaints as compared to population norms.

As such, findings may not apply generally. That said, the control group is demographically similar to the TBI group and is likely an appropriate comparison group for this sample. Most notably, the study reports small effect sizes in a relatively small, heterogenous sample and thus some effects might be present but not have statistical significance. It should also be noted that the TBI sample represents a chronic TBI group as most members suffered injuries at least three years earlier. Therefore, compensatory mechanisms and neural reorganization may temper some of the changes in cognitive-affective processes that may be more prominent in the acute or post-acute phases. Since individuals tend to undergo assessment during the post-acute phase, future research would benefit from including participants soon after they suffered injuries. There was no validated measure of performance validity included in this study. The measures used are being investigated for embedded measures of effort in another on-going research study. Re-analysis of these data may be conducted as new information is obtained regarding how to account for effort with the measures included in this study. Finally, since this study was exploratory, significance tests were not adjusted for multiple comparisons. However, its findings are useful for generating hypotheses for future research.

Implications.

This research shows that measuring changes to positive and negative valence systems after TBI may be a fruitful endeavor, particularly if coupled with measures of arousal. More specifically, the AFT and CAVLT point to changes in negative arousal systems in response to negatively valenced faces and negatively valenced words. However, the effect of valence appears to be domain specific (e.g. faces versus words) and research within one domain (e.g. emotion language) may not generalize to other cognitive-affective domains (e.g., facial affect

recognition). Findings from the EWFT demonstrate that this measure is sensitive to the effect of mood on verbal fluency but not neurological injury from TBI. As such, when coupled with traditional verbal fluency tests, it could help differentiate verbal fluency deficits caused by TBI versus psychological distress. For studies interested in affective processing after TBI, we recommend the use of the AFT and CAVLT.

REFERENCES

Abeare, C. A., Freund, S., Kaploun, K., McAuley, T., & Dumitrescu, C. (2016). The Emotion Word Fluency Test (EWFT): Initial psychometric, validation, and physiological evidence in young adults. *Journal of Clinical and Experimental Neuropsychology*, 1–15. https://doi.org/10.1080/13803395.2016.1259396

Adolphs, R., Tranel, D., & Denburg, N. (2000). Impaired emotional declarative memory following unilateral amygdala damage. *Learning & Memory*, *7*(3), 180–186. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/10837507

Allerdings, M. D., & Alfano, D. P. (2006). Neuropsychological correlates of impaired emotion recognition following traumatic brain injury. *Brain and Cognition*, *60*(2), 193–194. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/16646115

Altgassen, M., Henry, J. D., Bürgler, S., & Kliegel, M. (2011). The influence of emotional target cues on prospective memory performance in depression. *Journal of Clinical and Experimental Neuropsychology*, *33*(8), 910–916. https://doi.org/10.1080/13803395.2011.574607

Andersson, S., Krogstad, J. M., & Finset, A. (1999). Apathy and depressed mood in acquired brain damage: relationship to lesion localization and psychophysiological reactivity. *Psychological Medicine*, *29*(2), 447–456. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/10218936

Ariza, M., Mataró, M., Poca, M. A., Junqué, C., Garnacho, A., Amorós, S., & Sahuquillo, J. (2004). Influence of extraneurological insults on ventricular enlargement and neuropsychological functioning after moderate and severe traumatic brain injury. *Journal of Neurotrauma*, *21*(7), 864–876. https://doi.org/10.1089/0897715041526203

Ashby, F. G., Isen, A. M., & Turken, A. U. (1999). A neuropsychological theory of positive affect and its influence on cognition. *Psychological Review*, *106*(3), 529–550. https://doi.org/10.1037/0033-295X.106.3.529

Babbage, D. R., Yim, J., Zupan, B., Neumann, D., Tomita, M. R., & Willer, B. (2011). Meta-analysis of facial affect recognition difficulties after traumatic brain injury. *Neuropsychology*, *25*(3), 277–285. https://doi.org/10.1037/a0021908

Barker-Collo, S., Jones, A., Jones, K., Theadom, A., Dowell, A., Starkey, N., & Feigin, V. L. (2015). Prevalence, natural course and predictors of depression 1 year following traumatic brain injury from a population-based study in New Zealand. *Brain Injury: [BI]*, *29*(7-8), 859–865. https://doi.org/10.3109/02699052.2015.1004759

Bland, A. R., Roiser, J. P., Mehta, M. A., Schei, T., Boland, H., Campbell-Meiklejohn, D. K., … Elliott, R. (2016). EMOTICOM: A Neuropsychological rest battery to evaluate emotion, motivation, impulsivity, and social cognition. *Frontiers in Behavioral Neuroscience*, *10*, 25. https://doi.org/10.3389/fnbeh.2016.00025

Bombardier, C. H., Fann, J. R., Temkin, N. R., Esselman, P. C., Barber, J., & Dikmen, S. S. (2010). Rates of major depressive disorder and clinical outcomes following traumatic brain injury. *JAMA: The Journal of the American Medical Association*, *303*(19), 1938–1945. https://doi.org/10.1001/jama.2010.599

Bombardier, C. H., Hoekstra, T., Dikmen, S., & Fann, J. R. (2016). Depression Trajectories during the First Year after Traumatic Brain Injury. *Journal of Neurotrauma*, *33*(23), 2115–2124. https://doi.org/10.1089/neu.2015.4349

Bourke, C., Douglas, K., & Porter, R. (2010). Processing of facial emotion expression in major depression: a review. *The Australian and New Zealand Journal of Psychiatry*, *44*(8), 681–696. https://doi.org/10.3109/00048674.2010.49635

Bower, G. H. (1981). Mood and memory. *The American Psychologist*, *36*(2), 129–148. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/7224324

Buhlmann, U., McNally, R. J., Etcoff, N. L., Tuschen-Caffier, B., & Wilhelm, S. (2004). Emotion recognition deficits in body dysmorphic disorder. *Journal of Psychiatric Research*, *38*(2), 201–206. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/14757335

Cacioppo, J. T., & Berntson, G. G. (1999). The Affect System: Architecture and Operating Characteristics. *Current Directions in Psychological Science*, *8*(5), 133–137. https://doi.org/10.1111/1467-8721.00031

Carroll, L. J., Cassidy, J. D., Peloso, P. M., Borg, J., von Holst, H., Holm, L., … WHO Collaborating Centre Task Force on Mild Traumatic Brain Injury. (2004). Prognosis for mild traumatic brain injury: results of the WHO Collaborating Centre Task Force on Mild Traumatic Brain Injury. *Journal of Rehabilitation Medicine: Official Journal of the UEMS European Board of Physical and Rehabilitation Medicine*, (43 Suppl), 84–105. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/15083873

Cato, M. A., Crosson, B., Gökçay, D., Soltysik, D., Wierenga, C., Gopinath, K., … Briggs, R. W. (2004). Processing words with emotional connotation: an FMRI study of time course and laterality in rostral frontal and retrosplenial cortices. *Journal of Cognitive Neuroscience*, *16*(2), 167–177. https://doi.org/10.1162/089892904322984481

Chan, D., Fox, N. C., Scahill, R. I., Crum, W. R., Whitwell, J. L., Leschziner, G., … Rossor, M. N. (2001). Patterns of temporal lobe atrophy in semantic dementia and Alzheimer's disease. *Annals of Neurology*, *49*(4), 433–442. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/11310620

Connor, K. M., & Davidson, J. R. T. (2003). Development of a new resilience scale: The Connor-Davidson resilience scale (CD-RISC). *Depression and Anxiety*, *18*(2), 76–82. Retrieved from https://onlinelibrary.wiley.com/doi/abs/10.1002/da.10113

Considine, C. M., Keatley, E., & Abeare, C. A. (2017). Cognitive-Affective Verbal Learning Test: An integrated measure of affective and neutral words. *Psychological Assessment*, *29*(3), 282–292. https://doi.org/10.1037/pas0000339

Corrigan, J. D., Selassie, A. W., & Orman, J. A. L. (2010). The epidemiology of traumatic brain injury. *The Journal of Head Trauma Rehabilitation*, *25*(2), 72–80. https://doi.org/10.1097/HTR.0b013e3181ccc8b4

Croker, V., & McDonald, S. (2005). Recognition of emotion from facial expression following traumatic brain injury. *Brain Injury: [BI]*, *19*(10), 787–799. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/16175839

Dalili, M. N., Penton-Voak, I. S., Harmer, C. J., & Munafò, M. R. (2015). Meta-analysis of emotion recognition deficits in major depressive disorder. *Psychological Medicine*, *45*(6), 1135–1144. https://doi.org/10.1017/S0033291714002591

Davidson, R. J., Ekman, P., Saron, C. D., Senulis, J. A., & Friesen, W. V. (1990). Approach-withdrawal and cerebral asymmetry: emotional expression and brain physiology. I. *Journal of Personality and Social Psychology*, *58*(2), 330–341. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/2319445

de Sousa, A., McDonald, S., & Rushby, J. (2012). Changes in emotional empathy, affective responsivity, and behavior following severe traumatic brain injury. *Journal of Clinical and Experimental Neuropsychology*, *34*(6), 606–623. https://doi.org/10.1080/13803395.2012.667067

de Sousa, A., McDonald, S., Rushby, J., Li, S., Dimoska, A., & James, C. (2010a). Understanding deficits in empathy after traumatic brain injury: The role of affective responsivity. *Cortex; a Journal Devoted to the Study of the Nervous System and Behavior*, *47*(5), 526–535. https://doi.org/10.1016/j.cortex.2010.02.004

de Sousa, A., McDonald, S., Rushby, J., Li, S., Dimoska, A., & James, C. (2010b). Why don't you feel how I feel? Insight into the absence of empathy after severe traumatic brain injury. *Neuropsychologia*, *48*(12), 3585–3595. https://doi.org/10.1016/j.neuropsychologia.2010.08.008

Delis, D. C., Kramer, J. H., Kaplan, E., & Ober, B. A. (2000). California Verbal Learning Test--Second Edition (CVLT-II). *San Antonio, TX: The Psychological Corporation*.

Demenescu, L. R., Kortekaas, R., den Boer, J. A., & Aleman, A. (2010). Impaired attribution of emotion to facial expressions in anxiety and major depression. *PloS One*, *5*(12), e15058. https://doi.org/10.1371/journal.pone.0015058

Derogatis, L. R. (2001). *BSI 18, Brief Symptom Inventory 18: Administration, scoring and procedures manual*. NCS Pearson, Incorporated.

Dethier, M., Blairy, S., Rosenberg, H., & McDonald, S. (2012). Spontaneous and posed emotional facial expressions following severe traumatic brain injury. *Journal of Clinical and Experimental Neuropsychology*, *34*(9), 936–947. https://doi.org/10.1080/13803395.2012.702734

Dillon, D. G., & Pizzagalli, D. A. (2018). Mechanisms of Memory Disruption in Depression. *Trends in Neurosciences*, *41*(3), 137–149. https://doi.org/10.1016/j.tins.2017.12.006

Drapeau, J., Gosselin, N., Peretz, I., & McKerral, M. (2017). Emotional recognition from dynamic facial, vocal and musical expressions following traumatic brain injury. *Brain Injury: [BI]*, *31*(2), 221–229. https://doi.org/10.1080/02699052.2016.1208846

Eckman, P. (1972). Universal and cultural differences in facial expression of emotion. In *Nebraska symposium on motivation* (Vol. 19, pp. 207-284).

Ekman, P., & Friesen, W. V. (1976). Measuring facial movement. *Environmental Psychology and Nonverbal Behavior*, *1*(1), 56–75. https://doi.org/10.1007/BF01115465

Elfenbein, H. A., & Ambady, N. (2002). On the universality and cultural specificity of emotion recognition: a meta-analysis. *Psychological Bulletin*, *128*(2), 203–235. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/11931516

Elliott, R., Rubinsztein, J. S., Sahakian, B. J., & Dolan, R. J. (2002). The neural basis of mood-congruent processing biases in depression. *Archives of general psychiatry*, *59*(7), 597-604.

Fann, J. R., Burington, B., Leonetti, A., Jaffe, K., Katon, W. J., & Thompson, R. S. (2004). Psychiatric Illness Following Traumatic Brain Injury in an Adult Health Maintenance Organization Population. *Archives of General Psychiatry*, *61*(1), 53–61. https://doi.org/10.1001/archpsyc.61.1.53

Fisher, A. C., Rushby, J. A., McDonald, S., Parks, N., & Piguet, O. (2015). Neurophysiological correlates of dysregulated emotional arousal in severe traumatic brain injury. *Clinical Neurophysiology: Official Journal of the International Federation of Clinical Neurophysiology*, *126*(2), 314–324. https://doi.org/10.1016/j.clinph.2014.05.033

Field, A. (2017). *Discovering statistics using IBM SPSS statistics: North American edition*. Sage.

Gaddy, M. A., & Ingram, R. E. (2014). A meta-analytic review of mood-congruent implicit memory in depressed mood. *Clinical Psychology Review*, *34*(5), 402–416. https://doi.org/10.1016/j.cpr.2014.06.001

Gawda, B., & Szepietowska, E. M. (2013). Semantic and affective verbal fluency: Sex differences. *Psychological Reports*, *113*(1), 246-256.

Gawda, B., Szepietowska, E., Soluch, P., & Wolak, T. (2017). Valence of affective verbal fluency: fMRI studies on neural organization of emotional concepts joy and fear. *Journal of Psycholinguistic Research*, *46*(3), 731-746.

Gendron, M., Lindquist, K. A., Barsalou, L., & Barrett, L. F. (2012). Emotion words shape emotion percepts. *Emotion*, *12*(2), 314–325. https://doi.org/10.1037/a0026007

Genova, H. M., Genualdi, A., Goverover, Y., Chiaravalloti, N. D., Marino, C., & Lengenfelder, J. (2017). An investigation of the impact of facial affect recognition impairments in moderate to severe TBI on fatigue, depression, and quality of life. *Social Neuroscience*, *12*(3), 303–307. https://doi.org/10.1080/17470919.2016.1173584

Gotlib, I. H., Krasnoperova, E., Yue, D. N., & Joormann, J. (2004). Attentional biases for negative interpersonal stimuli in clinical depression. *Journal of Abnormal Psychology*, *113*(1), 121–135. https://doi.org/10.1037/0021-843X.113.1.121

Gould, K. R., Ponsford, J. L., Johnston, L., & Schönberger, M. (2011). The nature, frequency and course of psychiatric disorders in the first year after traumatic brain injury: a prospective study. *Psychological Medicine*, *41*(10), 2099–2109. https://doi.org/10.1017/S003329171100033X

Hamann, S. (2001). Cognitive and neural mechanisms of emotional memory. *Trends in Cognitive Sciences*, *5*(9), 394–400. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/11520704

Hamann, S. B., Monarch, E. S., & Goldstein, F. C. (2000). Memory enhancement for emotional stimuli is impaired in early Alzheimer's disease. *Neuropsychology*, *14*(1), 82–92. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/10674800

Hamann, S., & Mao, H. (2002). Positive and negative emotional verbal stimuli elicit activity in the left amygdala. *Neuroreport*, *13*(1), 15–19. https://doi.org/10.1097/00001756-200201210-00008

Hanks, R. A., Rapport, L. J., Waldron Perrine, B., & Millis, S. R. (2016). Correlates of resilience in the first 5 years after traumatic brain injury. *Rehabilitation Psychology*, *61*(3), 269–276. https://doi.org/10.1037/rep0000069

Hart, A. J., Whalen, P. J., Shin, L. M., McInerney, S. C., Fischer, H., & Rauch, S. L. (2000). Differential response in the human amygdala to racial outgroup vs ingroup face stimuli. *Neuroreport*, *11*(11), 2351–2355. https://doi.org/10.1097/00001756-200008030-00004

Hart, T., Benn, E. K. T., Bagiella, E., Arenth, P., Dikmen, S., Hesdorffer, D. C., … Zafonte, R. (2014). Early trajectory of psychiatric symptoms after traumatic brain injury: relationship to patient and injury characteristics. *Journal of Neurotrauma*, *31*(7), 610–617. https://doi.org/10.1089/neu.2013.3041

Hart, T., Hoffman, J. M., Pretz, C., Kennedy, R., Clark, A. N., & Brenner, L. A. (2012). A longitudinal study of major and minor depression following traumatic brain injury. *Archives of Physical Medicine and Rehabilitation*, *93*(8), 1343–1349. https://doi.org/10.1016/j.apmr.2012.03.036

Hart, T., Seignourel, P. J., & Sherer, M. (2009). A longitudinal study of awareness of deficit after moderate to severe traumatic brain injury. *Neuropsychological Rehabilitation*, *19*(2), 161–176. https://doi.org/10.1080/09602010802188393

Hattingh, C. J., Ipser, J., Tromp, S. A., Syal, S., Lochner, C., Brooks, S. J., & Stein, D. J. (2012). Functional magnetic resonance imaging during emotion recognition in social anxiety disorder: an activation likelihood meta-analysis. *Frontiers in Human Neuroscience*, *6*, 347. https://doi.org/10.3389/fnhum.2012.00347

Hawthorne, G., Gruen, R. L., & Kaye, A. H. (2009). Traumatic brain injury and long-term quality of life: findings from an Australian study. *Journal of Neurotrauma*, *26*(10), 1623–1633. https://doi.org/10.1089/neu.2008.0735

Henry, J. D., & Crawford, J. R. (2004). A meta-analytic review of verbal fluency performance in patients with traumatic brain injury. *Neuropsychology*, *18*(4), 621.

Henry, J., & Crawford, J. R. (2005). A meta-analytic review of verbal fluency deficits in depression. *Journal of Clinical and Experimental Neuropsychology*, *27*(1), 78–101. https://doi.org/10.1080/138033990513654

Henry, J. D., Phillips, L. H., Crawford, J. R., Ietswaart, M., & Summers, F. (2006a). Theory of mind following traumatic brain injury: the role of emotion recognition and executive dysfunction. *Neuropsychologia*, *44*(10), 1623–1628. https://doi.org/10.1016/j.neuropsychologia.2006.03.020

Henry, J. D., Phillips, L. H., Crawford, J. R., Theodorou, G., & Summers, F. (2006b). Cognitive and psychosocial correlates of alexithymia following traumatic brain injury. *Neuropsychologia*, *44*(1), 62–72. https://doi.org/10.1016/j.neuropsychologia.2005.04.011

Hogeveen, J., Bird, G., Chau, A., Krueger, F., & Grafman, J. (2016). Acquired alexithymia following damage to the anterior insula. *Neuropsychologia*, *82*, 142-148.

Hoofien, D., Gilboa, A., Vakil, E., & Donovick, P. J. (2001). Traumatic brain injury (TBI) 10-20 years later: a comprehensive outcome study of psychiatric symptomatology, cognitive abilities and psychosocial functioning. *Brain Injury: [BI]*, *15*(3), 189–209. https://doi.org/10.1080/026990501300005659

Ietswaart, M., Milders, M., Crawford, J. R., Currie, D., & Scott, C. L. (2008). Longitudinal aspects of emotion recognition in patients with traumatic brain injury. *Neuropsychologia*, *46*(1), 148–159. https://doi.org/10.1016/j.neuropsychologia.2007.08.002

Jensen, C. G., Hjordt, L. V., Stenbæk, D. S., Andersen, E., Back, S. K., Lansner, J., … Hasselbalch, S. G. (2016). Development and psychometric validation of the verbal affective memory test. *Memory* , *24*(9), 1208–1223. https://doi.org/10.1080/09658211.2015.1087573

Juengst, S. B., Adams, L. M., Bogner, J. A., Arenth, P. M., O'Neil-Pirozzi, T. M., Dreer, L. E., … Wagner, A. K. (2015). Trajectories of life satisfaction after traumatic brain injury: Influence of life roles, age, cognitive disability, and depressive symptoms. *Rehabilitation Psychology*, *60*(4), 353–364. https://doi.org/10.1037/rep0000056

Juengst, S. B., Arenth, P. M., Whyte, E. M., & Skidmore, E. R. (2014). Brief report of affective state and depression status after traumatic brain injury. *Rehabilitation Psychology*, *59*(2), 242–246. https://doi.org/10.1037/a0036294

Kashluba, S., Hanks, R. A., Casey, J. E., & Millis, S. R. (2008). Neuropsychologic and functional outcome after complicated mild traumatic brain injury. *Archives of Physical Medicine and Rehabilitation*, *89*(5), 904–911. https://doi.org/10.1016/j.apmr.2007.12.029

Kensinger, E. A., Brierley, B., Medford, N., Growdon, J. H., & Corkin, S. (2002). Effects of normal aging and Alzheimer's disease on emotional memory. *Emotion* , *2*(2), 118–134. https://doi.org/10.1037//1528-3542.2.2.118

Kensinger, E. A., & Corkin, S. (2003). Memory enhancement for emotional words: are emotional words more vividly remembered than neutral words? *Memory & Cognition*, *31*(8), 1169–1180. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/15058678

Kensinger, E. A., & Corkin, S. (2004). Two routes to emotional memory: distinct neural processes for valence and arousal. *Proceedings of the National Academy of Sciences of the United States of America*, *101*(9), 3310–3315. https://doi.org/10.1073/pnas.0306408101

Kensinger, E. A., & Schacter, D. L. (2006). Amygdala activity is associated with the successful encoding of item, but not source, information for positive and negative stimuli. *The Journal of Neuroscience: The Official Journal of the Society for Neuroscience*, *26*(9), 2564–2570. https://doi.org/10.1523/JNEUROSCI.5241-05.2006

Kessels, R. P. C., Montagne, B., Hendriks, A. W., Perrett, D. I., & de Haan, E. H. F. (2014). Assessment of perception of morphed facial expressions using the Emotion Recognition Task: normative data from healthy participants aged 8-75. *Journal of Neuropsychology*, *8*(1), 75–93. https://doi.org/10.1111/jnp.12009

Kessler, R. C., Petukhova, M., Sampson, N. A., Zaslavsky, A. M., & Wittchen, H.-U. (2012). Twelve-month and lifetime prevalence and lifetime morbid risk of anxiety and mood disorders in the United States. *International Journal of Methods in Psychiatric Research*, *21*(3), 169–184. https://doi.org/10.1002/mpr.1359

Kim, E., Lauterbach, E. C., Reeve, A., Arciniegas, D. B., Coburn, K. L., Mendez, M. F., … ANPA Committee on Research. (2007). Neuropsychiatric complications of traumatic brain injury: a critical review of the literature (a report by the ANPA Committee on Research). *The Journal of Neuropsychiatry and Clinical Neurosciences*, *19*(2), 106–127. https://doi.org/10.1176/jnp.2007.19.2.106

Kim, S., Rath, J. F., Zemon, V., Cavallo, M. M., McCraty, R., Sostre, A., & Foley, F. W. (2018). Problem solving, biofeedback, and severe brain injury: The moderating role of positive affect. *Rehabilitation Psychology*, *63*(1), 148–154. https://doi.org/10.1037/rep0000197

Kissler, J., Herbert, C., Peyk, P., & Junghofer, M. (2007). Buzzwords: early cortical responses to emotional words during reading. *Psychological Science*, *18*(6), 475–480. https://doi.org/10.1111/j.1467-9280.2007.01924.x

Klumpp, H., & Deldin, P. (2010). Review of brain functioning in depression for semantic processing and verbal fluency. *International Journal of Psychophysiology*, *75*(2), 77-85.

Knox, L., & Douglas, J. (2009). Long-term ability to interpret facial expression after traumatic brain injury and its relation to social integration. *Brain and Cognition*, *69*(2), 442–449. https://doi.org/10.1016/j.bandc.2008.09.009

Kochanek, P. M., Berger, R. P., Bayir, H., Wagner, A. K., Jenkins, L. W., & Clark, R. S. B. (2008). Biomarkers of primary and evolving damage in traumatic and ischemic brain injury: diagnosis, prognosis, probing mechanisms, and therapeutic decision making. *Current Opinion in Critical Care*, *14*(2), 135–141. https://doi.org/10.1097/MCC.0b013e3282f57564

Koster, E. H. W., De Raedt, R., Leyman, L., & De Lissnyder, E. (2010). Mood-congruent attention and memory bias in dysphoria: Exploring the coherence among information-

processing biases. *Behaviour Research and Therapy*, *48*(3), 219–225. https://doi.org/10.1016/j.brat.2009.11.004

Kreibig, S. D. (2010). Autonomic nervous system activity in emotion: a review. *Biological Psychology*, *84*(3), 394–421. https://doi.org/10.1016/j.biopsycho.2010.03.010

Kreutzer, J. S., Seel, R. T., & Gourley, E. (2001). The prevalence and symptom rates of depression after traumatic brain injury: a comprehensive examination. *Brain Injury: [BI]*, *15*(7), 563–576. https://doi.org/10.1080/02699050010009108

Kroenke, K., Strine, T. W., Spitzer, R. L., Williams, J. B., Berry, J. T., & Mokdad, A. H. (2009). The PHQ-8 as a measure of current depression in the general population. *Journal of Affective Disorders*, *114*(1-3), 163-173.

Langenecker, S. A., Bieliauskas, L. A., Rapport, L. J., Zubieta, J.-K., Wilde, E. A., & Berent, S. (2005). Face emotion perception and executive functioning deficits in depression. *Journal of Clinical and Experimental Neuropsychology*, *27*(3), 320–333. https://doi.org/10.1080/13803390490490515720

Langlois, J. A., Rutland-Brown, W., & Wald, M. M. (2006). The epidemiology and impact of traumatic brain injury: a brief overview. *The Journal of Head Trauma Rehabilitation*, *21*(5), 375–378. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/16983222

Leppänen, J. M., Milders, M., Bell, J. S., Terriere, E., & Hietanen, J. K. (2004). Depression biases the recognition of emotionally neutral faces. *Psychiatry Research*, *128*(2), 123–133. https://doi.org/10.1016/j.psychres.2004.05.020

Lindquist, K. A., Barrett, L. F., Bliss-Moreau, E., & Russell, J. A. (2006). Language and the perception of emotion. *Emotion*, *6*(1), 125–138. https://doi.org/10.1037/1528-3542.6.1.125

Lindquist, K. A., Satpute, A. B., Wager, T. D., Weber, J., & Barrett, L. F. (2016). The brain basis of positive and negative affect: Evidence from a meta-analysis of the human neuroimaging literature. *Cerebral Cortex*, *26*(5), 1910–1922. https://doi.org/10.1093/cercor/bhv001

Marsh, A. A., Kozak, M. N., & Ambady, N. (2007). Accurate identification of fear facial expressions predicts prosocial behavior. *Emotion*, *7*(2), 239–251. https://doi.org/10.1037/1528-3542.7.2.239

Matsumoto, D. (2002). Methodological requirements to test a possible in-group advantage in judging emotions across cultures: comment on Elfenbein and Ambady (2002) and evidence. *Psychological Bulletin*, *128*(2), 236–242. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/11931517

Matt, G. E., Vázquez, C., & Campbell, W. K. (1992). Mood-congruent recall of affectively toned stimuli: A meta-analytic review. *Clinical Psychology Review*, *12*(2), 227–255. https://doi.org/10.1016/0272-7358(92)90116-P

McDonald, S. (2013). Impairments in social cognition following severe traumatic brain injury. *Journal of the International Neuropsychological Society: JINS*, *19*(3), 231–246. https://doi.org/10.1017/S1355617712001506

McDonald, S. (2017). Emotions are rising: The growing field of affect neuropsychology. *Journal of the International Neuropsychological Society: JINS*, *23*(9-10), 719–731. https://doi.org/10.1017/S1355617717000844

McDonald, S., Flanagan, S., Rollins, J., & Kinch, J. (2003). TASIT: A new clinical tool for assessing social perception after traumatic brain injury. *The Journal of Head Trauma*

Rehabilitation, *18*(3), 219–238. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/12802165

McKinlay, W. W., & Brooks, D. N. (1984). Methodological problems in assessing psychosocial recovery following severe head injury. *Journal of Clinical Neuropsychology*, *6*(1), 87–99. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/6699188

Meachen, S.-J., Hanks, R. A., Millis, S. R., & Rapport, L. J. (2008/5). The reliability and validity of the Brief Symptom Inventory−18 in persons with traumatic brain injury. *Archives of Physical Medicine and Rehabilitation*, *89*(5), 958–965. Retrieved from http://www.sciencedirect.com/science/article/pii/S0003999308000567

Milders, M., Ietswaart, M., Crawford, J. R., & Currie, D. (2008). Social behavior following traumatic brain injury and its association with emotion recognition, understanding of intentions, and cognitive flexibility. *Journal of the International Neuropsychological Society: JINS*, *14*(2), 318–326. https://doi.org/10.1017/S1355617708080351

Miller, D. M., Nowinski, J., Victorson, D. E., Peterman, A., & Perez, L. A. (2005). The Neuro-Qol Project: Establishing research priorities through aualitative research and consensus development. *Quality of Life Research: An International Journal of Quality of Life Aspects of Treatment, Care and Rehabilitation*, 2031–2031.

Neumann, D., McDonald, B. C., West, J., Keiski, M. A., & Wang, Y. (2016). Neurobiological mechanisms associated with facial affect recognition deficits after traumatic brain injury. *Brain Imaging and Behavior*, *10*(2), 569–580. https://doi.org/10.1007/s11682-015-9415-3

Neumann, D., & Zupan, B. (2019). Empathic responses to affective film clips following brain injury and the association with emotion recognition accuracy. *Archives of Physical*

Medicine and Rehabilitation, *100*(3), 458–463. https://doi.org/10.1016/j.apmr.2018.07.431

Norman, M. A., Evans, J. D., Miller, W. S., & Heaton, R. K. (2000). Demographically corrected norms for the California verbal learning test. *Journal of Clinical and Experimental Neuropsychology*, *22*(1), 80-94.

Osborn, A. J., Mathias, J. L., & Fairweather-Schmidt, A. K. (2014). Depression following adult, non-penetrating traumatic brain injury: a meta-analysis examining methodological variables and sample characteristics. *Neuroscience and Biobehavioral Reviews*, *47*, 1–15. https://doi.org/10.1016/j.neubiorev.2014.07.007

Pedrosa Gil, F., Ridout, N., Kessler, H., Neuffer, M., Schoechlin, C., Traue, H. C., & Nickel, M. (2009). Facial emotion recognition and alexithymia in adults with somatoform disorders. *Depression and Anxiety*, *26*(1), E26–E33. https://doi.org/10.1002/da.20456

Perez, L., Huang, J., Jansky, L., Nowinski, C., Victorson, D., Peterman, A., & Cella, D. (2007). Using focus groups to inform the Neuro-QOL measurement tool: exploring patient-centered, health-related quality of life concepts across neurological conditions. *The Journal of Neuroscience Nursing: Journal of the American Association of Neuroscience Nurses*, *39*(6), 342–353. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/18186419

Ponsford, J., Draper, K., & Schönberger, M. (2008). Functional outcome 10 years after traumatic brain injury: its relationship with demographic, injury severity, and cognitive and emotional status. *Journal of the International Neuropsychological Society*, *14*(2), 233-242.

Posner, J., Russell, J. A., & Peterson, B. S. (2005). The circumplex model of affect: An integrative approach to affective neuroscience, cognitive development, and psychopathology. *Development and psychopathology*, *17*(3), 715-734.

Rapcsak, S. Z., Galper, S. R., Comer, J. F., Reminger, S. L., Nielsen, L., Kaszniak, A. W., … Cohen, R. A. (2000). Fear recognition deficits after focal brain damage: a cautionary note. *Neurology*, *54*(3), 575–581. https://doi.org/10.1212/wnl.54.3.575

Rapoport, M., McCauley, S., Levin, H., Song, J., & Feinstein, A. (2002). The role of injury severity in neurobehavioral outcome 3 months after traumatic brain injury. *Neuropsychiatry, Neuropsychology, and Behavioral Neurology*, *15*(2), 123–132. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/12050475

Rolls, E. T. (2013). A biased activation theory of the cognitive and attentional modulation of emotion. *Frontiers in Human Neuroscience*, *7*, 74. https://doi.org/10.3389/fnhum.2013.00074

Rosenberg, H., Dethier, M., Kessels, R. P. C., Westbrook, R. F., & McDonald, S. (2015). Emotion perception after moderate–severe traumatic brain injury: The valence effect and the role of working memory, processing speed, and nonverbal reasoning. *Neuropsychology*, *29*(4), 509. https://doi.org/10.1037/neu0000171

Rosenberg, H., McDonald, S., Dethier, M., Kessels, R. P. C., & Westbrook, R. F. (2014). Facial emotion recognition deficits following moderate-severe Traumatic Brain Injury (TBI): re-examining the valence effect and the role of emotion intensity. *Journal of the International Neuropsychological Society: JINS*, *20*(10), 994–1003. https://doi.org/10.1017/S1355617714000940

Rosenberg, H., McDonald, S., Rosenberg, J., & Frederick Westbrook, R. (2018). Amused, flirting or simply baffled? Is recognition of all emotions affected by traumatic brain injury? *Journal of Neuropsychology*, *12*(2), 145–164. https://doi.org/10.1111/jnp.12109

Rosenberg, H., McDonald, S., Rosenberg, J., & Westbrook, R. F. (2019). Measuring emotion perception following traumatic brain injury: The Complex Audio Visual Emotion Assessment Task (CAVEAT). *Neuropsychological Rehabilitation*, *29*(2), 232–250. https://doi.org/10.1080/09602011.2016.1273118

Russell, J. A. (1980). A circumplex model of affect. *Journal of Personality and Social Psychology*. Retrieved from https://psycnet.apa.org/record/1981-25062-001

Sanchez, A., Vazquez, C., Marker, C., LeMoult, J., & Joormann, J. (2013). Attentional disengagement predicts stress recovery in depression: an eye-tracking study. *Journal of Abnormal Psychology*, *122*(2), 303–313. https://doi.org/10.1037/a0031529

Sass, K., Fetz, K., Oetken, S., Habel, U., & Heim, S. (2013). Emotional verbal fluency: A new task on emotion and executive function interaction. *Behavioral Sciences*, *3*(3), 372-387.

Schretlen, D. J., & Shapiro, A. M. (2003). A quantitative review of the effects of traumatic brain injury on cognitive functioning. *International Review of Psychiatry* , *15*(4), 341–349. https://doi.org/10.1080/09540260310001606728

Scott, G. G., O'Donnell, P. J., Leuthold, H., & Sereno, S. C. (2009). Early emotion word processing: evidence from event-related potentials. *Biological Psychology*, *80*(1), 95–104. https://doi.org/10.1016/j.biopsycho.2008.03.010

Seel, R. T., Kreutzer, J. S., Rosenthal, M., Hammond, F. M., Corrigan, J. D., & Black, K. (2003). Depression after traumatic brain injury: a National Institute on Disability and

Rehabilitation Research Model Systems multicenter investigation. *Archives of Physical Medicine and Rehabilitation*, *84*(2), 177–184. https://doi.org/10.1053/apmr.2003.50106

Shieh, G. (2010). On the Misconception of Multicollinearity in Detection of Moderating Effects: Multicollinearity Is Not Always Detrimental. *Multivariate Behavioral Research*, *45*(3), 483–507. https://doi.org/10.1080/00273171.2010.483393

Sifneos, P. E. (1973). The prevalence of "alexithymic" characteristics in psychosomatic patients. *Psychotherapy and Psychosomatics*, *22*(2), 255–262. https://doi.org/10.1159/000286529

Singer, J. A., & Salovey, P. (1988). Mood and memory: Evaluating the network theory of affect. *Clinical Psychology Review*, *8*(2), 211–251. https://doi.org/10.1016/0272-7358(88)90060-8

Spikman, J. M., Milders, M. V., Visser-Keizer, A. C., Westerhof-Evers, H. J., Herben-Dekker, M., & van der Naalt, J. (2013). Deficits in facial emotion recognition indicate behavioral changes and impaired self-awareness after moderate to severe traumatic brain injury. *PloS One*, *8*(6), e65581. https://doi.org/10.1371/journal.pone.0065581

Spikman, J. M., Timmerman, M. E., Milders, M. V., Veenstra, W. S., & van der Naalt, J. (2012). Social cognition impairments in relation to general cognitive deficits, injury severity, and prefrontal lesions in traumatic brain injury patients. *Journal of Neurotrauma*, *29*(1), 101–111. https://doi.org/10.1089/neu.2011.2084

Straube, T., Sauer, A., & Miltner, W. H. R. (2011). Brain activation during direct and indirect processing of positive and negative words. *Behavioural Brain Research*, *222*(1), 66–72. https://doi.org/10.1016/j.bbr.2011.03.037

Surcinelli, P., Codispoti, M., Montebarocci, O., Rossi, N., & Baldaro, B. (2006). Facial emotion recognition in trait anxiety. *Journal of Anxiety Disorders*, *20*(1), 110–117. https://doi.org/10.1016/j.janxdis.2004.11.010

Surguladze, S., Brammer, M. J., Keedwell, P., Giampietro, V., Young, A. W., Travis, M. J., … Phillips, M. L. (2005). A differential pattern of neural response toward sad versus happy facial expressions in major depressive disorder. *Biological Psychiatry*, *57*(3), 201–209. https://doi.org/10.1016/j.biopsych.2004.10.028

Teasdale, G., & Jennett, B. (1974). Assessment of coma and impaired consciousness. A practical scale. *The Lancet*, *2*(7872), 81–84. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/4136544

Tottenham, N., Tanaka, J. W., Leon, A. C., McCarry, T., Nurse, M., Hare, T. A., … Nelson, C. (2009). The NimStim set of facial expressions: judgments from untrained research participants. *Psychiatry Research*, *168*(3), 242–249. https://doi.org/10.1016/j.psychres.2008.05.006

Turkstra, L. S., Kraning, S. G., Riedeman, S. K., Mutlu, B., Duff, M., & VanDenHeuvel, S. (2017). Labelling facial affect in context in adults with and without TBI. *Brain Impairment: A Multidisciplinary Journal of the Australian Society for the Study of Brain Impairment*, *18*(1), 49–61. https://doi.org/10.1017/BrImp.2016.29

van Tol, M. J., Demenescu, L. R., Van der Wee, N. J., Kortekaas, R., Marjan, N., Den Boer, J. A., ... & Veltman, D. J. (2012). Functional magnetic resonance imaging correlates of emotional word encoding and recognition in depression and anxiety disorders. *Biological psychiatry*, *71*(7), 593-602. https://doi.org/10.1016/j.biopsych.2011.11.016

Vytal, K., & Hamann, S. (2010). Neuroimaging support for discrete neural correlates of basic emotions: a voxel-based meta-analysis. *Journal of cognitive neuroscience*, *22*(12), 2864-2885.

Warriner, A. B., Kuperman, V., & Brysbaert, M. (2013). Norms of valence, arousal, and dominance for 13,915 English lemmas. *Behavior Research Methods*, *45*(4), 1191–1207. https://doi.org/10.3758/s13428-012-0314-x

Watson, D., Clark, L. A., & Tellegen, A. (1988). Development and validation of brief measures of positive and negative affect: the PANAS scales. *Journal of Personality and Social Psychology*, *54*(6), 1063–1070. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/3397865

Watson, D., & Tellegen, A. (1985). Toward a consensual structure of mood. *Psychological Bulletin*, *98*(2), 219–235. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/3901060

Wearne, T., Osborne-Crowley, K., Rosenberg, H., Dethier, M., & McDonald, S. (2018). Emotion recognition depends on subjective emotional experience and not on facial expressivity: evidence from traumatic brain injury. *Brain Injury: [BI]*, 1–11. https://doi.org/10.1080/02699052.2018.1531300

Werner, C., & Engelhard, K. (2007). Pathophysiology of traumatic brain injury. *British Journal of Anaesthesia*, *99*(1), 4–9. https://doi.org/10.1093/bja/aem131

Wiegner, S., & Donders, J. (1999). Performance on the California Verbal Learning Test after traumatic brain injury. *Journal of Clinical and Experimental Neuropsychology*, *21*(2), 159–170. https://doi.org/10.1076/jcen.21.2.159.925

Wilde, E. A., Bigler, E. D., Hunter, J. V., Fearing, M. A., Scheibel, R. S., Newsome, M. R., … Levin, H. S. (2007). Hippocampus, amygdala, and basal ganglia morphometrics in

children after moderate-to-severe traumatic brain injury. *Developmental Medicine & Child Neurology*, *49*(4), 294–299. Retrieved from https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1469-8749.2007.00294.x

Wilde, E. A., Whiteneck, G. G., Bogner, J., Bushnik, T., Cifu, D. X., Dikmen, S., … von Steinbuechel, N. (2010). Recommendations for the use of common outcome measures in traumatic brain injury research. *Archives of Physical Medicine and Rehabilitation*, *91*(11), 1650–1660.e17. https://doi.org/10.1016/j.apmr.2010.06.033

Williams, M. W., Rapport, L. J., Millis, S. R., & Hanks, R. A. (2014). Psychosocial outcomes after traumatic brain injury: life satisfaction, community integration, and distress. *Rehabilitation Psychology*, *59*(3), 298–305. https://doi.org/10.1037/a0037164

Williams, C., & Wood, R. L. (2010). Alexithymia and emotional empathy following traumatic brain injury. *Journal of clinical and experimental neuropsychology*, *32*(3), 259-267.

Williamson, M. L. C., Elliott, T. R., Berry, J. W., Underhill, A. T., Stavrinos, D., & Fine, P. R. (2013). Predictors of health-related quality-of-life following traumatic brain injury. *Brain Injury: [BI]*, *27*(9), 992–999. https://doi.org/10.3109/02699052.2013.801512

Woud, M. L., Zhang, X. C., Becker, E. S., Zlomuzica, A., & Margraf, J. (2016). Catastrophizing misinterpretations predict somatoform-related symptoms and new onsets of somatoform disorders. *Journal of Psychosomatic Research*, *81*, 31–37. https://doi.org/10.1016/j.jpsychores.2015.12.005

Wundt, W. M., & Judd, C. H. (1897). *Outlines of psychology*(Vol. 1). Scholarly Press.

Yates, P. J. (2003). Psychological adjustment, social enablement and community integration following acquired brain injury. *Neuropsychological Rehabilitation*, *13*(1-2), 291–306. https://doi.org/10.1080/09602010244000408

Zhang, F., & Parmley, M. (2015). Emotion attention and recognition of facial expressions among close friends and casual acquaintances. *Journal of Social and Personal Relationships*, *32*(5), 633–649. https://doi.org/10.1177/0265407514541073

Zupan, B., Babbage, D., Neumann, D., & Willer, B. (2014). Recognition of facial and vocal affect following traumatic brain injury. *Brain Injury: [BI]*, *28*(8), 1087–1095. https://doi.org/10.3109/02699052.2014.901560

APPENDICES

APPENDIX A. Demographics Questionnaire.

DEMOGRAPHIC INTAKE FORM

Participant ID Number: _____ Today's Date: _____

Interviewer: _____

PERSONAL INFORMATION

Age: Gender: M F Date of Birth: Race:
Marital Status: Single Married Divorced Separated Widowed
Writing Hand (as a child): Right Left Both

EDUCATION HISTORY

Highest grade or degree achieved:
Number of years of formal education:
What kind of grades did you get in school?

PAST MEDICAL HISTORY

Do you have a history of any of the following? (Circle) Stroke TIAs Dementia Brain tumour

Seizures Multiple Sclerosis Headaches Migraines

Insomnia Intellectual Disability

MENTAL HEALTH HISTORY

Before your brain injury were you ever diagnosed with or treated for:

Anxiety Depression Panic Attacks Schizophrenia Bipolar Alcoholism

Substance abuse Sleep difficulties

Describe onset, duration, and treatment:

After your brain injury were you ever diagnosed with or treated for:

Anxiety Depression Panic Attacks Schizophrenia Bipolar Alcoholism

Substance use Sleep difficulties

Describe onset, duration, and treatment:

Ever been in a psychiatric hospital	Yes No When?_____

FAMILY MENTAL HEALTH HISTORY

Do any of the following disorders run in your family? (circle all that apply)

Anxiety Depression Panic Attacks Schizophrenia Bipolar Alcoholism

Substance use

Other: _____

CURRENT PSYCHOSOCIAL STATUS

Primary Language Spoken at Home: Fluent in English? Y N

Current/Past Social Habits
How many hours of sleep did you get last night? _____ Do you feel rested? Yes No How many hours do you typically get? _____ Do you typically feel sleepy at any point during the day? Describe. Yes No

APPENDIX B. Cognitive-Affective Verbal Learning Test

Sample image.

Instructions: I am going to read a list of words to you. Listen carefully, because after I am done, I would like you to repeat back as many words as you can remember. Do not worry about the order of the words, just try to repeat back as many as you can remember. Are you ready? *Trial 1*
I will now read that same list of words again. Repeat back as many of the words as you can remember, in any order. Do not leave out words simply because you repeated them in the last trial.
Are you ready? *Trials 2-5*

	1st Trial	2nd Trial	3rd Trial	4th Trial	5th Trial
column					
triumphant					
context					
theory					
aroused					
sad					
method					
engine					
happy					
utensil					
lonely					
misery					
reserved					
tool					
afraid					
proud					

APPENDIX C. Ambiguous Faces Test.

Example stimuli.

Neutral	Resentful	Hateful	Intrigued	Confident

APPENDIX D. Emotion Word Fluency Test

For this next task, I would like you to give me as many different EMOTION words as you can in 1 minute.

Emotions
15”
30”
45”
60”

APPENDIX E. Positive and Negative Affective Schedule- 20

Indicate the extent you have felt this way over the past week.		Very slightly or not at all	A little	Moderately	Quite a bit	Extremely
PANAS 1	Interested	1	2	3	4	5
PANAS2	Distressed	1	2	3	4	5
PANAS3	Excited	1	2	3	4	5
PANAS4	Upset	1	2	3	4	5
PANAS5	Strong	1	2	3	4	5
PANAS6	Guilty	1	2	3	4	5
PANAS7	Scared	1	2	3	4	5
PANAS8	Hostile	1	2	3	4	5
PANAS9	Enthusiastic	1	2	3	4	5
PANAS10	Proud	1	2	3	4	5
PANAS11	Irritable	1	2	3	4	5
PANAS12	Alert	1	2	3	4	5
PANAS13	Ashamed	1	2	3	4	5
PANAS14	Inspired	1	2	3	4	5
PANAS15	Nervous	1	2	3	4	5
PANAS16	Determined	1	2	3	4	5
PANAS17	Attentive	1	2	3	4	5
PANAS18	Jittery	1	2	3	4	5
PANAS19	Active	1	2	3	4	5
PANAS20	Afraid	1	2	3	4	5

APPENDIX F. BSI – Example Questions

Brief Symptom Inventory

1	Not at all
2	A little bit
3	Moderately
4	Quite a bit
5	Extremely

1. Nervousness or shakiness inside.

2. Faintness or dizziness.

3. The idea that someone else can control your thoughts.

4. Feeling others are to blame for most of your troubles.

5. Trouble remembering things.

6. Feeling easily annoyed or irritated.

7. Pains in heart or chest

8. Feeling afraid in open spaces.

9. Thoughts of ending your life.

10. Feeling that most people cannot be trusted.

11. Poor appetite.

12. Suddenly scared for no reason.

13. Temper outbursts that you could not control.

14. Feeling lonely even when you are with people.

15. Feeling blocked in getting things done.

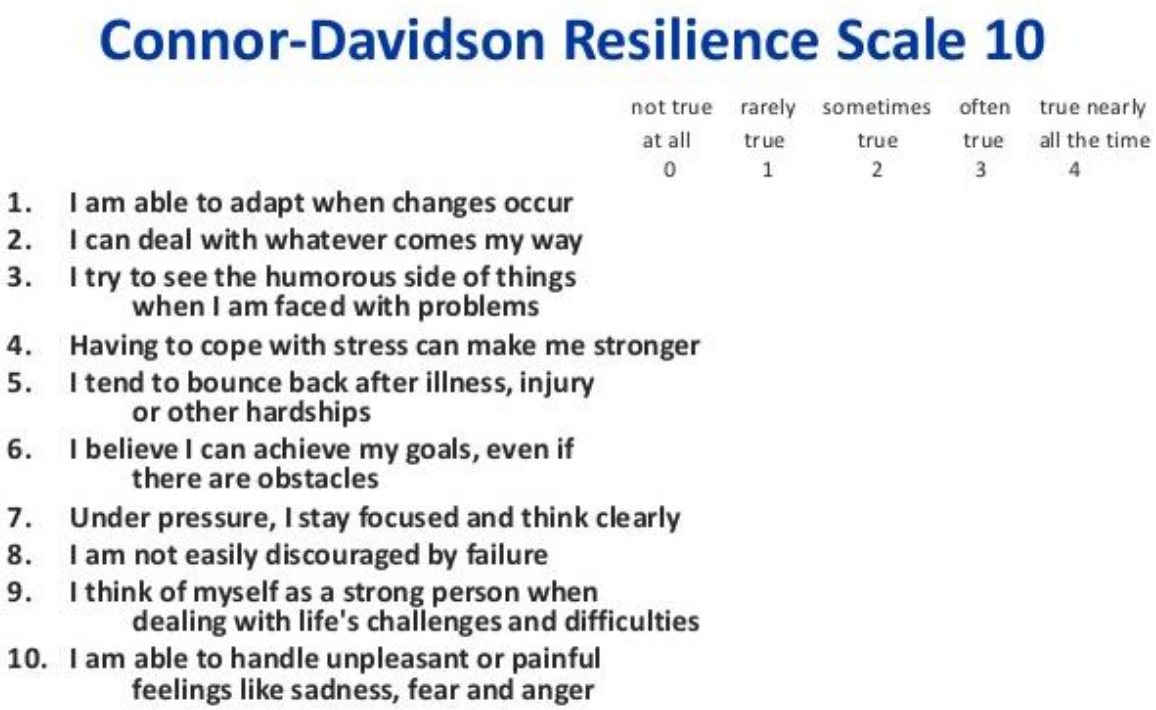
16. Feeling lonely.

17. Feeling blue.

18. Feeling no interest in things.

APPENDIX G. Conner-Davidson Resiliency Scale.

Example image.



APPENDIX H. Neuro-QOL.Short Forms.

Ability to Participate in Social Roles and Activities – Short Form

Please respond to each question or statement by marking one box per row. In the past 7 days…	Never	Rarely	Sometimes	Often	Always
I can keep up with my family responsibilities……	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
I am able to do all of my regular family activities…….	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
I am able to socialize with my friends…..	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
I am able to do all of my regular activities with friends…….	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
I can keep up with my social commitments……..	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
I am able to participate in leisure activities…….	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
I am able to perform my daily routines…..	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
I can keep up with my work responsibilities (include work at home)….	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

Satisfaction with Social Roles and Activities – Short Form

Please respond to each question or statement by marking one box per row. In the past 7 days…	Not at all	A little bit	Somewhat	Quite a bit	Very much
I am bothered by my limitations in regular family activities	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1
I am disappointed in my ability to socialize with my family……...	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1
I am bothered by limitations in my regular activities with friends……	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1
I am disappointed in my ability to meet the needs of my friends	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1

VITA AUCTORIS

Eva Keatley was born in 1986 in Brussels, Belgium. She graduated from Washington International School in 2004. From there she went on to the University of California, San Diego where she obtained a B.Sc. in Cognitive Science in 2009. She obtained her Master's in Clinical Psychology at the University of Windsor in 2015. She is currently a candidate for the Doctoral degree in Clinical Psychology at the University of Windsor and hopes to graduate in Fall 2019.