Emotion Recognition after Traumatic Brain Injury (TBI) - A General or a Selective Impairment?

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Emotion Recognition after Traumatic Brain Injury (TBI) - A General or a Selective Impairment?

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A thesis submitted in fulfilment of the requirements for the degree of Doctor of Philosophy/Master of Psychology (Clinical)

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Abstract

Moderate-severe Traumatic Brain Injury (TBI) has been shown to reduce the ability to correctly recognise the emotions expressed by others. Perception of negative emotions (sadness, disgust, fear, and anger) is reportedly affected more than positive (happiness and surprise) ones. The overarching aim of this thesis was to re-examine emotion recognition in individuals with TBI, and specifically, to explore whether TBI impairs the recognition of some emotions more than others. This was done by applying the Emotion Recognition Task (ERT; Montagne, Kessels, De Haan, & Perrett, 2007), and the Complex Audio-Visual Emotion Assessment Task (CAVEAT), a novel measure of emotion recognition which was designed to overcome the limitations of the conventional emotion recognition measures. The role of neuropsychological functioning in emotion recognition was also examined in light of the dynamic nature of the tasks used in this thesis. The psychometric properties of the CAVEAT and its ecological validity were also examined.
These were addressed by eight studies, which together constitute an empirical endeavour to explore emotion recognition deficits in TBI. Study 1 and 2 used the ERT to investigate the recognition of the six basic emotions across varying intensity. Studies 3A-3C described the development and pilot testing of CAVEAT, and Study 3D tested performance on the six basic emotions from the CAVEAT. Study 4 explored the psychometric properties of the CAVEAT, and Study 5 examined the role of neuropsychological functioning in CAVEAT performance and its ecological validity.
Combined, these findings suggest that moderate-severe TBI results in an overall impairment in emotion recognition, which is largely independent from neuropsychological functioning. The evidence of selective impairment in recognising some emotions compared to others (e.g., negative compared to positive), might be an artefact of the conventional measures of facial affect recognition used, which do not examine variance in the difficulty of emotions and which, consequently, may produce erroneous conclusions about differential impairment. These findings weaken arguments that emotion recognition is mediated by separate neural pathways underlying the recognition of positive and negative emotions and which are differentially affected by TBI. Finally, they strengthen the role of emotion recognition in the social dysfunction following TBI.

ORIGINALITY STATEMENT

I hereby declare that this submission is my own work and to the best of my knowledge it contains no materials previously published or written by another person, or substantial proportions of material which have been accepted for the award of any other degree or diploma at UNSW or any other educational institution, except where due acknowledgement is made in the thesis. Any contribution made to the research by others, with whom I have worked at UNSW or elsewhere, is explicitly acknowledged in the thesis. I also declare that the intellectual content of this thesis is the product of my own work, except to the extent that assistance from others in the project's design and conception or in style, presentation and linguistic expression is acknowledged.

Signed ___________________________

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Abstract

Traumatic brain injury (TBI), which most commonly results from motor-vehicle accidents, falls, assaults, and warfare, is estimated to affect approximately 10 million people each year, and is a leading cause of death and disability in young adults. A growing body of research indicates that a large proportion of people with moderate-severe TBI are impaired in their ability to correctly recognise the emotions expressed by others, and that these deficits are observed when emotions are presented as a static photograph of a face, a video presentation, emotionally charged voices, or audio-visual displays. A common finding of emotion recognition research is that people with TBI show a greater impairment in their ability to recognise negative emotions (fear, sadness, anger, and disgust) compared to positive emotions (happiness and surprise). The reasons for this 'valence effect' are not well understood. While it is possible that TBI has a greater impact on negative emotional expressions due to the propensity for damage to occur in these ventral frontal systems, this explanation seems unlikely given the heterogeneous nature of TBI, and the finding that greater impairment of negative emotions is consistently observed in other neurological and psychiatric patient groups as well. An alternative explanation might be that the valence-based discrepancy in emotion recognition that is observed in TBI is an artefact of the tasks used.

The overarching aim of this thesis was to re-examine emotion recognition in individuals with moderate-severe TBI, and specifically, to explore whether TBI indeed results in specific impairments in recognising some emotions compared to others, and if the valence effect largely reported in the literature is a true consequence of TBI, or an artefact of the conventional emotion recognition measures used. This was done by applying an existing task, the ERT (Montagne, Kessels, De Haan, & Perrett, 2007), and by developing a new task, the CAVEAT to allow to examine the emotion recognition

difficulties post TBI. In addition, this thesis aimed to re-examine the role of neuropsychological functioning in emotion recognition, in light of the dynamic nature of the tasks used in this thesis. Finally, it aimed to explore the utility of CAVEAT as a clinical tool, examining its validity and reliability, and to investigate the relationship between emotion recognition as measured by CAVEAT and social functioning.

Study 1 aimed to investigate the valence effect in TBI, while examining emotion recognition across different intensities (low, medium and high), as measured by the ERT. Twenty-seven individuals with TBI and 28 matched control participants completed the ERT. Findings revealed that the TBI group was more impaired in overall emotion recognition, and less accurate recognising negative emotions. However, examining the performance across the different intensities indicated that this difference was driven by some emotions (e.g., happiness) being much easier to recognise than others (e.g., fear and surprise). These findings suggested that individuals with TBI have an overall deficit in facial emotion recognition, and that both people with TBI and control participants found some emotions more difficult than others.

Study 2 aimed to extend of the findings of Study 1 by examining differential accuracy across emotions that were (1) all full blown intensity (100%: as typically used in earlier reports) and (2) of varying intensities to equate for difficulty level, in TBI and control participants. In light of the dynamic nature of the ERT stimuli, it also aimed to examine the influences of other neuropsychological impairments on emotion perception accuracy when relative difficulty level across emotions was kept consistent. The results between the two conditions varied: (i) 100% intensity: the TBI group was impaired, compared to controls in recognising anger, fear and disgust, but not happiness, surprise or sadness, and performed worse on negative than positive emotions (ii) “equated intensity": the TBI group was poorer than controls overall, but not differentially poorer for negative emotions. Although processing speed and non-verbal reasoning were associated with emotion accuracy, injury severity by itself was a unique predictor. This suggests that when task difficulty is taken into account, individuals with TBI show impairment in recognising all facial emotions. There was no evidence for a specific impairment for negative emotions or any particular emotion. Impairment was accounted for by injury severity, rather than being a secondary effect of reduced neuropsychological functioning.

Study 3 outlined the development and pilot testing of the CAVEAT, which was developed to address the limitations of conventional emotion recognition measures. Studies 3A-3C aimed to develop a version of the CAVEAT which is both sensitive to emotion perception difficulties following TBI and other brain impairments and predictive of real world functioning. Study 3D was an auxiliary validity study that compared performance of the TBI and control groups on a subgroup of emotions from the CAVEAT that represented the six basic emotions used in conventional emotion research. This set of studies arrived at a final form of CAVEAT which was applied in Study 4 and 5 to assess emotion recognition in people with TBI and healthy controls.

Study 4 aimed to establish the psychometric properties of the CAVEAT by examining performance of a TBI group and matched controls in order to provide estimates of its reliability and validity. The findings revealed that CAVEAT demonstrated high construct validity, as evident by correlations with other measures of emotion recognition and social cognition related measures such as empathy and alexithymia (convergent validity) and discriminating between groups that are expected to have differences in their ability to recognise emotions (discriminant validity).

Additionally, CAVEAT was shown to have strong internal consistency, demonstrating that all items consistently measured emotion recognition. These findings provided some evidence for the psychometric properties of CAVEAT, indicating that it can be used as a clinical test for assessing emotion recognition in people with moderate-severe TBI.

Study 5 used CAVEAT to re-examine whether moderate-severe TBI resulted in a specific impairment in perception of some emotions compared to others (e.g., negative vs. positive and social vs. non-social). It also aimed to assess the role of neuropsychological functioning in CAVEAT performance and the relationship between emotion recognition and scores on selected measures of social outcome. Thirty-two participants with TBI and 32 matched controls completed CAVEAT, and TBI participants also completed self-report measures of psychosocial functioning. The findings revealed the TBI group performed substantially more poorly in recognising all emotions, rather than displaying a selective impairment in recognising some emotions compared to others. Although processing speed, non-verbal reasoning, and working memory were associated with emotion recognition, only injury severity and non-verbal reasoning made a unique contribution to CAVEAT performance. Emotion recognition performance in the TBI group was associated with self-reported apathy and number of friends. The findings suggest that emotion recognition deficits are a direct consequence of TBI, and have a direct effect on the social dysfunction that is associated with TBI.

Combined, the findings of these studies suggest that moderate-severe TBI results in an overall impairment in emotion recognition, which is largely independent from neuropsychological functioning. The evidence of selective impairment in recognising some emotions compared to others (e.g., negative compared to positive) in prior research, might be an artefact of the wide use of conventional measures of facial affect recognition. These measures, which do not examine variance in the difficulty of emotions may produce erroneous conclusions about differential impairment in the recognition of some emotions compared to others. These findings weaken arguments that emotion recognition is mediated by separate neural pathways underlying the recognition of positive and negative emotions and which are differentially affected by TBI. Taken together, these findings reveal that emotion recognition deficits are a direct consequence of TBI, and have a direct effect on the social dysfunction that is associated with TBI, strengthening the need to include emotion recognition as a remediation target.

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Publications Relating to this Thesis

CHAPTER 2

Rosenberg, H., McDonald, S., Dethier, M., Kessels, R. P. C., & Westbrook, 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, 20*, 1-20. doi: 10.1017/S1355617714000940

CHAPTER 3

Rosenberg, H., Dethier, M., Kessels, R. P. C., Westbrook, R. F., & McDonald, S. (2015, February 2). Emotion Perception after Moderate–Severe Traumatic Brain Injury: The Valence Effect and the Role of Working Memory, Processing Speed, and Nonverbal Reasoning. *Neuropsychology*. Advance online publication. http://dx.doi.org/10.1037/neu0000171

CHAPTER 6

Rosenberg, H., McDonald, S., Rosenberg, J., Westbrook, R. F. (Submitted). Amused, flirting or simply baffled? Is recognition of all emotions affected by Traumatic Brain Injury (TBI)?

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List of Abbreviations

ANOVA	Analysis of Variance
ANCOVA	Analysis of Covariance
BEES	Balanced Emotional Empathy Scale
CAVEAT	Complex Audio-Visual Emotion Assessment Task
CAVEAT BASIC	Complex Audio-Visual Emotion Assessment Task which includes vignettes pertaining to the six basic emotions
COWAT	Controlled Oral Word Association Test
CT	Computed tomography
DASS-21	Depression Anxiety Stress Scales, 21-item version
DS	Digit Span, a subscale of WAIS-III
DSC	Digit Symbol Coding, a subscale of WAIS-III
ERT	Emotion Recognition Task
FEEL	Facially Expressed Emotion Labelling
FrSBe	The Frontal Systems Behavior Scale
GLM	General linear model
HTT	Hamburger turning task
JACFEE	Japanese and Caucasian Facial Expressions of Emotion
MERT	Multimodal Emotion Recognition Test
MR	Matrix Reasoning, a subscale of WAIS-III
MVA	Motor Vehicle Accident

PONS	Profile of Nonverbal Sensitivity
PTA	Post traumatic amnesia
RMET	Reading the Mind in the Eyes Test
SPRS	Sydney Psychosocial Reintegration Scale
TAS-20	Toronto Alexithymia Scale
TASIT	The Awareness of Social Interference Test
TASIT EET	The Awareness of Social Interference Test, Emotion Evaluation Test
TBI	Traumatic Brain Injury
ToM	Theory of Mind
TRENDS	Tool for Recognition of Emotions in Neuropsychiatric Disorders
WAIS-III	Wechsler Adult Intelligence Scale-Third Edition
WCST	Wisconsin Card Sorting Test
WTAR	Wechsler Test of Adult Reading

CHAPTER 1

General Introduction

Traumatic brain injury (TBI)

Traumatic brain injury (TBI) is a form of acquired brain injury, which occurs when external trauma, such as a blow to the head, injures the brain. Common causes include motor vehicle accidents, falls, assaults, and warfare, and these vary by age, socioeconomic factors, and geographic region (Bruns & Hauser, 2003). TBI is a highly prevalent condition, with an estimated 10 million new cases each year worldwide, and results in devastating long-term consequences (Langlois, Rutland-Brown, & Thomas, 2006). TBI has been shown to have a profound effect one's physical, cognitive, emotional and psychosocial functioning both immediately after the injury and long term (Hoofien, Gilboa, Vakil, & Donovick, 2001).

TBI severity is usually classified by three categories: mild, moderate and severe. Although there is usually a dose-response relationship between injury severity and post-injury outcomes, there is insufficient evidence to determine at what level of severity the adverse effects are demonstrated (Temkin, Corrigan, Dikmen, & Machamer, 2009). To make matters more complicated, the definitions of severity have changed over the past few decades. Initially a severe TBI was defined as that incurring a period of altered consciousness of 1 day or greater and very severe as 7 days or more (W. Russell & Smith, 1961). A later classification system (Williamson, Scott, & Adams, 1996) re-defined a moderate injury as a period of altered consciousness of 1-7 days, and severe injuries as associated with a period of confusion of longer than 7 days. The current research has used the later classification; however, it is important to acknowledge that some of the research cited in this thesis is based upon the original definition of severity, noting that this may sometimes include individuals with moderate injuries as defined by the later classification system. Thus, this thesis refers to individuals with moderate-severe TBI, recognising that based on the older classification system, they would all be classified as having severe and very severe injuries.

Research indicates that people with moderate-severe TBI suffer a range of deficits including neurophysical, cognitive and psychosocial (Hoofien et al., 2001; Langlois et al., 2006; Lezak, 1978; Thomsen, 1984), and these are evident both shortly after the injury and long-term (Hoofien et al., 2001). While all of these deficits affect post-injury functioning and quality of life, the effects of TBI on psychosocial functioning have been shown to pose an even greater barrier to adjustment and rehabilitation than the effects on physical and cognitive functioning (Eslinger, Grattan, & Geder, 1995; Grattan & Ghahramanlou, 2002; Yates, 2003). These psychosocial deficits are the focus of this thesis.

According to their relatives, individuals who sustain moderate-severe TBI often have changes in personality and behaviour, such as unreasonable and socially inappropriate behaviour, childishness, dislike or disinterest of others, self-centeredness, and argumentativeness (Brooks, Campsie, Symington, Beattie, & McKinlay, 1986). Thus, it is not surprising that following moderate-severe traumatic brain injury (TBI) many individuals experience a breakdown in social functioning, including reduced social networks, loss of employment, and disruption to intimate relationships (Elsass & Kinsella, 1987; Hallett, Zasler, Maurer, & Cash, 1994; Kersel, Marsh, Havill, & Sleigh, 2001; Oddy & Humphrey, 1980; Tate, Lulham, Broe, Strettles, & Pfaff, 1989; Tate, Broe, & Lulham, 1989; Thomsen, 1974; Ylvisaker & Feeney, 2000).

In a recent review of social functioning after TBI, Temkin et al. (2009) reported that TBI decreases the probability of employment after injury, lengthens the timing of their return to work (if they do return to employment), and decreases the probability that they will return to their pre-injury position. TBI was also reported to adversely affect leisure and recreation activities, social relationships, quality of life, independent living, and functional status, with a dose-response relationship between severity of injury and social outcomes, with individuals who sustained moderate-severe injuries affected the most (Temkin et al., 2009).

Overall, studies examining long-term outcome post TBI reveal, at best, a medium level of functional disability, with a rate of unemployment rate of at least 40-50% and a rate of social isolation of approx. 50-60% (see Hoofien et al., 2001) for a review). In an old but important study, a subgroup of individuals who sustained severe injuries experienced a substantial decrease in number of friends compared to pre-injury (Oddy, Humphrey, & Uttley, 1978). Bond and Godfrey (1997) compared videotaped social interaction of individuals with and without TBI. The conversations of patients with TBI were rated as significantly more effortful, less interesting, and less appropriate, than those of control subjects. This led the authors to conclude that patients with TBI are beset by problems in their social communication and behaviour.

While there are likely to be a number of factors underlying the reduced psychosocial functioning following TBI, deficits in emotion recognition have been proposed to be particularly important, as emotion recognition underlies the ability to infer the mental states of others (Bornhofen & McDonald, 2008; Knox & Douglas, 2009; Radice-Neumann, Zupan, Babbage, & Willer, 2007). Subsequently, individuals with an impaired ability to interpret facial expression may be unable to gauge the appropriateness of their own behaviour, may not fully understand the communication of others, and may not respond appropriately to others (McDonald, 2013). The ability to quickly and effectively recognise how others are feeling is crucial for successful social interactions as it provides feedback for social behaviour in interpersonal communications. Consequently, emotion recognition deficits following TBI have received an increasing amount of scientific attention over the past decades.

Emotion recognition in TBI

A growing body of research has indicated that a large proportion of individuals with TBI are impaired in their ability to correctly recognise the emotions expressed by others. This impairment has been observed when people have to judge emotional expressions, whether these are presented as a static photograph of a face, a video presentation, emotionally charged voices, or audio-visual displays (R. E. Green, Turner, & Thompson, 2004; Hopkins, Dywan, & Segalowitz, 2002; McDonald, 2003; McDonald & Flanagan, 2004; Milders, Fuchs, & Crawford, 2003; Spell & Frank, 2000). These deficits are quite robust. A recent meta-analysis on 296 adults with moderate-to-severe TBI and 296 matched controls (Babbage et al., 2011) revealed that individuals with TBI, on average, performed 1.1 SD below healthy controls on measures of facial emotion recognition. Ietswaart, Milders, Crawford, Currie, and Scott (2008) reported that, shortly after injury, patients with TBI had impaired emotion recognition for both faces and voices, compared to an orthopaedic patient control group, with no evidence of recovery at one year follow-up. This suggested that deficits in emotion recognition in this population are a direct impact of brain injury, rather than a consequence of sheer isolation from social networks and poor community reintegration, a possibility considered by a few researchers (e.g., Bornhofen & McDonald, 2008).

Emotion recognition difficulties post TBI are a serious concern. It is estimated that currently, more than 3.6 million people who sustained TBI in the United States and Europe experience significant ongoing disability due to impairments in their ability to correctlly recognise emotions from the face (Babbage et al., 2011). As noted by Babbage et al. (2011), if these incidence rates apply globally, currently, 39 million people worldwide might suffer from impairments in the ability to recognise facial affect. This numbers are astonishing, especially considering that these numbers are of a total pool of 136 million people who suffer a significant and ongoing disability following TBI (Babbage et al., 2011; Thurman, 1999).

Neural bases of emotion recognition deficits in TBI

Despite growing awareness of the prevalence of emotion perception deficits following TBI, the neural basis of these deficits is not well understood, largely due to the multifaceted nature of the injury (Bornhofen & McDonald, 2008b). Research has suggested that there are several subsystems related to emotion perception which are primarily situated in the frontal and temporal regions. Emotion perception involves complex interactions between these interrelated structures which change at different stages of the perceptual processes, as well as in response to associated cognitive demands (Bornhofen & McDonald, 2008b). Detailed description of these structures is outlined in a few comprehensive reviews (Adolphs & Damasio, 2000; Phillips, Drevets, Rauch, & Lane, 2003).

Phillips et al. (2003) identified a number of neuroanatomical structures that might potentially underpin key processes involved in emotion recognition. The authors proposed two closely linked neural systems, a ventral system (which includes the amygdala, insula, and ventral regions of the anterior cingulate gyrus and prefrontal cortex), and a dorsal system (which includes the dorsal regions of the prefrontal cortex and anterior cingulate gyrus, as well as the hippocampus). According to this model, the ventral system supports the rapid orientation to, appraisal and identification of emotionally significant information, especially threat-related, and the production of affective responses (which occur even before consciousness). The dorsal system is responsible for the effortful processing of emotional stimuli, including the engagement of other cognitive processing such as memory, language, and importantly, regulation of emotional behaviour (Bornhofen & McDonald, 2008b). The authors noted that while being anatomically independent, the two systems are not functionally independent, and subsequently, damage to either system is likely to disturb emotion perception in general. According to this model, the processes underpinned by the ventral system initiate activity in the dorsal system, and, conversely, the dorsal system can modulate or inhibit ventral activity to facilitate the rapid processing of critical emotional information (such as threat to our survival) and to ensure that our behavioural responses are contextually appropriate (Bornhofen & McDonald, 2008b). Additional evidence suggests that the somatosensory cortices may also play a role in emotion perception, with activation providing sensory information "as if" the emotional expression was one's own (Adolphs, Damasio, Tranel, Cooper, & Damasio, 2000).

There is also a debate regarding the involvement of the two hemispheres in emotional processing, and while findings remain inconclusive (Critchley et al., 2000), most, but not all evidence, is suggestive of right hemispheric primacy in emotional processing (see Bornhofen & McDonald, 2008b, for a review). Other account suggests hemispheric asymmetry in processing positive and negative emotions, with some suggesting the left hemisphere mediates processing of positive emotions, and the right hemisphere processes negative emotions (Silberman & Weingartner, 1986). Others suggest that positive emotions are processed bilaterally, whereas negative emotions are processed mainly by the right hemisphere (Adolphs et al., 2001a). To further complicate this issue, other data have suggested that the right hemisphere might be predominant in processing all emotional expressions across modalities, while the left hemisphere is modality specific (Kucharska-Pietura et al., 2003). As reviewed by Bornhofen and McDonald (2008b), although findings remain inconclusive (Critchley et al., 2000a), most evidence appears, at least, suggestive of right hemispheric primacy in emotion processing (Adolphs et al., 1996, 2002; Erhan et al., 1998). In addition, some evidence suggests that dynamic and static and auditory and visual emotional stimuli might be differentially processed (Adolphs, Damasio, & Tranel, 2002).

The neural structures associated with emotion processing, whether distributed bilaterally or lateralised, may be particularly vulnerable to damage following TBI due to the anatomical location of these structures in the temporal and frontal lobes (Fontaine et al., 1999). Most of these structures are situated near the ventral surface of the brain, which is vulnerable to abrasion and contusion as a result of being scraped across the floor of the skull (Bigler, 2001; Bigler, 2007; Bigler & Maxwell, 2011). While rapid acceleration–deceleration forces in TBI (such as those occurring during motor vehicle collisions) lead to heterogeneous brain damage, they commonly result in damage to the ventral surfaces of the frontal and temporal lobes with a number of focal injuries concentrated in the orbitomedial frontal lobes (Adams et al., 1985; Bigler, 2007; Fujiwara, Schwartz, Gao, Black, & Levine, 2008) with attendant, diffuse, axonal damage (Adams et al., 1989). Focal frontal injuries are known to result in emotion perception deficits and might, at least partially, explain the emotion recognition difficulties in TBI (Hornak, Rolls, & Wade, 1996).

Conceptualisation of Emotion

To better understand the emotion recognition difficulties in TBI, it is useful to consider the role emotion recognition and expression has in everyday life and how theoretical accounts have developed to account for this. Fundamentally, accurate emotion perception has been conceptualised as bestowing an evolutionary advantage for humans. The ability to quickly and accurately identify emotionally salient information in the physical and social environment and form appropriate behavioural responses is critical for our survival (Darwin, 1872/1965). The face and its expressions are a particularly important source of information in the social environment (Adolphs, 2002, 2003; Darwin, 1872/1965; Ekman, 1992, 1993; J.A. Russell, 1997). We have evolved complex neural systems that rapidly and accurately decode facial expressions that allow us to detect the emotional state of others, and provide cues for appropriate responding in a variety of complex social interactions (Rolls, 2000). Given the crucial role played by emotional faces in social function, over the past two decades there has been intense research activity in affective neurosciences addressed at understanding the neural mechanisms that support facial emotion perception (Fusar-Poli et al., 2009). Further, since it is commonly acknowledged that a well-grounded and valid conceptualisation of emotional knowledge is crucial to understanding the relation between the mind and the brain (Buck, 2000), several attempts to conceptualise different types of emotions have developed.

Current psychological theories of emotion differ greatly with respect to the number of emotions the theory explains and the principles that are evoked for the differentiation (Scherer, 2000). Further, they differ in the extent to which individual emotions are seen as discrete states rather than regions of a more continuous manifold

(Adolphs, 2002). In general, two main theoretical accounts of emotion perception have developed: Discrete Category and Dimensional Models.

The **Discrete Category Model** is one of the most popular conceptualisations of the nature of emotion (Scherer, 2000), and it argues for the existence of a small set of discrete emotions mediated by central affect programs (Darwin, 1872; Ekman, 1992, 1999; Izard, 1971; Panksepp, 2000; Tomkins, 1982). The term affect program refers to a neural mechanism that stores patterns for and triggers complex emotional responses that are often quick, organized, complex and difficult to control (Murphy, Nimmo-Smith, & Lawrence, 2003). The basis for a limited set of affect programs arose from research indicating that certain emotions are invariant across cultures and are represented by distinctive facial expressions (Ekman, 1992; Izard, 1971). It is now mostly accepted that six basic emotional expressions, i.e., happiness, surprise, sadness, fear, anger, and disgust, are universally perceived (Ekman et al., 1969, 1987). The narrowness of this model means it does not account for the wider array of human emotion, such as amusement, pride, jealousy, and worry (Scherer, 2000). Despite its weaknesses, however, this model has had a profound influence on emotion research, to the extent that most current emotion research is, in one way or another, influenced by the assumption of discrete fundamental emotions (Scherer, 2000). This is especially evident in current measures of emotion perception that mostly consist of a small selection of six or seven emotions, an important issue that will be discussed in a later section.

In contrast to the categorical view, **Dimensional Accounts** (e.g., Carver, Sutton, & Scheier, 2000; Davidson, 1998; J.A. Russell & Barrett, 1999) consider all emotions to be represented by a small number of dimensions that code for constructs such as emotional valence (positive vs. negative), action tendency (approach vs. withdrawal), arousal (calm vs. excited), and dominance (low vs. high). While offering a different interpretation of emotion, this account is not necessarily incompatible with the Discrete Category account and both have received some empirical support in the literature. Of the dimensional accounts of emotion, valence and action tendency have received the most attention, and the dimensions of dominance and arousal have received the least.

The fact that the valence dimension has received the most consideration compared to other emotion dimensions might be, at least partially, attributable to the importance and salience that pleasantness versus unpleasantness plays in our lives and development. Negative valence ranges from the bad, disagreeable, or unpleasant while positive valence refers to the good, agreeable, or pleasant (Scherer, 2000). Consistent with this account, a convergence of evidence from studies of people with brain damage, brain-based behavioural studies of people with emotional disorders, and EEG investigations of clinical populations and healthy controls suggest that positive and negative emotions are implemented by neural systems that are at least partially separable (Murphy et al., 2003).

The valence dimension substantially overlaps with the approach/avoidance dimension, since we are likely to approach positive stimuli and avoid negative. One potential exception to this is anger, which belongs to the negative valence, but might be viewed as being associated with both approach (if the anger is expressed actively) and avoidance (if the anger is expressed passively). Subsequently, several investigators equated positive and negative emotions with approach and avoidance respectively (Mendoza & Ruys, 2001), while others proposed critical distinctions such as emphasis on goal-directed action (Davidson, 1998). Whether grouped into a single dimension or viewed separately, the rapid and correct recognition of a stimulus as pleasant or unpleasant, and subsequently, eliciting approach or avoidance behaviour is likely to have an evolutionary advantage, with people who could not quickly and correctly make this distinction being less like to survive, reproduce, and pass on their genes to their offspring.

Another distinction has been made between social emotions (those related to social behaviour) and non-social emotions (e.g. fear) (Buck & Duffy, 1980). Social emotions were proposed to be associated with cultural and social ‘display rules’ and involve mentalistic construction of emotions as internal states, requiring the development of Theory of Mind (ToM), and developing later in childhood (Banerjee, 1997; Baron-Cohen, Jolliffe, Mortimore, & Robertson, 1997; Shamay-Tsoory, Lavidor, & Aharon-Peretz, 2008). A few studies have examined the recognition of complex emotions such as pride, embarrassment (Capps, Yirmiya, & Sigman, 1992), and jealousy (Bauminger, 2004). Despite the importance of complex social emotions, the attention they have received in the literature is substantially lower than that allocated to basic emotions (Shamay-Tsoory et al., 2008).

Do people with TBI really have problems with specific emotional categories/dimensions?

Emotion recognition research largely suggests that individuals with TBI show a greater impairment in their ability to recognise negative (fear, anger, disgust, and sadness) emotions compared to positive (happiness and surprise) (Braun, Baribeau, Ethier, Daigneault, & Proulx, 1989; Callahan, Ueda, Sakata, Plamondon, & Murai, 2011; Croker & McDonald, 2005; Dimoska, McDonald, Pell, Tate, & James, 2010; Green et al., 2004; Hopkins et al., 2002; Jackson & Moffat, 1987; Kucharska-Pietura, Phillips, Gernand, & David, 2003; McDonald et al., 2003; Prigatano & Pribam, 1982, Spikman, Milders, et al, 2013), although this is not reported consistently (e.g., McDonald & Saunders, 2005, Ietswaart, Milders, Crawford, Currie, & Scott, 2008). If it is the case that people with TBI are selectively impaired in recognising negative emotions, this has significant implications in terms of advancing theoretical knowledge of brain-behaviour relationships in TBI and also clinical applications (targets for assessment, remediation and management). However, the evidence to date is not compelling.

Orientation to and processing of threat-related emotions have been linked specifically to the ventromedial frontal regions, the amygdala, right parietal cortex and insula (Adolphs, 2002a; Adolphs, J.A. Russell, & Tranel, 1999; Adolphs & Tranel, 2004; Graham, Devinsky, & LaBar, 2007; Harmer, Thilo, Rothwell, & Goodwin, 2001; Phillips et al., 1997; Sato et al., 2002). Ventromedial frontal regions are particularly susceptible to TBI (Adams et al., 1985; Bigler, 2007; Fujiwara, Schwartz, Gao, Black, & Levine, 2008; Levin et al., 1987). Consequently, the differential impairment in the recognition of negative emotions that is observed in the majority of the research in TBI might suggest specific deficits in the ventromedial frontal system (McDonald, 2013). This seems unlikely, however, given the heterogeneity in the extent and location of neuropathology following TBI. Moreover, the ‘valence effect’ (i.e., the worse recognition of negative than positive emotions) is also observed in other neurological and psychiatric patient groups that have a wide variety of structural or functional cerebral impairments. These include Alzheimer's disease (Kohler et al., 2005), schizophrenia (Mandal, Pandey, & Prasad, 1998), stroke (Braun, Traue, Frisch, Deighton, & Kessler, 2005), and frontotemporal dementia (Fernandez-Duque & Black, 2005).

If the valence effect is due to damage to specialised neural systems underpinning negative versus positive emotions, it would be anticipated that some brain disorders would result in greater impairment of positive emotions than negative. However, this does not appear to be the case. A search of the literature reveals that while negative emotions are frequently differentially impaired, there is no evidence for a *selective* impairment in the recognition of positive expressions following damage of specific brain regions, or in patients with either psychiatric or neurological disorders (Hennenlotter & Schroeder, 2006).

While the literature suggests that the recognition of positive emotions is commonly spared, this is not to say that this is always the case. One study reported a single patient with amygdala damage, who was slightly impaired in her appraisal of happiness (Anderson & Phelps, 2000). Spikman, Boelen et al. (2013) also found impairments in the recognition of not only negative emotions but happiness and surprise in a mixed group of brain injury patients, including a large group of TBI patients. Interestingly, this seemed particular to male patients. In a study focused on TBI, a subgroup of patients with TBI with severe emotion recognition deficits were compared to a subgroup without (Zupan & Neumann, 2013). The impaired subgroup was poorer at recognising both positive and negative emotions, although the recognition of positive emotions was impaired to a much lesser extent than recognition of negative emotions, as evident by a very small effect size for positive emotions ($ŋ_p^2$ =.07) relative to negative ($ŋ_p^2$ =.60). This pattern was replicated in a more recent study of affect recognition (face and voice) across low and high intensities in a large sample of 203 participants with moderate-severe TBI (Zupan, Babbage, Neumann, & Willer, 2014). Importantly, these authors stressed that other factors, such as stimulus intensity and item difficulty, may have played a role in affect recognition.

In summary, it appears that following TBI, the recognition of negative emotions is more impaired than recognition of positive emotions (with the exception of a few important cases reviewed above). While it is possible that TBI has a greater impact on negative emotional expressions due to the propensity for damage to occur in these ventral frontal systems, this explanation seems unlikely given the heterogeneous nature of TBI, and the finding that greater impairment of negative emotions is consistently observed in other neurological or psychiatric patient groups as well. In addition, the literature largely suggests that happiness is a unique class of emotional facial expression that is almost universally recognised, regardless of clinical pathology. An alternative explanation might be that the valence-based discrepancy in emotion recognition that is observed in TBI is an artefact of the tasks used. The possibility that inherent differences in tasks used to assess positive and negative emotions lead to a valence effect in emotion recognition following TBI can be explored by examining current measures of emotion recognition.

Ecological validity

Another issue that is critical to the examination of emotion perception in people with TBI and other clinical disorders, is the extent to which the measures used have ecological validity. Ecological validity has been defined as the ability of tests to predict real world performance (Sbordone, 2001; C. H. Silver, 2000). However, in the literature, the term is often used interchangeably to describe measures of emotion recognition that resemble natural displays of emotions as seen in the real world (e.g., Rapcsak et al., 2000). The ‘naturalness’ of measures of emotion is increased by using dynamic displays of emotion, by including multi-modal cues (voice, face, gesture) and by the use of spontaneous, i.e. genuine rather than posed expressions. Throughout this thesis, ecological validity will refer to the tests ability to predict real life functioning, rather than referring to naturalistic displays of emotions.

It is a common criticism of many measures used to assess the abilities of people with brain injuries, including conventional neuropsychological tests, that despite their contribution in measuring the nature and degree of neuropsychological difficulties and informing rehabilitation, they have limited ecological validity in terms of predicting how individuals will function in everyday settings (McDonald, Flanagan, Martin, & Saunders, 2004). Since the accuracy of predicting real-life functioning in different domains on the basis of test scores increases in accordance with the similarity between the test requirements and these real-life demands (Sbordone, 2001; Wilson, 1993), it is important to develop assessment tools which map directly onto real life functioning. Using naturalistic stimuli is not only important for improving ecological validity, but also because these stimuli are complex and will therefore tax the complexity of brain systems that are likely to be involved in real life emotion perception and which may be compromised following TBI. Thus the use of naturalistic displays is not only of practical benefit (potentially increasing ecological validity) but also of benefit in terms of advancing theories regarding emotion perception.

To date, only a few studies have examined the relation between emotion perception deficits and real world functioning in TBI. Some studies found no association between facial emotion recognition and behavioural deficits, as indicated by proxy reports of their social and emotional behaviour or between their facial emotion recognition and their level of social integration, both shortly after TBI, and in the chronic stage (Croker & McDonald, 2005; Milders et al., 2003; Milders, Ietswaart, Crawford, & Currie, 2008). Other studies (e.g., Knox & Douglas, 2009; McDonald, Flanagan, Martin, & Saunders, 2004; Spikman et al., 2013; Struchen et al., 2008; Watts & Douglas, 2006) reported an association between emotion recognition and real life social functioning. This discrepancy can be partially related to the different measures employed by the different studies to assess both emotion recognition and social functioning. Overall, it seems that associations between real life functioning and audiovisual measures of emotion recognition (e.g., TASIT; McDonald, Flanagan, & Rollins, 2002) have been reported more consistently (e.g., McDonald et al., 2004; Watts & Douglas, 2006) than association with measures limited to photographs of facial expressions (e.g., Knox & Douglas, 2009; Spikman et al., 2013).

Interestingly, Knox and Douglas (2009) reported that while emotion recognition as assessed by both audiovisual and static tasks was correlated with social integration, the correlation between audiovisual emotion recognition measures and social integration score weakened when cognitive ability was controlled for. This was not the case for the emotion perception task that was limited to photographs (Ekman & Friesen, 1976). This suggested that the processing of dynamic, multimodal expressions of emotion may be more reflective of real world problems but also more reliant upon a range of cognitive abilities than the processing of static facial images.

Current emotion recognition measures

There are many unanswered questions regarding the true nature of emotion perception disorders following TBI. Of critical importance is the possibility that differential impairment, for example with respect to valence, is an artefact of the emotion recognition measures (e.g., Adolphs, 2002; Hennenlotter & Schroeder, 2006). When reviewing the emotion perception literature, it is evident that the vast majority of studies used the faces from the Pictures of Facial Affect (Ekman & Friesen, 1976) which consist of photographs of six females and five males displaying each of the six 'basic' facial expressions, as well as a neutral expression. Although this measure has proved an invaluable resource, it includes only a small number of faces, expressing posed, static, and uni-modal displays of a limited number of emotions.

Additional measures that have been developed more recently include the NimStim Face Stimulus Set (Tottenham, Borscheid, Ellertsen, Marcus, & Nelson, 2002), Japanese and Caucasian Facial Expressions of Emotion (JACFEE; Matsumoto, & Ekman, 1988), Facially Expressed Emotion Labelling (FEEL; Kessler, Bayerl, Deighton, & Traue, 2002), the FACES database (Ebner & Lindenberger, 2010), Karolinska Directed Emotional Faces Database (Lundqvist, Flykt, & Öhman, 1998), Tool for Recognition of Emotions in Neuropsychiatric Disorders; TRENDS; Behere et al., 2008), and Gur et al. (2002) set of 3-dimensional images. These newer measures attempt to increase the face validity of emotion recognition measures by increasing their resemblance to natural displays of emotion, as it is seen in the real world, by including a greater variety of photos of people from different genders, ages, and races, with some (e.g., FACES; Ebner & Lindenberger, 2010) providing photographs of facial expressions reflecting genuine emotional experience as well as posed.

However, these measures are still closely modelled on the original Pictures of Facial Affect by Ekman and Friesen (1976) and include a small number of faces, mostly expressing posed, static, and uni-modal displays of a limited number of emotions. Consequently, reports of worse recognition of negative than positive emotions are mostly based on comparing the recognition of four negative emotions (sadness, fear, anger, and disgust) with two positive (happiness and surprise). Thus, there are problems, not only with the use of static, posed, unimodal emotions, but also the uneven distribution of negative and positive emotions, and variability in difficulty level. Each of these limitations is described below.

(1) Unequal number of positive and negative emotions. Since comparisons between positive and negative emotions usually involve at least twice as many negative emotions (fear, anger, sadness, and disgust) as positive (the category mostly consists of happiness and surprise or happiness only), the observed valence effect could be at least partially due to the number of discrete expressions belonging to each valence (Crocker & McDonald, 2005) leading to increased reliability of measures of negative affect (based on 4 emotions) relative to positive.

(2) Differential task difficulty. Certain emotional expressions could simply be more difficult to recognise than others. For instance, happiness can be detected by a single feature, the smile, whereas discriminations among negatively valanced emotions requires additional information about the configuration of the face (Adolphs, 2002). Thus, it may be that happiness is simply too easy and therefore inappropriate to use when examining recognition of emotion from facial expressions (Demaree et al., 2005). These issues were clearly illustrated by cross-cultural studies of facial emotion processing. The results of 12 major cross-cultural studies have been combined (Biehl, Matsumoto, Ekman, Hearn et al., 1997; J.A. Russell, 1994) to examine patterns across more than 3,000 participants from 43 different population samples. These data revealed that recognition scores are highest (94%) for happiness and lowest (70%) for fear (see Rapcsak et al., 2000). Consistent with these data, more recent evaluations of current databases of facial emotion recognition revealed that happy faces were identified more accurately, earlier, and faster than other faces, whereas judgments of fearful faces were the least accurate, the latest, and the slowest (Calvo & Lundqvist, 2008; Palermo &

Coltheart, 2004). This is clearly problematic when drawing conclusions regarding a valence effect arising from brain injury, as emotion recognition differences might be confounded by floor and ceiling effects.

This issue was highlighted further by a comprehensive study which used an emotion labelling task in a large sample of patients with focal left, right or bilateral lesions, including ventromedial frontal and amygdala damage. As expected, neurologic patients were impaired compared to controls in recognising facial expressions. All participants showed worse recognition of negative emotions, especially fear (Rapcsak et al., 2000), relative to positive ones. However, when general difficulty was accounted for, not even patients with unilateral or bilateral amygdala pathology demonstrated a disproportionate impairment in recognising fear. This study suggested that emotion perception can be disrupted by damage to a range of brain structures but that specific emotions, especially fear, are not necessarily implicated above others even when dedicated neural networks are compromised.

Researchers in the field of TBI have attempted to directly address task difficulty in their manipulation of experimental materials. For example, Ietswaart et al. (2008) used computer-interpolated images to make the Ekman and Friesen faces more sensitive by morphing facial expressions that are likely to be confused with each other (such a ‘happiness-surprise'; Calder et al., 1996). The authors reported that the TBI group was worse than controls in recognising the facial expression blends overall, but did not show a selective impairment in recognising some expressions compared to others, i.e., they did not show a valence effect (Ietswaart et al., 2008). This attempt to make the stimuli more sensitive reinforced the notion that differential task difficulty confounds the valence construct. However, because the stimuli were blended based on emotion confusability, conclusions regarding the recognition of individual emotions are limited. In addition to this limitation, the participants with TBI had much less severe injuries (including mostly mild and moderate injuries) than in previous studies of emotion perception. This might explain the absence of group differences in the selective recognition of some emotions on the morphed facial expression, a standard labelling task, and prosody, which were reported in this study. These important studies illustrate how problems of task difficulty may be confounding emotion recognition research. As noted Rapcsak et al. (2000), only when testing materials are carefully equated for levels of difficulty will it be possible to definitively address the question of emotion-specific recognition impairment in brain injured individuals.

Because of the lack of control over item difficulty, current measures of emotion recognition, such as described above, are not properly designed to address the valence effect in TBI or any population. Nor do these measures provide the opportunity to examine differences in recognition of the other dimensions of emotion, such as basic versus complex, social versus non-social, approach versus avoidance.

(3) Surprise lacks a clear valence. It is debatable whether surprise is indeed a positive emotion. It seems that it was classified into the ‘positive’ category simply because it does not have a negative connotation unlike the other four negative emotions. However, in contrast to the other five emotions, surprise does not have a clear valence (Kreibig, 2010), as one can be pleasantly or unpleasantly surprised. Thus, surprise can be separated to a ‘positive’ and ‘negative’ surprise, and it is not clear if the recognition of both follows the same pattern.

Classifying surprise in the positive category is not just a conceptual problem (referring to which valence does surprise belong to), but a problem in terms of items included in the surprise category in the conventional sets (e.g., Ekman & Friesen, 1976; Tottenham, Borscheid, Ellertsen, Marcus, & Nelson, 2002). The surprise displayed by actors in these sets more closely resembles fear than anything positive, which is probably reflected in the high confusability rates of surprise and fear (e.g., Montagne, Schutters, et al., 2006; Palermo & Coltheart, 2004).

(4) Static displays of emotion. The conventional emotion recognition measures mostly consist of static photographs of facial expressions. Despite their wide use, static photographic stimuli bear little resemblance to naturally occurring facial expressions which are dynamic, evolving rapidly from one emotion to another and providing additional cues via facial movement (Bassili, 1978). As noted by McDonald (2013), dissociations between recognition of dynamic and static facial expressions have been observed in patients with non-traumatic brain lesions (Adolphs, Tranel, & Damasio, 2003; Humphrey, Donnelly, & Riddoch, 1993) and suggest two separable neural systems, dorsal fronto-parietal zones mediating facial movement, and ventral fronto-temporal systems mediating static images (Adolphs et al., 2003). An additional difficulty with using static displays of emotions is that static images provide the opportunity to observe an emotion for a long time which is in contrast to how emotions change in real time.

(5) Uni-modality. Conventional measures of emotion recognition are mostly uni-modal, including only a visual mode of display. Real life emotional displays are typically multi-modal, including visual, vocal, prosody, and facial and body movement, but this is not modelled by the conventional emotion recognition measures. The role of multiple cues was illustrated as early as two centuries ago, when early pioneers of emotion research (Darwin 1872, 1965; James, 1890) investigated recognition of emotion with photographs of whole-body posture (de Gelder, 2009). Despite this, an examination of the social and affective neuroscience literature reveals that over 95 per cent of studies have used faces as stimuli, with 5 percent using scenes or auditory information, such as human voices, environmental sounds, or music. The smallest number has looked into whole-body expressions (de Gelder, 2009). When humans perceive emotions in real life, bodily expressions such as posture, tone of voice, body language are crucial in determining the emotional state of the subject and faces are rarely viewed in isolation. For this reason, it can be questioned whether measures limited to facial expressions are likely to be sensitive to the full range of difficulties in emotion recognition seen in clinical populations.

(6) Posed. Conventional emotion recognition measures, with a few exceptions (e.g., FACES; Ebner & Lindenberger, 2010), mostly consist of posed stimuli, with models/actors coached to express the typical displays of the each emotion. Posed displays of emotion will differ from spontaneous expressions. For example, people who are genuinely fearful, may express fear differently from when they are instructed to pose a fearful expression, without actually experiencing fear. Further, displays of genuine emotion are usually mediated by display rules (McDonald, Flanagan, Rollins, & Kinch, 2003; Shamay-Tsoory et al., 2008) and include a tendency to ‘play against’ expressions of strong emotion. For example, when a healthy person is genuinely feeling sad or angry they usually tend to resist the feeling and attempt to conceal and cope with the emotion. As a result, they may deliberately try to look less sad or angry and might adapt facial expressions that are more commonly associated with other emotions, such as smiling. This is not limited to displays of negative emotions, as people also tend to ‘keep a lid on’ strong positive emotions, so that displays of strong positive emotions such as happiness, excitement and positive surprise (such as winning a competition or coming first in an exam) tend to be controlled or reined in (McDonald et al., 2003).

(7) Failure to include the wider range of emotions that typically reflect human experience. As discussed above, the current emotion recognition measures are largely limited to a small number of emotions (usually 6), and consequently, fail to account for emotions from the different dimensions, including more complex and social emotions.

Recognition of the limitations posed by using conventional measures of facial affect, modelled on Ekman and Friesen's stimuli, has resulted in the development of alternative measures which attempt to partially address these limitations. A few examples include the Profile of Nonverbal Sensitivity (PONS; Rosenthal, Hall, DiMatteo, Rogers, & Archer, 1979), The Awareness of Social Inference Test; TASIT (McDonald et al., 2002), Reading the Mind in Films (Golan, Baron-Cohen, Hill, & Golan, 2006) and Multimodal Emotion Recognition Test (MERT; Bänziger, Grandjean, & Scherer, 2009). The PONS incorporates stimuli in a number of modalities such as face only, body only, voice only, or combination of the above (Bänziger et al., 2009; Bänziger, Scherer, Hall, & Rosenthal, 2011). The MERT includes 10 emotions (anxiety, panic fear, sadness, despair, happiness, elation, hot anger, cold anger, disgust, and contempt), which are conceptualised as representing two variants for each of five major emotion families, differing on the intensity/arousal dimension. Each of the 10 emotions is instantiated by three film clips which can be viewed in four modalities (facial or vocal cues only, facial and vocal cues and still photographs (Bänziger et al., 2009). While the MERT includes 10 emotions instead of the standard six, only two of them can be classified as positive, compared to eight negative. In addition, the emotions are posed and the vocal displays were developed to mimic emotional prosody, but lack meaning, which is inconsistent with how emotional prosody is expressed in real life. The Awareness of Social Interference Test (TASIT; McDonald et al., 2002) includes an emotion recognition task, using stimuli which were developed to generate relatively consistent accuracy scores across the different stimuli in healthy individuals, attempting to minimise item difficulty. It also uses spontaneous (rather than posed) displays of emotion. However, TASIT only includes the standard six emotions, as well as a neutral expression. Reading the Mind in Film (Golan et al., 2006) incorporates dynamic, multimodal displays of a larger array of emotion than the standard six, however, the stimuli were selected from movies which introduces a confound of familiarity with test materials and of how accurately the different videos actually represent a particular emotion.

While these measures constitute an important development in emotion recognition research, and substantially contribute to our understanding of emotion, they do not fully address the limitations outlined above. Thus, the question of whether people with TBI experience differential difficulties with some emotions compared to others remains unanswered.

The current thesis approached this issue systematically as follows.

A systematic exploration of the differential difficulty posed by the six "basic emotions"

Studies 1 and 2 examine the differential difficulty issue in detail, by exploring emotion recognition following TBI using a newly developed measure, the Emotion Recognition Task (ERT; Montagne, Kessels, et al., 2007). The ERT incorporates morphed dynamic displays of six emotions which can be examined across varying intensity, thus allowing evaluation of emotion recognition across task difficulty. The ERT has an added advantage of using a task which incorporates dynamic stimuli, therefore being somewhat more akin to real life facial displays of emotion. While the ERT is an improvement on the current measures, it shares some of their confounds as it is also limited to six posed, uni-modal emotions, including double the number of negative emotions as positive, and including surprise which lacks a clear valence. To address these remaining limitations, a new measure of emotion perception is required and that was the basis of the remainder of studies in this thesis.

Development of a measure of emotion recognition that taps a broad and naturalistic array of emotions

As evident from the literature review of emotion recognition research above, the current range of emotion recognition measures have provided an important impetus for revealing deficits in emotion recognition and for expanding our understanding of emotion recognition in healthy and clinical populations. However, they have a number of limitations which reduce the conclusions that can be made regarding emotion recognition impairments in TBI and other clinical populations. Not only do current emotion recognition measures fail to provide a proper examination of the valence effect, they do not provide the means to examine the broader range of emotions present in the human experience. Nor do many provide the means to assess emotion displays as they typically occur in everyday settings. As such they fail to accurately reflect the full range of challenges faced by people trying to interpret emotions in everyday social interactions.

Thus, Studies 3-5 outline and discuss the development, validation, and use of the Complex Audio-Visual Emotion Assessment Task (CAVEAT), a novel measure of emotion recognition which was designed to overcome those limitations.

The role of neuropsychological functioning in emotion recognition in TBI

Neuropsychological deficits in working memory, processing speed and non-verbal reasoning are common outcomes on TBI (Crawford, Johnson, Mychalkiw, & Moore, 1997; Madigan, DeLuca, Diamond, Tramontano, & Averill, 2000; McDowell, Whyte, & D'Esposito, 1997; Slovarp, Azuma, & LaPointe, 2012). Research into the relation between emotion recognition and neuropsychological impairments has produced mixed outcomes with some studies revealing clear associations (McDonald et al., 2006b; Yim, Babbage, Zupan, Neumann, & Willer, 2013) while others have found none, suggesting that emotion perception can be impaired independent of other cognitive abilities (Spikman, Timmerman, Milders, Veenstra, & van der Naalt, 2012). However, as outlined above, the emotion recognition research in general and in TBI specifically, has largely focused on static photos, such as the stimuli developed by Ekman and Friesen (1976). Whether or not cognitive ability has a role in the perception of emotions, when these are dynamic and multi-modal, changing over time, and inclusive of a wider range of cues, remains to be examined. Thus, the role of neuropsychological functions in emotion recognition needs to be revisited.

Consequently, an additional aim of this thesis was to test the hypothesis that the emotion recognition deficit in the TBI group, if observed in these studies, is a direct consequence of brain injury, rather than being a secondary consequence of reduced neuropsychological functioning, in particular processing speed, working memory, and non-verbal reasoning.

General aims of this thesis

The overarching aim of this thesis was to re-examine emotion recognition in individuals with moderate-severe TBI. The first goal was to clarify whether the valence effect largely reported in the literature is a true consequence of TBI, or an artefact of the conventional emotion recognition measures used. This was done using a newly developed task (ERT; Montagne, Kessels, et al., 2007) which examines recognition of the six basic emotions at different intensity levels. This provided the opportunity to examine relative accuracy of people with TBI across different levels of difficulty (Study 1) and to examine their performance when different emotions were equated on difficulty (Study 2). Second, a new task, the Complex Audio-Visual Emotion Assessment Task (CAVEAT) was developed to include a larger number of emotions than the standards six to investigate emotion recognition more widely, across different emotion dimensions. Following the aims of this thesis, CAVEAT was also designed to provide genuine (rather than posed), dynamic, multiple facial, auditory and body cues to increase its approximation to real world emotion perception.

In addition, this thesis aimed to examine the role of neuropsychological functioning in emotion recognition, in light of the dynamic nature of the tasks used in this thesis. Finally, it aimed explore the utility of CAVEAT as a clinical tool, examining its validity and reliability, and to investigate the relationship between emotion recognition as measured by CAVEAT and social functioning. The individual aims of each of the five studies included in this thesis are described below.

Study 1 aimed to examine whether individuals with moderate-severe TBI are more impaired in overall emotion recognition, and specifically, more impaired in the recognition of negative as opposed to positive emotions, compared to controls. In addition, it examined emotion recognition at different intensity levels, to investigate whether group differences are influenced by floor or ceiling effects.

Study 2 aimed to extend of the findings of Study 1 and to re-examine the valence effect in people with moderate-severe TBI compared to demographically matched control participants. It aimed to examine differential accuracy across emotions that were (1) all full blown intensity (100%: as typically used in earlier reports) and (2) of varying intensities to equate for difficulty level. It also aimed to examine the influences of other neuropsychological impairments on emotion perception accuracy when relative difficulty level across emotions was kept consistent. Thus, it aimed to re-examine the hypotheses that the emotion recognition deficit in the TBI group is a specific emotion recognition deficit arising directly from TBI compared to the alternative position, i.e., that poor emotion perception following TBI is secondary to reduced working memory, processing speed, and non-verbal reasoning. Since the literature findings in this area have been mixed, and mostly inclusive of static stimuli, expanding this to dynamic test materials is important.

Study 3 aimed to outline the development of CAVEAT and the validation process underlying the development of its final form (studies 3A-3C) which was used in studies 4 and 5. Study 3D aimed to examine the recognition rates of the six basic emotions in a subset of CAVEAT to examine accuracy of both groups on the limited set of emotions, which is most commonly used in emotion recognition research.

Study 4 aimed to assess CAVEAT's validity and reliability, and its utility as a clinical tool to assess emotion recognition deficits in clinical populations by exploring its psychometric qualities in TBI and matched controls. **Study 5** aimed to investigate the valence effect, the role of neuropsychological functioning and to provide a preliminary examination of its ecological validity, ie., the relationship between emotion recognition on CAVEAT with selected social outcome measures in a group of adults with moderate-severe TBI. In addition, it aimed to assess performance on a much broader range of emotions than the conventional six, encompassing exemplars from a variety of emotion conceptualisations including: the valence dimension (which overlapped with approach tendency), basic versus complex emotions, and social versus non-social[1].

[1] Examining the arousal and dominance dimensions fell outside of the scope of this thesis.

CHAPTER 2

Study 1. Facial emotion recognition deficits following moderate-severe Traumatic Brain Injury (TBI): Re-examining the valence effect and the role of emotion intensity[2].

Many individuals who sustain moderate-severe traumatic brain injuries (TBI) are poor at recognising emotional expressions, with a greater impairment in recognising negative (such as fear, disgust, sadness and anger) than positive (such as happiness and surprise) emotions. One explanation for this difference holds that distinct neural substrates underlie recognition of positive and negative emotions. In particular, the amygdala in an integrated system with the ventral and orbital frontal lobes, has been proposed to mediate the processing of specifically negative valanced stimuli (Adolphs, 2001). Thus, it is possible that TBI has a greater impact on negative emotional expressions due to the propensity for damage to occur in these ventral frontal systems. However, as outlined in the Introduction, this explanation seems unlikely given the heterogeneous nature of TBI, and the finding that greater impairment of negative emotions is consistently observed in other neurological or psychiatric patient groups as well (Braun et al., 2005; Kohler et al., 2005; Mandal et al., 1998). Further, the evidence for impaired recognition of happy faces following damage of specific brain regions, or in patients with either neurological or psychiatric disorders is limited (Hennenlotter & Schroeder, 2006).

Is the valence effect a real neurological phenomenon or is it an artefact of the emotion recognition tasks used? In order to address this issue, the current study

[2] Study published in: Rosenberg, H., McDonald, S., Dethier, M., Kessels, R. P. C., & Westbrook, 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*, *20*, 1-20. doi: 10.1017/S1355617714000940

examined the performance of a group of individuals with moderate-severe TBI and matched controls on The Emotion Recognition Task (ERT; Montagne, Kessels, et al., 2007).

The ERT affords a number of advantages over traditional measures. It uses video clips of emotional expressions of increasing intensity which mirror the natural transition of real facial expressions, thus providing a more naturalistic portrayal of emotion. Importantly, presentation of a range of intensities for each emotion provides a means to examine each emotion at different levels of difficulty. The ERT has been shown to be sensitive in numerous clinical populations, specifically, schizophrenia (Scholten, Aleman, Montagne, & Kahn, 2005), autism spectrum disorder (Law Smith, Montagne, Perrett, Gill, & Gallagher, 2010), obsessive-compulsive disorder (Montagne et al., 2008), bipolar disorder (Gray et al., 2006), depersonalisation disorder (Montagne, Sierra, et al., 2007), amygdalectomy (Ammerlaan, Hendriks, Colon, & Kessels, 2008), frontotemporal dementia (Kessels et al., 2007), social anxiety disorder (Montagne, Schutters, et al., 2006), and stroke (Montagne, Nys, et al., 2007). By use of the ERT, this study provided an examination of whether people with moderate-to-severe TBI are more impaired in recognising some emotions than others, and specifically negative compared to positive[3], while addressing differential item difficulty. Since the ERT provides an advantage over the traditional emotion recognition measures by including emotional expressions across gradually increasing intensity, this study will allow the investigation of subtle emotion recognition difficulties across low, medium and high intensities. This is especially important since traditional measures are confounded by

[3] While, as noted by Kreibig (2010), surprise is better conceptualised as an ambiguously valanced emotion, it was included in the positive category in this and subsequent study (1-2), using the ERT, to follow the conventions of emotion research. Subsequenty, in the later studies (3-5) using the CAVEAT, following Kreibing's conceptualisation, surprise is separated to a positive and negatve variants.

task difficulty, and subsequently, these differences can only be detected with a sensitive measure like the ERT.

Consistent with previous research, it was predicted that individuals with moderate-severe TBI would be 1) more impaired in overall emotion recognition compared to demographically matched control participants (between-group difference), and 2) more impaired in the recognition of some emotions than others, relative to controls (group x emotion interaction) and specifically negative emotions (anger, disgust, fear and sadness) compared to positive emotions (happy and surprise) (group x valence interaction). Finally, this study aimed to evaluate emotion recognition at different intensity levels to investigate whether between-group differences are influenced by floor or ceiling effects. It was predicted that difficult emotions (such as fear) might produce a 'floor' effect such that both control and TBI participants have comparably low accuracy for low intensity expressions but might differ on high intensity expressions. Conversely, easy emotions (such as happy) might produce a ceiling effect whereby both groups have comparably high accuracy for high intensity expressions but differ on low intensity. If this prediction is correct a group x intensity x emotion interaction would be expected, which would be teased out by examining each emotion separately.

Method

Participants

Clinical sample. Participants were twenty-nine individuals with TBI (21 male, 8 female). They were recruited from several brain injury units in Sydney, Australia, and met the following criteria: (1) all had sustained a moderate-severe TBI (had post-traumatic amnesia; PTA greater than 1 day), (2) were at least 1 year post-injury, (3) were able to comprehend and adhere to instructions, and (4) had no identified aphasia or agnosia.

Two individuals with TBI were excluded from the study as they were experiencing high symptomatology of depression and/or anxiety (as measured by the Depression Anxiety and Stress Scale (DASS-21; Lovibond & Lovibond, 1995), cut offs for extremely severe symptoms of depression and anxiety are 28 and 20, respectively), resulting in 27 TBI participants (20 male, 7 female). Twenty three of these participants also took part in two other studies examining emotion expression production in our laboratory (Dethier, Blairy, Rosenberg, & McDonald, 2012, 2013), but there was no overlap in exprerimental procedures. The TBI participants were aged from 21 to 68 years (M age = 46.93 years, SD = 12.45) and had achieved an average 13.74 years (SD=2.81) of education (range 9-22 years). They have experienced PTA ranging from 3 to 189 days (M = 82.67, SD = 55.99), and time post injury ranged from 2 to 40 years (M= 13.74, SD = 9.23). PTA scores were obtained from medical records, with an exception of a few participants for whom medical records were unavailable. In these cases the injury was judged as severe because each reported a duration of coma exceeding 24 hours, conventionally regarded as indicating a severe injury (Corrigan, Selassie, & Orman, 2010). Based on this classification, one participant was classified as having a moderate TBI and 26 had severe TBI. Injuries were sustained as a consequence of motor vehicle accidents (n =17), falls (n =6), assaults (n = 2), and accidental hits to the head during sporting events (n = 2). As is common with this population, the injuries of the TBI participants were heterogeneous, and included skull fractures, contusions, intracerebral or subarachnoid haemorrhages, and subdural haemorrhages. CT scans (obtained from clinical records) revealed comparable distributions of left (n=16), right (n=15) and frontal injuries (n=13), with a large number of participants having overlapping injuries (e.g. left-hemisphere and frontal). For five participants, CT scans did not identify the injury site, or were unavailable. Prior to the TBI, they had been employed in occupations ranging from unskilled (n = 5) to skilled trade (n = 8), clerical (n = 2), professional or managerial (n =8), or full/part-time study (n = 4). At the time of participating in this study, five TBI participants were working in unskilled positions, three in skilled positions, one in a clerical position, three in professional/ managerial positions, three were in full or part time study, and 12 were unemployed. Description of demographic variables and socio-emotional functioning is outlined in Table 2.1.

Table 2.1

Demographics and measures of socio-emotional functioning of TBI (n=27) and Control (n=28) group

	TBI group		**Control group**	
	M (SD)	**Range**	**M (SD)**	**Range**
Sex	m=20, f=7		m=16, f=12	
Age	46.93 (12.45)	21-68	41.50 (14.35)	19-64
Educ. Level (years)	13.74, (2.81)	9-22	14.93 (2.16)	10-19
DASS-21				
• **Depression**	6.29 (6.27)	0-22	8.00 (7.10)	0-26
• **Anxiety**	2.75 (4.04)	0-18	5.19 (5.41)	0-19
• **Stress**	9.75 (8.32)	0-34	11.59 (11.51)	0-32
PTA (days)	82.67 (55.99)	3-189	N/A	N/A

Note. M, mean; SD, Standard deviation; f, female, m, male; PTA; post traumatic amnesia. There are no significant group differences in all variables (p>.05)

Control group. Twenty nine healthy individuals (17 male, 12 female) were recruited from the general community. One participant was excluded from the analyses as he was currently experiencing extremely severe anxiety (as measured by the DASS-21; Lovibond & Lovibond, 1995), resulting in 28 control participants. These participants also took part in two other studies that were conducted in our laboratory (Dethier et al., 2012, 2013). Control participants were aged from 19 to 64 years (M age = 41.50 years, SD = 14.35), had a mean education level of 14.93 years (SD = 2.16 years, range 10-19 years), and were matched as closely as possible to the TBI participants in respect to age, sex, years of education, and pre-injury occupation. At the time of the study, they had been employed in occupations ranging from unskilled (n= 3) to skilled trade (n = 2), clerical (n = 3), professional or managerial (n = 9), part/full-time study (n = 7), and four participants were unemployed. For both groups, exclusion criteria included history of developmental, psychiatric, or neurological disorders (with the exclusion of the TBI in the clinical group), uncorrected vision or hearing impairments, inability to communicate effectively, and severe emotional distress, as measured by DASS-21 (Lovibond & Lovibond, 1995).

Materials

The Emotion Recognition Task (ERT; Montagne, Kessels, et al., 2007)

The ERT is a computer-generated program consisting of a series of 216 video clips of facial emotion expressions across different intensities ranging from 20-100%, which is achieved by blending them with a neutral expression. The stimuli were developed using algorithms (Benson & Perrett, 1991) which created intermediate morphed images between a face expressing no emotion (0%) and one expressing a full-blown emotion

(100%). The stimuli were based on colour photographs from four actors (two female and two male) who posed a neutral face and six emotional expressions (i.e., happiness, surprise, fear, sadness, anger, and disgust). The resulting images were used to construct video clips of increasing emotional expression in 10% steps, from 20% to 100%, which gave rise to nine video clips for each emotion (6) and for each actor, i.e. a total of 216 clips. The ERT is sensitive to a wide range of clinical populations such as, social anxiety (Montagne, Schutters, et al., 2006), post-traumatic stress (Poljac, Montagne, & de Haan, 2011), bipolar (Gray et al., 2006), obsessive-compulsive (Montagne et al., 2008), and depersonalisation disorders (Montagne, Sierra, et al., 2007), frontotemporal dementia (Kessels et al., 2007), stroke (Montagne, Nys, et al., 2007), amygdalectomy (Ammerlaan et al., 2008), Huntington's disease (Montagne, Kessels, Kammers, et al., 2006), Korsakoff's amnesia (Montagne, Kessels, Wester, & de Haan, 2006), schizophrenia (Scholten et al., 2005), and autism spectrum disorder (Law Smith et al., 2010).

Participants first viewed four practice trials followed by the actual task. During the task, participants saw, in a random order, the 24 video clips changing from neutral to 20% expression, followed by the 24 clips from neutral to 30%, and continued in blocks of increments of 10% until they reached the final sequence of clips in which the neutral face changed into a full-blown expression (100%). The duration of each clip depended on the emotional intensity presented, with longer clips for more intense emotions (e.g., duration ranged from approximately 1 s for 40% emotion, to 3 s for 100% emotion. After the clip played, the static image of the final intensity remained on screen while six emotional expression labels were displayed on the left of the expression (it was not possible to select the label before the clip played). The trials did not have a time restriction, with the next trial starting once the participant chose the label for the expression on the screen (the task would not progress to the next item until a response was made by a participant). The ERT takes approx. 20 min to complete, and all participants were able to maintain attention and concentration for this period. To minimise boredom and fatigue, and increase attention to the task, participants were informed of task length before commencing, and asked if they would like a break. Since this study only examined ERT accuracy and not response time, participants could also take short rest breaks during the task if they felt that they were getting fatigued. The dependent variable is accuracy for each emotion at different intensities. For a detailed description of the stimuli development, see Frigerio, Burt, Montagne, Murray, and Perrett (2002), Montagne, Kessels, et al. (2007).

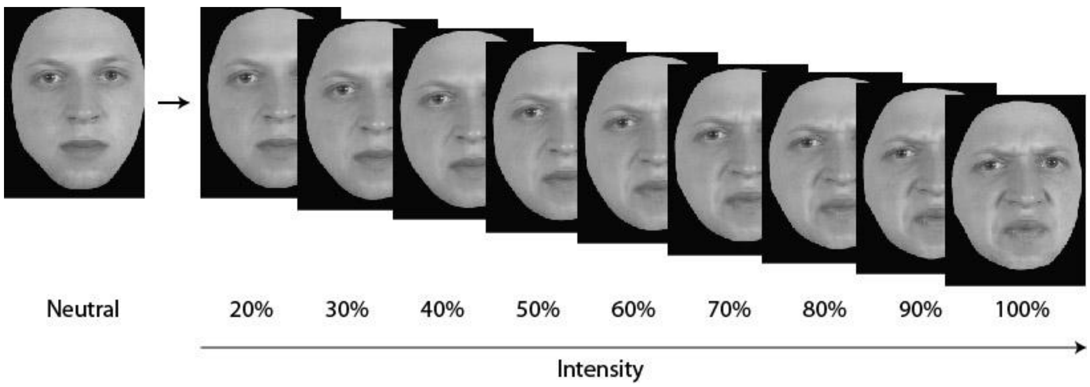

Figure 2.1. The Emotion Recognition Task (ERT; Montagne et al., 2007). Picture shows nine picture frames of gradually increasing emotional intensity of a disgusted expression. The actual test shows these frames morphing from a neutral expression in 10% increments (starting with 20% intensity).

Additional Measures

Depression Anxiety and Stress Scale (DASS-21; Lovibond & Lovibond, 1995). The 21-item, short form of the DASS was administered to all participants to assess their psychological status. The DASS-21 is a well-established measure in both clinical and non-clinical populations (Antony, Bieling, Cox, Enns, & Swinson, 1998; Henry & Crawford, 2005) and has strong psychometric properties (Lovibond & Lovibond, 1995).

Data Analysis

The nine intensity levels were combined into three groups to increase the number of trials for each level of intensity, and allow a simpler comparison across levels of intensity. This resulted in three intensity levels of low (20%, 30%, and 40%), medium (50%, 60%, and 70%), and high (80%, 90%, and 100%). The overall results were analysed using a general linear model (GLM) repeated-measures ANOVA, with one between-subjects factor (group) with two levels (TBI vs. controls), and two within-subjects factors: emotion type, with six levels (anger, disgust, fear, happy, sad, and surprise), and emotion intensity, with three levels (low, medium, and high) conducted using IBM SPSS Statistics version 21.0. Follow-up analyses involved repeated measures ANOVA for each emotion. Bonferroni correction was applied to all simple effect contrasts, which resulted in a corrected probability level of $\alpha=0.017$ (i.e., .05/3). A positive vs. negative emotions contrast analysis was conducted using the PSY Statistical Program (Bird, 2011). Following Ferguson's (2009) guidelines for a minimum effect size representing a 'practically' significant effect for social science data, we considered all effect sizes larger than $\eta p^2=.04$, as clinically significant. A power analysis was conducted with IBM SPSS Statistics version 21.0. Given the obtained effect sizes, the achieved power in the analyses for the main effects and interaction contrasts ranged from .74 to 1, and from .55 to .99 for simple effect contrasts.

Procedure

Participants were informed of the study procedures and gave written informed consent to participate in the study. The procedures were approved by the Human Research Ethics Board of the University of New South Wales, and conducted at the neuropsychology laboratory at the University.

Results

Confounding Variables and ERT Reliability

There were no significant differences between the TBI and control groups on distribution of sex [X^2 (1, n=55) = 1.08, p =.3], pre-injury occupation [X^2(1, n=52) =8.84, p =.11], age ($F_{1,53}$=2.24, p=.14), or education level ($F_{1,53}$=3.11, p=.08). There were also no between-group differences for depression ($F_{1,53}$=0.90, p=.35), anxiety ($F_{1,53}$=3.59, p=.06), and stress ($F_{1,53}$=4.66, p=.50) as measured by the DASS-21 (Lovibond & Lovibond, 1995). Chronbach's Alpha for the six emotions included in the ERT from the current sample ranged from .7-.9. According to the George and Mallery (2003) guidelines, these reliabilities ranged from acceptable (>.7) to excellent (>.9).

Analyses of Emotion Recognition

The total correct trials of the six emotions across the three intensity levels (low, medium and high) for TBI and control participants are presented in Figure 2.2.

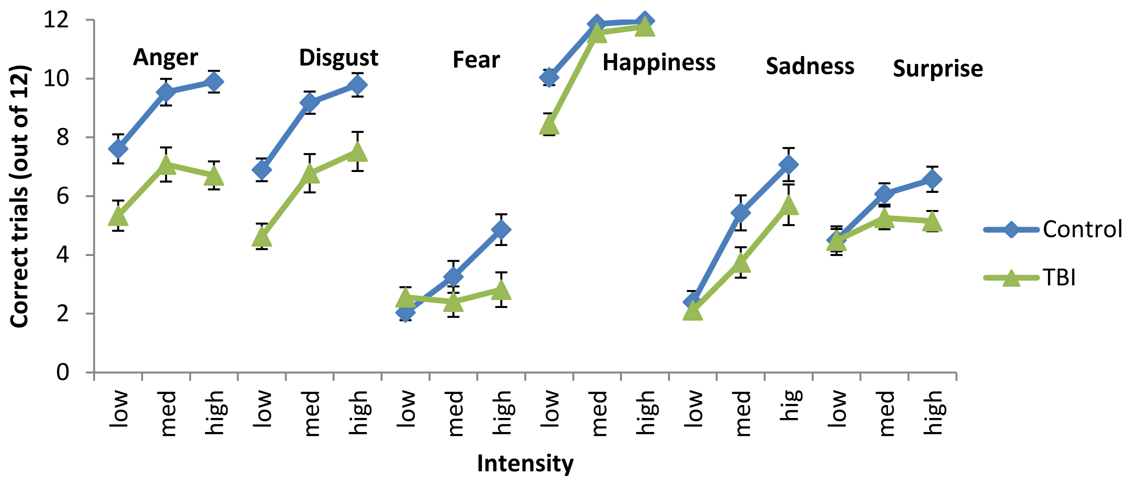

Figure 2.2. Total correct trials of six basic emotions across three intensity levels (low: 20-40%, medium: 50-70%, high: 80-100%) in participant with TBI (n=27) and controls (n=28). The error bars represent standard error of the mean.

Overall emotion accuracy

A mixed-design ANOVA revealed a significant main effect of group ($F_{1,53}$=22.59, p=.00002, ηp^2= .30), indicating that, consistent with our first hypothesis, the TBI group performed more poorly overall than controls. The ANOVA also revealed a significant group x emotion interaction ($F_{5,53}$= 3.59, p=.005, ηp^2=.06), suggesting that, consistent with our second hypothesis, differences between TBI and control groups differed according to emotion category. This was, however, tempered by a significant three way interaction between group, intensity and emotion ($F_{7,53}$= 2.62, p=.01, ηp^2=.05) suggesting that, consistent with our third hypothesis, there was a complex interaction between group differences and intensity level that differed for the different emotions.

Accuracy for different types of emotion

To examine the two-way interaction, and in order to tease out the second hypothesis that recognition impairment would differ across emotions, six 2 (group) x 3 (intensity) mixed-design ANOVAs, were conducted, one for each emotion. These revealed that participants with TBI performing significantly more poorly than controls on anger ($F_{1,53}$=21.15, p=.00003, ηp^2=.29), disgust ($F_{1,53}$=16.09, p=.0002, ηp^2=.23), and happiness ($F_{1,53}$=14.71, p=.0003, ηp^2=.22). While observation of Figure 2.2 suggests that there was a trend for TBI participants to perform more poorly than controls on the remaining three emotions, these main effects failed to reach significance [fear ($F_{1,53}$=1.99, p=.16, ηp^2=.04), sadness ($F_{1,53}$=3.45, p=.07, ηp^2=.06), and surprise ($F_{1,53}$=3.03, p=.09, ηp^2=.05)]. However, intensity played a role here, and is discussed further below.

A specific interaction contrast comparing accuracy of the two positive emotions to the four negative emotions revealed that individuals with TBI had significantly poorer recognition of negative than positive emotions, compared to controls ($F_{1,53}$=7.87, p=.007, ηp^2=.13). However, observation of Figure 2.2 reveals that this difference was driven by high accuracy on happy facial expressions compared to the other emotions, while the recognition of surprise was more similar to the recognition of the negative emotions, especially sadness.

The influence of intensity across emotions

The three-way interaction (group x intensity x emotion) of the overall ANOVA suggests that not only did intensity affect accuracy differently for the different emotions, but this pattern was different in the TBI group compared to the controls. This suggestion was confirmed by the subsequent ANOVAs, which revealed a significant group x intensity interactions for fear ($F_{1,53}$=7.59, p=.001, ηp^2=.13) and happiness ($F_{1,53}$=8.86, p=.002, ηp^2=.14), but not for the other emotions. In order to explore the effect of intensity across the six emotions, three Bonferroni-corrected simple effect contrasts, for each emotion, with a corrected probability level of α=0.017 (i.e., .05/3), were conducted. These comparisons revealed that the TBI group performed significantly more poorly than controls in anger and disgust, across all three intensity levels (ps≤.005, ηp^2≤.35), while in fear and surprise they performed significantly more poorly only in the high intensity level (ps ≤.013, ηp^2=.11), but no difference was found in low and medium intensities (ps ≥.13, ηp^2≤.04). Interestingly, the opposite pattern was observed in happiness, with the TBI group performing significantly more poorly than controls in low intensity expressions (p=.001, ηp^2=.2), but not in the medium and high intensity trials (ps≥.02, ηp^2≤.09). In sadness, there was no difference in emotion recognition between controls and TBI participants in all three intensities (p≥.04, ηp^2≤.08).

Labelling Errors

Average error scores were calculated to examine the type of errors made by control and TBI participants averaged across the nine intensities (see Table 2.2). Visual inspection of the error scores revealed that in both groups, some facial expressions were frequently confused with others, which was especially evident for fear and surprise. Inspection also revealed that in the control and TBI groups, surprise was most frequently labelled as happiness (46% and 48% respectively), and fear was most commonly labelled as surprise (59% and 57% respectively). It is especially striking that in both groups, fearful expressions were twice more likely to be incorrectly labelled as surprise (59% and 57% respectively) than correctly labelled as fear (28% and 22%

respectively). Similarly, both groups were almost as likely to incorrectly label surprised expressions as happy (46% and 48% respectively) as they were to correctly recognise them as surprise (48% and 41% respectively). Interestingly, this confusion did not work in reverse, since in both groups happiness was very rarely labelled as surprise (1% in control and 5% in TBI group) and surprise was rarely labelled as fear (1% in control and 4% in TBI group).

Table 2.2

Percentage of error types for TBI (n=27) and control participants (n=28) for each of the six emotions, averaged across the nine intensities. The correct responses are in bold. For example, on average, the control group correctly labelled fearful expressions as fear 28% of the time, and incorrectly labelled them as surprise 59% of the time

		Label given by participant (%)					
Group	*Actual Emotion*	*Anger*	*Disgust*	*Fear*	*Happiness*	*Sadness*	*Surprise*
TBI	Anger	**53**	18	10	3	11	5
	Disgust	28	**53**	4	5	7	3
	Fear	4	6	**22**	7	5	57
	Happiness	1	3	1	**88**	2	5
	Sadness	11	15	21	6	**32**	15
	Surprise	3	3	4	48	2	**41**
Controls	Anger	**75**	9	5	3	4	3
	Disgust	20	**72**	3	2	2	1
	Fear	2	2	**28**	5	3	59
	Happiness	1	2	1	**94**	1	1
	Sadness	11	10	21	5	**41**	11
	Surprise	1	2	1	46	2	**48**

Discussion

This study investigated facial emotion recognition deficits in people with TBI, using the ERT (Montagne, Kessels, et al., 2007), a sensitive measure of emotion recognition which incorporates morphed displays of facial expressions of gradually increasing intensities. By using this task, it was possible to ask whether the TBI group was more impaired in overall emotion recognition, and specifically, more impaired in the recognition of negative as opposed to positive emotions, compared to controls. In addition, emotion recognition was examined at different intensity levels, to investigate whether group differences are influenced by floor or ceiling effects.

Consistent with prior research (Babbage et al., 2011; Bornhofen & McDonald, 2008b; Radice-Neumann, Zupan, Babbage, & Willer, 2007), it was found that individuals with TBI had worse facial emotion recognition than matched controls. Across the different intensities, individuals with TBI were worst at recognising facial expressions of anger, followed by disgust, and happiness. There was also a trend for poorer recognition of surprise, sadness, and fear in the TBI group compared to the controls, but these effects failed to reach statistical significance. Further, as predicted, and consistent with previous literature (Croker & McDonald, 2005; R. E. Green et al., 2004; Hopkins et al., 2002), individuals with TBI were more impaired on the overall recognition of the negative, compared to the positive emotions. However, examining the recognition of the individual emotions revealed that this difference was more complex than a simple positive versus negative distinction, and was dramatically affected by intensity.

Finally, emotion recognition in the different intensity levels was examined, to investigate whether there were floor and ceiling effects, which affected between-group differences. The findings show that as intensity increased, it became easier for both groups to recognise the emotions correctly. However, the benefit individuals with TBI received from an increase in intensity was contingent on the emotion type. The TBI group benefited from increased intensity *more* than controls on happiness, as evident by an impaired recognition of happy expressions compared to controls in low, but not medium and high intensities. Contrary to this, TBI patients showed the opposite pattern on fear and surprise, benefiting *less* than controls from increase in intensity, as evident by impaired recognition of these emotions in high, but not low and medium intensities. For the remaining three emotions - anger, sadness and disgust - the TBI group benefited as much as control participants from increased intensity.

The response patterns for happiness, fear, and surprise are especially interesting as an illustration of the problem posed by differential difficulty levels in emotion research. Happiness is clearly an “easy” emotion. Individuals with TBI performed at the same level as controls on the high-intensity version of this expression, approaching ceiling. One reason why happiness is easier to recognise than other emotions is that it can be inferred by detecting a single feature, the smile, making this emotion unlikely to be confused with other emotions. In contrast, discriminations among negatively valanced emotions require additional information about the configuration of the face (Adolphs, 2002b). Thus, inferring happiness from full intensity facial expressions might simply be too easy (Demaree, Everhart, Youngstrom, & Harrison, 2005). Interestingly, the opposite pattern was observed in fear, where responses of both groups were approaching a floor on low intensity. This suggests that while fear becomes easier to recognise with increased intensity, it remains a difficult emotion to recognise overall, especially for individuals with TBI, but even in healthy controls (Biehl, Matsumoto, Ekman, Hearn, & et al., 1997; J. A. Russell, 1994).

A similar pattern to that observed in fear is also observed in surprise. Both groups performed similarly (poorly) on low and medium intensities but the TBI group was differentially poor relative to controls on the high intensity exemplars. Fear and surprise not only showed similar response patterns across the different intensities, but also share physical resemblance in terms of facial features, such as open eyes, raised forehead, and a slightly open mouth (Bornhofen & McDonald, 2010). Their similarity is also partially reflected in the error patterns. Both TBI and control groups were twice as likely to label fearful faces as surprised, than to correctly identify them as fearful. In contrast, surprise was very rarely labelled as fear, and more frequently confused with happiness. This suggests that the categorisation of surprise in the positive category alongside happiness is problematic, since it shares common features with both happiness and fear, and is consistent with the idea that it does not have as clear valence as the other emotions (Kreibig, 2010).

The finding that fear is a difficult emotion to recognise, even for healthy controls, and remains so even with increased intensity, raises the question as to why? Such a finding contradicts the view that a fearful expression signals threat in the environment, bestowing it with a special status and causing early triggering of the amygdala circuit (Adolphs, 2002a, 2002b). According to this account, because fear and anger are processed preferentially, they should trigger increased accuracy of recognition in order to initiate adaptive behavioural responding (LeDoux, 1995; Vuilleumier, 2002). In contrast to this account, these findings revealed that fear has attributes in common with surprise that make it confusing and difficult to recognise. Further, the recognition pattern of fear is very different from the pattern of anger, which is also considered to be a part of the threat network.

One possible explanation for these results is that threat signals lose their special status when participants were asked to label the expressions, rather than simply orient to them. This is consistent with a theoretical account proposing structurally and temporally dissociable parallel pathways for threat perception, an early processing route (amygdala and ventromedial cortex) and a later conscious level route (encompassing dorsolateral cortex, hippocampus etc.) (Phillips et al., 2003) that enables cognitive processing of the stimuli. Even so, this does not explain why fear is differentially difficult to cognitively process and identify. It is possible that the low recognition rates of fearful expressions might at least partially be attributed to the high confusability with surprised expressions that was reported in this and others studies.

For example, these results were consistent with the findings of a larger study by Palermo and Coltheart (2004) who evaluated responses of a non-clinical sample to a collection of widely used facial expression stimuli, such as Pictures of Facial Effect (Ekman & Friesen, 1976), the NimStim Face Stimulus Set (Tottenham et al., 2002), among others, and reported that fearful faces were most often confused with surprised faces (31.1%). These findings are hardly surprising in light of substantial physical resemblance in terms of facial features, such as raised forehead and eyebrows, a slightly open mouth and open eyes, between the two expressions (Bornhofen & McDonald, 2010). Consistent with these data, more recent evaluations of current databases of facial emotion recognition revealed that happy faces were identified more accurately, earlier, and faster than other faces, whereas judgments of fearful faces were the least accurate, the latest, and the slowest (Calvo & Lundqvist, 2008; Palermo & Coltheart, 2004).

These findings substantially increase our understanding of the emotion recognition deficits following TBI and stress the importance of task difficulty, which, if ignored, may confound findings and lead to incorrect conclusions. Taken together, these findings contradict the claim that it is specifically the recognition of negative emotions that is impaired by TBI, but rather suggest that particular facial configurations may be more ambiguous, and therefore more difficult, for both people with TBI and non-injured, healthy adults to ascertain. These results indicate that differential difficulty across different categories of emotions for people with TBI reflects the same pattern of differential difficulties that is experienced by non-injured controls. Differences between groups that do emerge reflect the influence of both ceiling and floor effects. One emotion (i.e., happiness), is so easy that it is almost universally recognised at full intensity, reflecting ceiling effects. To find any group differences it needs to be at much lower intensity. Conversely, other emotions, particularly fear, are so difficult that both people with TBI and non-injured controls are very poor at identification. Possibly because of this high level of difficulty, participants with TBI are less able than their non-injured peers to make use of increasing intensity as a cue, and remain impaired, such that group differences only emerge at the easiest (100% intensity) level.

These findings suggest that people with TBI have an overall deficit in recognising facial affect, rather than a specific deficit in the recognition of some emotions compared to others (for example, positive vs. negative). However, the differential difficulty level of each emotion (and the varying influences of floor and ceiling effects across the emotions) makes a direct comparison across the emotions difficult. Thus, in Study 2, information on accuracy of performance in Study 1 was used as a means to directly compare emotions from the six categories, while keeping difficulty level relatively constant. This would allow a direct between-group comparison between the six emotions, which crucially, is not confounded by valence. In addition, the ERT intensity and presentation time are confounded by increased presentation time for more intense emotions. In Study 2, the selected stimuli varied in presentation time, with the more intense stimuli being presented for longer than the less intense stimuli. Although these two attributes were confounded, one offset the other i.e., more difficult emotions were viewed at a more intense level, and for longer. Potentially, both factors facilitated recognition rates such that each of these stimuli generated a similar level of recognition by healthy controls. As the aim of the study was to equate difficulty level, rather than intensity or viewing time, the variance in both these attributes across stimuli was not critical to the focus of the study.

CHAPTER 3

Study 2. Emotion perception after moderate-severe Traumatic Brain Injury: The valence effect and the role of working memory, processing speed and non-verbal reasoning[4].

Study 1 examined emotion recognition across low, medium and high intensities in individuals with TBI and matched controls. The study indicated that individuals with TBI were more impaired in overall emotion recognition and, consistent with earlier reports, less accurate in the recognition of negative emotions. However, the pattern of performance across the different intensities suggested that the 'valence effect' was driven by some emotions (e.g., happiness) being much easier to recognise than others (e.g., fear and surprise) for both individuals with TBI and healthy controls. An empirical test of this hypothesis is to select an intensity level for each emotion that produces a uniform accuracy level in control participants. These "equated" emotions should reveal whether TBI produces differential impairments for particular emotions. This was the approach taken in the current study.

As noted in the Introduction, the 'valence effect' in emotion recognition has been used as evidence for differing neural pathways underpinning the recognition of some emotions rather than others. Specifically, a ventral-frontal pathway encompassing the amygdala, ventromedial frontal lobes etc. has been conceptualised as a pathway to mediate rapid appraisal of negative (specifically threat) related stimuli. If the valence effect does not hold, then an alternate neuropsychological explanation for emotion recognition deficits in TBI needs to be considered. One suggestion is that emotion

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[4] Study published in: Rosenberg, H., Dethier, M., Kessels, R. P. C., Westbrook, R. F., & McDonald, S. (2015, February 2). Emotion Perception after Moderate–Severe Traumatic Brain Injury: The Valence Effect and the Role of Working Memory, Processing Speed, and Nonverbal Reasoning. *Neuropsychology*. Advance online publication. http://dx.doi.org/10.1037/neu0000171

perception deficits following TBI do not arise from specific impairment to specialised neural structures that underpin emotion processing, but rather as a consequence of impaired neuropsychological functioning that is associated with TBI. Emotional expressions in the real world are dynamic, shifting and changing rapidly. The ERT mirrors this dynamic presentation to an extent. In order to be able to identify and label such expressions, efficient processing speed, non-verbal processing and language are required. While simple naming is usually intact post TBI, neuropsychological deficits in working memory, processing speed and non-verbal reasoning are common outcomes (Crawford, Johnson, Mychalkiw, & Moore, 1997; Madigan, DeLuca, Diamond, Tramontano, & Averill, 2000; McDowell, Whyte, & D'Esposito, 1997; Slovarp, Azuma, & LaPointe, 2012). Research into the relation between emotion recognition and neuropsychological impairments has produced mixed outcomes with some studies revealing clear associations (McDonald et al., 2006; Yim et al., 2013) while others have found none (e.g., Spikman et al., 2012).

The current study examined the valence effect in people with moderate-severe TBI compared to demographically matched control participants who were also the participants in Study 1. It aimed to examine differential accuracy across emotions that were (1) all full blown intensity (100%: as typically used in earlier reports) and (2) of varying intensities to equate for difficulty level. It also aimed to examine the influences of other neuropsychological impairments on emotion perception accuracy when relative difficulty level across emotions was kept consistent.

Consistent with previous literature, Study 2 tested the hypothesis that the TBI group would be worse at recognising full-blown (100% intensity) negative than positive emotions. Secondly, it tested the hypothesis that, when emotions were “equated” for difficulty, TBI participants will show an overall emotion recognition deficit, rather than selective impairment in the recognition of some emotions rather than others, compared to controls. Third, it aimed to re-examine the hypotheses that the emotion recognition deficit in the TBI group is a specific emotion recognition deficit arising directly from TBI compared to the alternative position, i.e., that poor emotion perception following TBI is secondary to reduced working memory, processing speed, and non-verbal reasoning. As noted above, revisiting the role of neuropsychological functioning in emotion recognition, as measured by the ERT is needed in light of the changing-dynamic nature of ERT stimuli.

Method

Participants

The clinical and control samples in this study are identical to those described in Study 1.

Materials

The Emotion Recognition Task (ERT; Montagne et al., 2007) is a computer-generated program containing a series of 216 video clips of facial emotion expressions across nine intensities. Please refer to Study 1 for detailed description of the ERT.

Control tasks, neuropsychological measures and tests of socio-emotional functioning

The Wechsler Test of Adult Reading (WTAR; David Wechsler, 2001), which involves the pronunciation of irregular words, was used to provide an estimate of premorbid intellectual level. The *Depression Anxiety and Stress Scale* (DASS-21; Lovibond & Lovibond, 1995) was administered to both groups to assess their emotional functioning.

In addition, three tests were administered to assess cognitive ability. These were all taken from the WAIS-III; (Wechsler, 1997b). *Digit Symbol coding (DSC)* requires the individual to write an associated symbol next to each digit as quickly as they can. This measure is sensitive to the effects of brain injury (Wechsler, 1997a) and was administered to assess processing speed capacity. *Digit Span (DS)* requires the individual to repeat an orally presented sequence of numbers in a particular order and manipulate them, and is a widely used measure of immediate attention span, or 'working memory'. Finally, *Matrix Reasoning (MR)* requires the individual to find an appropriate piece to complete a matrix. This subtest was used as sensitive measure of non-verbal concept formation and non-verbal reasoning.

Procedure

The participants were informed of the study procedures and gave written consent to participate in the study. All procedures were approved by the Human Research Ethics (HREC) Board of the University New South Wales, and conducted at the neuropsychology laboratory at the University. Participants were administered the DASS-21 (Lovibond & Lovibond, 1995), followed by the ERT, and then neuropsychological measures, unless these were administered on a prior occasion, for participants who participated in a research in our laboratory recently. All measures were administered in a single session, unless the neuropsychological measures were completed previously.

Data Analysis

The data were analysed using a general linear model (GLM) repeated-measures ANOVA, with one between-subjects factor (group) with two levels (TBI vs. controls), and one within-subjects factor (emotion type) with six levels (anger, disgust, fear, happy, sad, and surprise), conducted using IBM SPSS Statistics version 21.0. Planned simple-effect contrasts were used to examine the differences between the two groups in each emotion. A negative versus positive emotions contrast analysis was conducted using the PSY Statistical Program (Bird, 2011). Correlational analyses between total equated emotion recognition accuracy and selected neuropsychological measures, PTA and WTAR were computed using Pearson's correlations and were followed by a simultaneous regression analysis.

Selecting stimuli for analysis by equating stimuli based on difficulty. In order to equate the six expressions on difficulty, six expressions which generated a similar level of recognition by control participants, were selected. The aim was to select stimuli which are correctly recognised by the control group 50 percent of the time, and, thus, equally difficult. However, as evident from Figure 3.1, differential difficulty between happiness and the other five expressions was so great, that a perfect match could not be achieved. In particular, while 100% (full blown intensity) fearful expressions were recognised by controls 50 percent of the time, the lowest intensity available for happiness was 20% and this was recognised 64.3 percent of the time. Thus, expression intensities were selected that were recognised correctly by the control group 50 percent of the time; in the cases of anger (20%), disgust (30%), fear (100%), sad (70%), and surprise (70%) and 64.3 percent in the case of happiness (20%). This resulted at four stimuli for each expression, the four actors at the selected level of intensity.

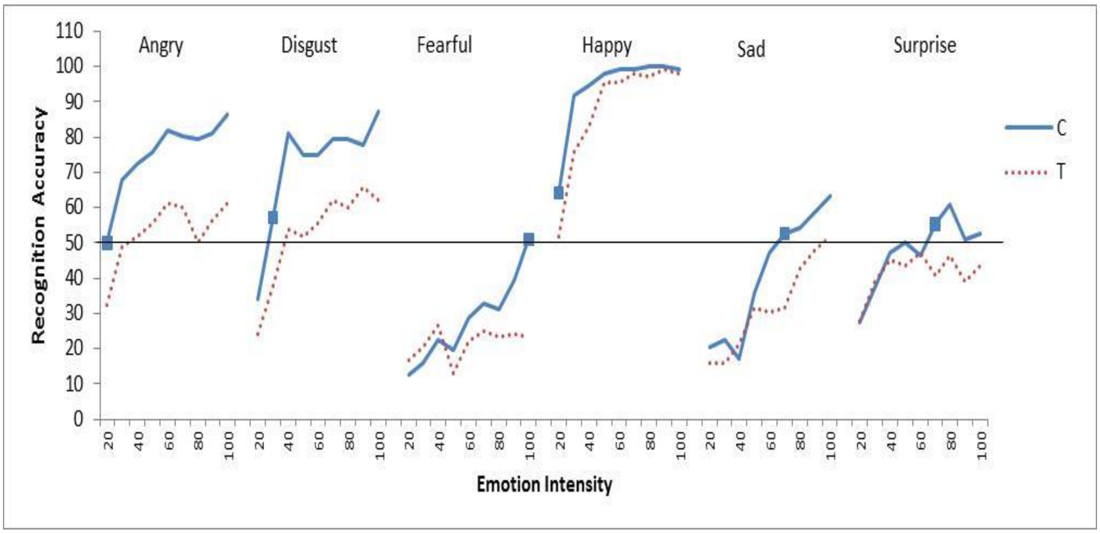


Figure 3.1. Total correct trials of six basic emotions across nine intensity levels in participant with TBI (n=27) and controls (n=28). To equate the six expressions on difficulty, stimuli were selected that were correctly recognised by the control group 50% of the time, and are thus equally difficult. This resulted in selecting 20% anger, 30% disgust, 100% fear, 70% sad, and 70% surprise. Since the recognition of happiness was well above 50% even for the lowest intensity, the lowest intensity (20%), which was recognised correctly 64.3% of the time was selected.

To ensure that the selection of intensities was valid, the selected intensities were compared to the ERT normative data (Kessels, Montagne, Hendriks, Perrett, & de Haan, 2013), which consists of a large sample of 357 healthy controls aged 8-75. This revealed that the control response rates were strikingly similar. In fact, in Kessels et al. (2013) dataset, the parallel stimuli would have been anger (30%), disgust (40%), fear (100%), sad (90%), surprise (70%) and happy (20%). The slight differences in the current stimuli compared to the normative data may reflect the fact that the latter had a much larger sample and included a wider range of ages, including younger and older individuals.

Results

Demographic and clinical features

Demographic, clinical and neuropsychological test scores are shown in Table 1. There were no significant differences between control and TBI groups on distribution of gender [χ^2 (1, n=55) = 1.08, p =.3], age ($F_{1,53}$=2.24, p=.14), education ($F_{1,53}$=3.11, p=.08) or pre-injury occupation [χ^2(1, n=55) =8.84, p =.11]. There were also no differences in reported symptoms of depression ($F_{1,53}$=0.90, p=.35), anxiety ($F_{1,53}$=3.59, p=.06), and stress ($F_{1,53}$=4.66, p=.50). However, there was a significant between-group difference on the WTAR scores ($F_{1,53}$=10.54, p=.002) with TBI participants, on average, scoring lower than control participants. This finding is not surprising given previous research demonstrating that such measures may be affected by injury severity (Freeman, Godfrey, Harris, & Partridge, 2001; Mathias, Bowden, Bigler, & Rosenfeld, 2007; Morris, Wilson, Dunn, & Teasdale, 2005; Riley & Simmonds, 2003). As a conservative approach, WTAR scores were examined separately for their role in emotion recognition. Further, to ensure that WTAR performance was not influencing results, the analysis was re-run on a subgroup of participants with TBI that were matched to the control group on WTAR scores (subgroup n=47, containing 22 controls and 25 TBI), and all the group differences remained. There was a significant between-group difference in the performance on neuropsychological measures. The TBI group performed significantly lower on DSC ($F_{1,52}$=28.78, p<.0001), DS ($F_{1,53}$=5.42, p=.024), and MR ($F_{1,51}$=10.27, p=.002).

Table 3.1

Demographics, measures of socio-emotional and neuropsychological functioning of TBI and Control group

	TBI (n=27) M (SD)	Control (n=28) M (SD)	Group difference
Sex	f=7, m=20	f=12, m=16	p =.3
Age	46.93 (12.45)	41.50 (14.35)	p=.14
Educ. Level (years)	13.74, (2.81)	14.93 (2.16)	p=.08
WTAR	103.78 (14.92)	115.24 (11.03)	p=.002*
PTA (days)	82.67 (55.99)	N/A	
Pre-injury occ	unskill trade(n = 5) skilled trade (n = 8) clerical (n = 2) prof/mang (n =8) student (n = 4) unemployed (n=0)	unskill (n= 3) skilled trade (n = 2) clerical (n = 3) prof/mang (n = 9) student (n = 7) unemployed (n=4)	p =.11
DASS-21			
• **Stress**	9.75 (8.32)	11.59 (11.51)	p=.50
• **Anxiety**	2.75 (4.04)	5.19 (5.41)	p=.06
• **Depression**	6.29 (6.27)	8.00 (7.10)	p=.35
DSC	7.58 (3.14)	12.00 (2.92)	p<.0001**
DS	9.56 (2.42)	11.47 (3.53)	p=.024*
MR	11.50 (3.14)	14.04 (2.61)	p=.002*

M, mean; SD, Standard deviation; f, female, m, male; PTA; post traumatic amnesia, occ, occupation; DSC, Digit Symbol Coding, DS, Digit Span; MR, Matrix Reasoning; unskill, unskilled; skill, skilled; prof/mang, professional/managerial;
*p<.05; *p<.01

Analysis of 100% expressions

A mixed-design repeated measures 2(group)×6(emotion) ANOVA revealed a significant main effect of group ($F_{1,53}$=38.98, p<.0001, ηp^2= .42), indicating that the TBI group was less accurate than controls in recognising full intensity emotional expressions. There was also a significant main effect of emotion ($F_{1,53}$=45.37, p<.0001, ηp^2= .46), indicating that overall, some emotions were more difficult to recognise than others. This was tempered by a significant interaction between group and emotion ($F_{1,53}$=2.84, p=.02, ηp^2= .51). Bonferroni-adjusted pairwise comparisons (adjusted α=.05/6=.008) revealed that the TBI group were worse than controls in recognising anger, disgust and fear (all ps≤.001), but not happiness, sadness and surprise (all ps≥ .11). The accuracy rates for both groups are illustrated in Figure 3.2.

Specific contrasts comparing accuracy of the two positive (happiness and surprise) to the four negative (anger, sadness, fear, and surprise) emotions revealed that both groups were poorer in recognising negative than positive emotions ($F_{1,53}$=27.61, p<.0001). An interaction contrast revealed that the TBI group was significantly poorer recognising negative than positive emotions compared to controls ($F_{1,53}$=13.44, p<.0001). Inspection of the confidence intervals revealed that the TBI group, on average, was performing between .26 and 1.15 SD poorer than the control group on recognising negative full blown facial expressions compared to positive.

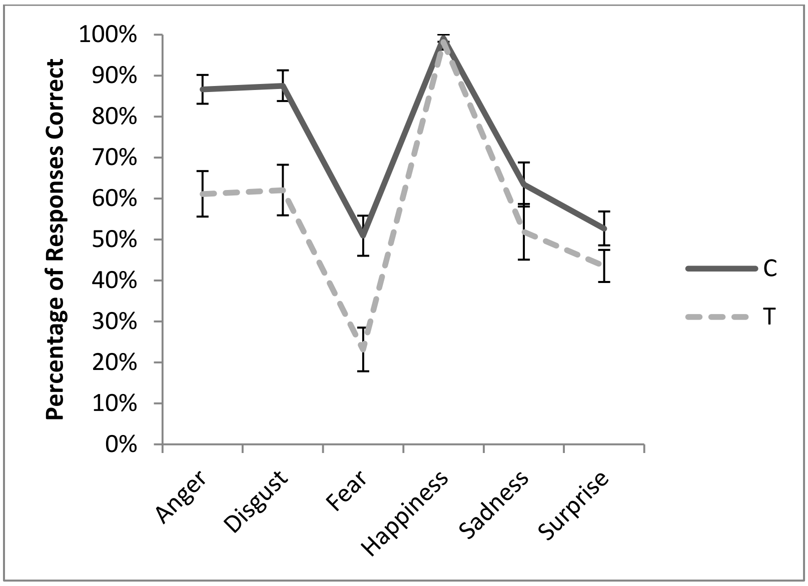


Figure 3.2. Emotion recognition in TBI and control groups using full-blown (100% intensity) emotional expressions. Error bars represent standard error of the mean. T, TBI; C, control.

Analysis of expressions equated on difficulty

In order to examine the equated emotions, a similar analysis was conducted for the 6 emotions at pre-selected intensities. A mixed-design repeated measures 2(group)×6(emotion) ANOVA revealed a significant main effect of group ($F_{1,53}$=28.05, p<.0001, ηp^2= .35), indicating that the TBI group was less accurate in emotion recognition that controls. There was also a significant main effect of emotion ($F_{1,53}$=5.25, p<.0001, ηp^2= .09), indicating that overall, some emotions were more difficult to recognise than others. However, the effect size of the emotion main effect was much smaller than the effect size of the emotion main effect in the 100% expressions (ηp^2= .09 vs. ηp^2= .46, respectively), indicating that the differential difficulty of the six emotions was reduced when they were equated. Bonferroni-adjusted pairwise comparisons (adjusted α=.05/5=.01) revealed that the significant emotion main effect was driven by the recognition of fear being lower than the mean ($F_{1,53}$=7.96, p=.007) and the recognition of happiness being higher than the mean ($F_{1,53}$=27.26, p>.0001). There was no group×emotion interaction for the equated emotions ($F_{1,53}$=.71, p=.62, ηp^2= .01), i.e., the TBI group was performing uniformly worse than controls across all six emotions. The data are shown in Figure 3.3.

Similarly, a specific contrast comparing accuracy of the two positive emotions to the four negative emotions revealed that overall, both groups were poorer in recognising negative than positive emotions ($F_{1,53}$=14.76, p<.0001), but no group×valence interaction was found ($F_{1,53}$=1.88, p=.18).

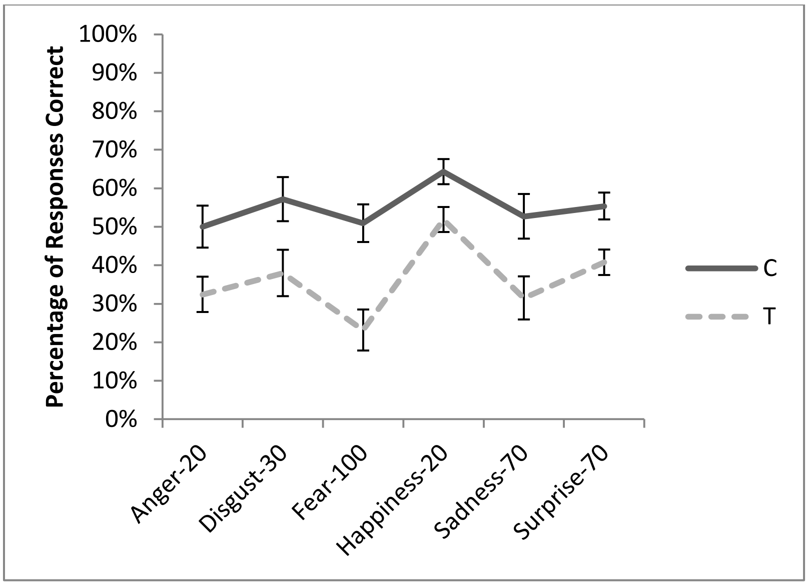


Figure 3.3. Emotion recognition in TBI and control groups using equated emotional expressions. Error bars represent standard error of the mean. T, TBI; C, control.

Correlations

Pearson correlations were conducted to examine whether emotion recognition (on equated measures) was correlated to performance on the Digit Span, Digit Symbol Coding and Matrix Reasoning subtests. WTAR was also included since the two groups differed on these scores. The correlational data are shown in Table 3.2. In this and subsequent analysis, PTA was included as a group variable (PTA=0 for controls) and as a measure of injury severity (higher values indicate greater injury severity). In this and subsequent analysis, Bonferroni correction (adjusted $\alpha=.05/5=.01$) was used for multiple comparisons. In light of the study hypotheses, all correlations were one-tailed.

There was a significant negative correlation between emotion recognition and PTA ($r=-.66$, $p<.001$), indicating that longer PTA (and more severe TBI) was associated with worse emotion recognition. There was a significant positive correlation between WTAR and emotion recognition ($r=.42$, $p=.001$), indicating that higher scores were associated with better performance on the ERT. There was a significant positive correlation between emotion recognition and Digit Symbol Coding ($r=.61$, $p<.001$) and also Matrix Reasoning ($r=.49$, $p<.001$), indicating that both processing speed and non-verbal reasoning are associated with overall emotion recognition. There was also a trend for an association between Digit Span and emotion recognition, which approached, but did not reach the conservative Bonferroni corrected significance level ($r=.30$, $p=.013$). The correlations were re-run in the TBI and control groups separately, and the results in TBI group were the same as reported above (PTA; $r=.49$, $p=.001$, Matrix Reasoning; $r=.31$, $p=.008$, Digit symbol; $r=.49$, $p=.006$, Digit Span n.s, $p=.09$), with the exception of a correlation between ERT and WTAR, which failed to reach significance ($r= .31$, p=.06). In the control group, there were no significant correlations with ERT performance (all ps≥.05).

Table 3.2.

Table of correlations between Emotion recognition (equated), PTA, WTAR, and neuropsychological measures

Variable	Emotion rec (eq)	PTA	WTAR	Digit span	Digit symbol coding	Matrix reasoning
Emotion rec (eq)	1	-.66**	.42**	.30 ns	.61**	.49**
PTA		1	-.36*	-.39**	-.58**	-.55**
WTAR			1	.56**	.48**	.47**
Digit span				1	.42*	.58**
Digit symbol coding					1	.56**
Matrix reasoning						1

NS = not significant (p>.01), correlation is significant at the* p<.01 (Bonferroni adjusted), **p<.001, Emotion rec (eq)= emotion recognition (equated), all correlations are one-tailed. PTA includes information about group membership (PTA=0 for control participants) and injury severity. Digit span p=.013.

Regression analysis

Since emotion recognition was established to be related to processing speed, non-verbal reasoning and working memory (trend only), these three constructs were examined to determine whether they could predict emotion recognition over and above group membership and injury severity (PTA) in the overall sample. WTAR was also entered into the model due to its correlation with emotion recognition. A significant model emerged: $F_{1,53}$=10.70, p<.001. The model explained 48.7% of the variance in emotion recognition (see Table 3.3). PTA (t=-3.42, p=.001), was the only significant predictor of emotion recognition that withstood the Bonferroni correction (α=.05/5=.01) with Digit Symbol Coding demonstrating a trend that failed to reach significance (t=2.12, p=.04). WTAR, Digit Span and Matrix Reasoning were not significant predictors (all ps ≥ .04). The regression analyses were re-run separately for TBI and control groups and the results remained the same as in the overall sample. In the TBI group, the single significant predictor for ERT score is PTA (t=. -2.62, p=.017), and in the control group, there are no significant predictors. This indicates that in both TBI and control participants, cognitive functioning does not predict emotion recognition performance.

Table 3.3.

The unstandardized and standardised regression coefficients for the variables entered into the model

Variable	B	SE B	β	*p*
PTA	-.005	.001	-.446	.001*
WTAR	.007	.006	.161	.216
Digit span	-.026	.027	-.129	.342
Digit symbol coding	.050	.024	.290	.039
Matrix reasoning	.015	.029	.074	.605

*Significant at the Bonferroni adjusted (α=.05/5=.01) p<.01

Discussion

This study investigated facial emotion recognition in individuals with moderate-severe TBI, as measured by the ERT (Montagne, Kessels, et al., 2007), a sensitive measure which incorporates a series of morphed facial expressions of gradually increasing intensity. Study 2 extended on Study 1 by examining the relationship between emotion recognition in TBI when emotions were equated for difficulty and by comparing performance to neuropsychological functioning. As an initial step emotion recognition in individuals with TBI was examined across stimuli of full-blown emotions (100% intensity), such as those most commonly used in emotion recognition research. In the next stage comparisons were made across groups using stimuli that were equated, as far as possible, on difficulty. On both measures, control and TBI participants found the negative emotions more difficult to recognise than positive. Moreover, on both measures, consistent with previous literature (e.g., Babbage et al., 2011; Ietswaart, Milders, Crawford, Currie, & Scott, 2008), the TBI group was worse in overall emotion recognition than matched controls. The fact that this difference persisted across recognition of full- blown and equated measures, further illustrates the robustness of the emotion recognition deficit in TBI.

However, the findings based upon the recognition of full-blown emotions yielded quite different implications about TBI deficits than did the equated measures. Across the conventional 100% intensity full-blown measures of emotion, individuals with TBI were selectively impaired in recognising anger, fear, and disgust, and unimpaired (i.e., performing to the same level as controls) in recognising happiness, surprise and sadness. When comparing recognition rates of positive and negative emotions, consistent with previous research (e.g., Croker & McDonald, 2005; R. E. Green et al., 2004; Hopkins et al., 2002), the TBI participants appeared to be more impaired in recognising negative than positive emotions. However, when using expressions that were equated on task difficulty, individuals with TBI displayed a *general impairment* in emotion recognition, rather than a *selective impairment* in the recognition of some emotions compared to others. Consequently, while the valence effect remained overall (i.e., both groups found negative emotions more difficult than positive), the TBI group was not differentially more impaired in recognising negative emotions compared to controls, in fact, they found the same emotions difficult.

These findings strengthen the argument that TBI results in an overall, general emotion recognition deficit, rather than a selective impairment in recognising some emotions compared to others (e.g., negative compared to positive). This suggests that the differential impairment in the recognition of negative emotions that is reported in the literature (e.g., Croker & McDonald, 2005; R. E. Green et al., 2004) might be an artefact of the stimuli rather than being a genuine neurological phenomenon. These findings also suggest that it is possible that the valence effect is indeed driven by the 'happy' smile, which makes facial expressions of happiness simply too easy to recognise, since they can be detected by a single feature (the smile). This makes happiness unlikely to be confused with other expressions which lack this feature, and involve additional information about the configuration of the face (Adolphs, 2002b).

While the study did not find evidence for selective impairment of negative emotions in this study, the data supported the view that emotion perception (regardless of valence) appears to be a specialised cognitive system. This ability was impaired in people with TBI, more so in those with more severe injuries, and was not accounted for by impairments in other cognitive systems. Processing speed, working memory and non-verbal reasoning were associated with performance on equated emotion recognition, but only injury severity (as measured by PTA) uniquely predicted emotion recognition performance. This suggests that emotion recognition difficulties in TBI are a direct result of brain injury, rather than being a consequence of reduced neuropsychological functioning or of sheer isolation from social networks and poor community reintegration (e.g., Bornhofen & McDonald, 2008c). Further, the fact that our TBI sample sustained their injuries a long time ago (time post injury ranged from 2 to 40 years) is consistent with recent research suggesting a general lack of recovery at one year follow-up (Milders et al., 2008). This emphasises the importance of emotion recognition rehabilitation following TBI (Bornhofen & McDonald, 2008c)

Overall, these findings provide further support for the detrimental effect of moderate-severe TBI on one's ability to recognise facial expressions, and contradict the claim that TBI results in a selective impairment in recognising negative, rather than positive emotions. Once emotions are equated for difficulty, individuals with TBI perform worse than controls across all emotions, but follow the same patterns of responses, i.e., finding the same emotions difficult. Further, the findings suggest that while emotion recognition is negatively associated with measures of non-verbal reasoning and processing speed in people with TBI (replicating earlier findings, e.g., McDonald et al., 2006; Yim et al., 2013), injury severity predicts emotion recognition performance over and above reduced working memory, non-verbal reasoning and processing speed. The importance of injury severity is consistent with the findings by Spikman et al. (2012), emphasising the notion of dose-response relationship in TBI (Temkin et al., 2009).

These results fail to support the argument that there are specific, dedicated neural networks that subserve discrete categories of facial expressions although they do suggest that facial affect recognition (in general) is a process that is, in important respects, independent from other cognitive systems. They also highlight the need for caution when drawing conclusions about selective impairment in the recognition of some emotions compared to others in clinical populations. Specifically, these findings suggest that the differential impairment in the recognition of negative versus positive emotions, which is often reported in the literature, is an artefact of the use of a limited set of 6 emotions and static, 100% full blown expressions, rather than representing a real neurological phenomenon. Thus, to validly explore differences in recognition rates between emotions stimuli should include a comparable number of positive and negative emotions, and should be equated on difficulty level. This measure which includes a wider range of emotions would be useful both clinically and theoretically.

As evident from the emotion recognition research outlined in the Introduction, and as demonstrated by the findings of Study 1 and 2, current emotion recognition measures, while significantly expanding our understanding of emotion perception in healthy and clinical populations, have a number of methodological limitations. Studies 1 and 2 attempted to address the confound of item difficulty and the limitation imposed by using static images, typical of much of the conventional emotion recognition measures. It did so by using the ERT (Montagne, Kessels, et al., 2007), a task incorporating dynamic displays of emotion across different intensities, to examine emotion recognition difficulties in individuals with TBI and matched controls. These studies indicated that emotion recognition is affected by item difficulty, with pronounced floor and ceiling effects, and that most importantly, the valence effect in TBI which is present when the 100% full-blown expressions are used, disappears when the standard six emotional expressions are equated on difficulty.

While demonstrating how methodological shortcomings of the conventional emotion recognition measures may confound the conclusions regarding emotion recognition deficits in TBI, these studies have failed to address the remaining limitations of these measures. Crucially, ERT still shares five out of the seven limitations of the conventional emotion recognition measures; (1) it includes twice as many negative emotions as positive, (3) includes surprise which lacks a clear valence as the other emotions, (5) is uni-modal, (6) includes posed emotions, and (7) is limited to only six emotions, failing to include the wider range of emotions that typically reflect human experience. These limitations are addressed in the following studies.

CHAPTER 4

Study 3. Complex Audio-Visual Emotion Assessment Task (CAVEAT) development

In Chapters 2 and 3 the ERT (Montagne, Kessels, et al., 2007) was used as an instrument to measure emotion perception in TBI, and made it possible to examine the effects of differential difficulty associated with different emotions. Even so, the ERT retains a number of the disadvantages of the conventional measures of emotion perception. Specifically, it is limited to six basic emotions while social life embraces many more. Further, stimuli are limited to visual displays of posed emotional expressions. This limits the extent to which such tests mirror real world functioning which is an important consideration for not only theoretical but also clinical and practical purposes. In light of this, the current emotion recognition measures require updating.

This chapter describes the development of the Complex Audio-Visual Emotion Assessment Task (CAVEAT) which was designed to address the limitations of conventional measures by (1) including equal number of positive and negative emotions, (2) selecting items with similar levels of task difficulty, (3) representing surprise as both positive and negative in valence, (4)-(5) incorporating dynamic, multi-modal cues, (6) representing genuine (not posed) displays of emotion, and (7) including a larger number of emotions, including more complex emotions that vary across different dimensions, mirroring the wider range of emotions as experienced in everyday life.

The overarching aim of the studies described in this chapter is to develop and pilot test CAVEAT, in order to arrive at a final version which is both sensitive to emotion perception difficulties following TBI and other brain impairments and predictive of real world functioning. In addition, the final study aimed to examine recognition rates of the basic six emotions included in the CAVEAT, in order to provide a direct comparison of the recognition rates of these basic six emotions in CAVEAT compared to other conventional tests.

Specifically, **Study 3A** aimed to test recognition of an initial set of vignettes (CAVEAT: Pilot #1) depicting 34 emotions on a group of healthy individuals, in order to identify the most reliable emotion categories and to remove the least reliable to develop the next version of CAVEAT. It also aimed to determine whether choosing one label from the full array of 34 possible emotions would be appropriate as a measure of accuracy. **Study 3B** aimed to use a refined version (CAVEAT: Pilot #2) with 30 emotions in a larger sample of undergraduate psychology students to further identify unreliable emotions and test an alternative response format where the emotion for each item was selected from a possible 4. In **Study 3C** three alternative versions of CAVEAT: Pilot #2, #3, and #4 were tested on a group of individuals with TBI and matched controls using three alternate response formats in order to establish the most suitable response which is not too difficult for people with moderate-severe TBI and not too easy for healthy controls. Finally, Study 3D aimed to examine performance of a TBI and control group on a subset of the six basic emotions included in the CAVEAT (fear, sadness, anger, disgust, happiness, and fear), in order to compare recognition rates to those reported in the literature using conventional measures of these six emotions.

Study 3A

This study explored the initial set of CAVEAT emotions comprising 136 items (34 emotions, four vignettes each) using a 34 item multiple-choice response format. It aimed to eliminate emotions that were the least reliable or redundant, and to examine whether this response format is appropriate.

Method

Participants

The task was administered to 14 (4 males, 10 females) students and research assistance staff at the School of Psychology at the University of New South Wales. Participation was voluntary, and consent was obtained in line with a protocol of university ethics Human Research Ethics Committee.

Materials

Complex Audio-Visual Emotion Assessment Task (CAVEAT): Pilot #1 was modelled on TASIT (McDonald et al., 2002), in particular the use of an audiovisual format and the inclusion of everyday scenarios involving one or two actors engaged in an ambiguous conversation (which gives no clue as to the emotions involved).

CAVEAT was developed in a few steps, each of which is described below.

CAVEAT development

Identifying emotions to be included in the measure. Potential emotions to be included in the measure were identified through internet and literature search, using Google, Google Scholar and Ovid search engines, with the keywords of ‘emotion’, ‘emotions’, and ‘feelings’. A list of 34 emotions was generated based on emotions that commonly repeated in the search. Four emotions were excluded since they were too similar to other emotions on the list, and could not be distinguished from others. The original list of emotions included in CAVEAT Pilot #1 is depicted in Table 4.1.

Stimuli development. A series of scripts were developed to be neutral and ambiguous in content, requiring actors to modulate their facial expressions, tone of voice, and body language and movement to express the desired emotions. The scripts are modelled on the ones used in the Awareness of Social Inference Test (TASIT; McDonald et al., 2002), a measure of social cognition developed in our laboratory and used in a wide range of clinical populations, such as TBI, Schizophrenia and ASD (McDonald et al., 2003). A group of nine professional actors (4 males, 5 females) were hired for CAVEAT development. The actors were trained in the 'method' acting style, requiring the actors to induce the target emotions in themselves prior to enacting a script. Since fear is consistently identified to be the most difficult and happiness the easiest emotion to recognise, actors were instructed by the director to express fear more intensely, as if they were terrified. The display of happiness remained as usual, since the inclusion of additional positive emotions was estimated to reduce the ceiling effect observed for happiness.

The actors were filmed expressing the target emotions either individually or in pairs (one person being the target actor expressing the required emotion, and the other one setting up the scene, such as handing over a box to the target actor). Each emotion was expressed four times, each time with a different script. These resulted in 180 scenes (four vignettes of each of the 30 emotions). After the scenes were filmed, the video footage was edited using Adobe Premier Elements version 9.0, to include a 10-30sec vignettes, four of each emotion. The generated vignettes were copied on to a DVD in a semi-random order, with the restriction that vignettes that contain the same emotion, script or actor, could not be viewed one after the other.

Emotion rating. Next, the list of emotion labels were ranked based on their valence, socialness, and approach tendency by a group of 15 (6 males, 9 females) raters from the laboratory staff and research students. The valence rating, in particular, was essential so as to divide the emotions into the positive and negative categories. These ratings provided an independent estimate of the category to which the emotions belonged. While it was not clear whether dichotomies based on social versus non-social and approach versus avoidance could be reliably identified, it was assumed that valence would be, i.e., "while only some people seem to know the difference between discrete emotion experiences, everyone knows the difference between a pleasant feeling and an unpleasant one" (Barrett, 2006, p 38).

CAVEAT Pilot #1 included 34 emotions with four vignettes for each emotion, resulting in a total of 136 vignettes. After watching each vignette, participants selected a label which best described the emotion/feeling of the target person in the scene, from a list of the 34 emotions. Two still frames (generated from the videos) of the CAVEAT are shown in Figure 4.1.

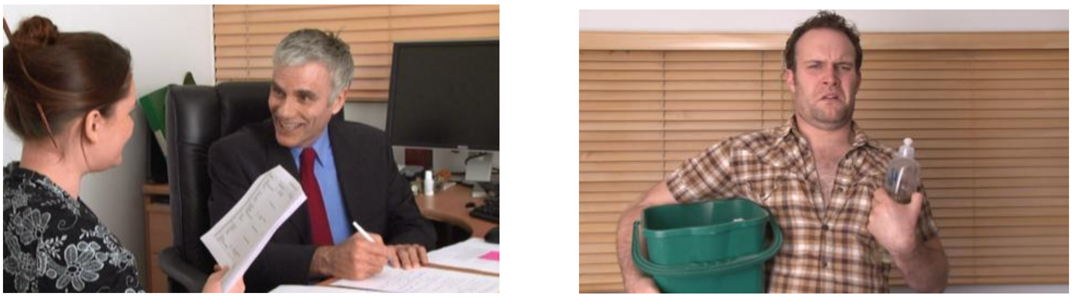


Figure 4.1. Sample still frames from CAVEAT. Picture on the left, target actor (male) is depicting a happy expression. Picture on the right, actor displaying a disgusted expression.

Procedure

Participants were given a DVD of the CAVEAT Pilot #1 and a response form. They were asked to complete the task individually in their own time, and were advised to allow one hour for the task. After completion, they passed their response sheets to the experimenter in a closed envelope.

Data Analysis

Data were analysed with Microsoft Excel 2010. Average percentages of correct and error responses were calculated and examined visually. The correct responses were ranked from highest to lowest to allow visual inspection. Confusability with other emotions was also calculated, (i.e., percentage of emotions incorrectly labelled as other emotions) and used to guide the decision to remove or retain emotions for the next step of pilot testing.

Results

Emotion rating. The combined agreement ratings for the emotions ranged from 93%-100% for valence, and from 53%-100% for social/non-social. Due to the lower agreement rates in the social/non-social dimension, six emotions (three social and three non-social) that had the highest inter-rater agreement were used to analyse this dimension. The dimension of approach versus avoidance was initially also included but this overlapped entirely with positive versus negative (even anger that can be viewed as approach oriented, was rated as an avoidance emotion). Thus, it was dropped from further analysis.

Recognition accuracy. Accuracy percentages for each emotion are outlined in Table 4.1. Inspection suggested that there were several emotions with very low accuracy rates, while others are recognised very well. Qualitatively, participants reported that the measure was very long and that they found it tiring, but were able to maintain concentration.

Table 4.1

CAVEAT Pilot #1 mean accuracy in percentages for 34 emotions, n=14, ranked from highest to lowest

Emotion #	Emotion	Accuracy (% correct)
1	Relieved	96.08%
2	Fearful/anxious	91.67%
3	Flirtatious	84.00%
4	Disinterested	75.51%
5	Angry	74.00%
6	Negatively surprised	72.55%
7	Amused	70.00%
8	Caring	66.00%
9	Neutral	70.00%
10	Baffled/unsure	67.35%
11	Suspicious	66.00%
12	Annoyed	63.27%
13	Bored	64.00%
14	Positively surprised	61.22%
15	Disgusted	59.62%
16	Sad	57.14%
17	Shy	56.00%
18	Happy	51.02%
19	Confident	51.02%
20	Contempt	52.00%
21	Enjoyment	54.00%
22	Worried	50.00%
23	Excited	42.00%
24	Hopeful	40.00%
25	Arrogant/cocky	42.00%
26	Cheeky/playful	34.69%
27	Proud	32.65%
28	Satisfaction	34.69%
29	Interested	29.41%
30	Contented	27.45%
31	Guilt	26.53%
32	Embarrassment	28.00%
33	Touched	23.53%
34	Shame	10.00%

Error patterns. The error matrix outlining the incorrect labels given to the different emotions is outlined in Appendix 1 (it was included in the Appendix due to its large size). Inspection revealed that a few emotions were highly confused with others, with 'boredom' and 'disinterest' overlapping to such an extent that they could be sensibly combined into a single category. Some emotions were confused with only a small number of emotions while others were commonly confused with a wide range of other emotions, (e.g., 'flirtatious' was only confused with two other emotions, while 'embarrassment' was confused with more than eight emotions). The error matrix also revealed problems with inclusion of 'neutral' as a category. The 'neutral' vignettes were mostly incorrectly labelled as 'disinterest' (71%). Conversely, other emotions were frequently labelled as a neutral expression (on nine occasions) which suggested that this category was selected as a default when participants were not able to identify the emotion.

Discussion

The findings for CAVEAT Pilot # 1 suggested that some emotions were not recognised reliably and were highly confusable with other emotions. Three emotions identified as the least reliable ('shame', 'contentment', 'touched') were removed and two emotions ('disinterest' and 'boredom') were collapsed into one category of 'disinterested/bored'. The emotions which remained in the task are outlined in Table 4.2.

In addition, the task took approximately one hour, and the participants reported that they were quite fatigued. Participants indicated that it was difficult to make a selection out of 34 emotions, and that they thought it would be easier for the selection to be narrowed down. A narrower response format with a lower number of emotions is trialled in the next study. In addition, the frequent use of the 'neutral' category suggested that participants were using it potentially as a default as a "don't know" category. In addition, ‘neutral’ was most commonly confused with ‘bored’ and ‘disinterested’, suggesting that the three might be perceived similarly by participants.

Finally, examining the agreement rates for emotion rating revealed that the intuition that valence would be reliable was correct (as evident by very high agreement ratings between raters), but reliability of socialness was less so. This is consistent with the notion that valence might be the most salient dimension of emotion (Barrett, 2006). Consequently, determining the valence of an emotion might be easier than determining it socialness, because the latter involves deciding on whether or not an emotion requires the representation of mental states (Burnett, Bird, Moll, Frith, & Blakemore, 2009). These ratings were used to classify emotions in Study 5 in order to determine if there are differences in the ease in which people with TBI recognise different types of emotion.

Study 3B

Based on the findings of Study 3A, Study 3B piloted a reduced, 30-emotions version of the CAVEAT on a sample of healthy undergraduate students, in order to continue to eliminate the least reliable emotions and investigate if a constrained multiple-choice is appropriate.

Method

Participants

Participants were 55 (23 males, 32 females) undergraduate psychology students at the University of New South Wales, and were aged 18 to 26 years (M=20.07, SD=1.93). Participation was voluntary, and consent was obtained in line with a protocol of university ethics Human Research Ethics Committee.

Materials

Complex Audio-Visual Emotion Assessment Task (CAVEAT) Pilot #2. The second pilot version of CAVEAT had 120-items (30 emotions x 4 vignettes) and used a constrained multiple choice response format in which there were four choices to select from for each item, one correct and three distractors. The distractors were selected in a semi random fashion, with two emotions selected from the same valence as the correct response, and one of opposite valence, as guided by the error matrix obtained from Study 3A.

Procedure

All procedures took part at a psychology group laboratory at the University of New South Wales. Demographic information was obtained and the participants were administered a static emotion recognition test followed by CAVEAT Pilot #2 which was administered individually on a computer, via VLC media player. Participants viewed each of the vignettes and then made a response on the response sheet provided. They could pause the videos as required, if they needed longer to make a response or needed a break. The measure took 40 min in total. The protocol was administered in groups of 6-10 people, each person completing all measures individually on a computer with headphones. An experimenter was always in the laboratory available to answer any questions and to assist with any procedures.

Data Analysis

Percentages of accuracy in recognising each emotion was calculated with Microsoft Excel 2010 by calculating the average percent correct for each emotion.

Results

Accuracy per emotion, ranked from highest to lowest for CAVEAT Pilot #2 is outlined in the left column of Table 4.2. The accuracy scores for CAVEAT Pilot #1 (which are depicted in Table 4.1) are replicated in the right column of Table 4.2 for convenience. Inspection suggests that the correct recognition rates were much higher for CAVEAT Pilot #2 than CAVEAT Pilot #1. Indeed, 10 of the 30 emotions had accuracies above 95%.

The error matrix for CAVEAT Pilot #2 was not examined due to the restriction of the response selection to 3 distractors that were semi-randomly generated.

Table 4.2

Accuracy across the 30 retained emotions, ranked from highest to lowest for CAVEAT Pilot #2 (left hand column) and CAVEAT Pilot #1 (right hand column)

	Emotion	**CAVEAT Pilot #2**	**CAVEAT Pilot #1**
1	Relieved	99.07%	96.08%
2	Angry	99.07%	74.00%
3	Disinterested/Bored	98.61%	75.51%
4	Fearful/anxious	98.61%	91.67%
5	Amused	98.15%	70.00%
6	Positively surprised	96.76%	61.22%
7	Worried	96.76%	50.00%
8	Annoyed	95.83%	63.27%
9	Arrogant/cocky	95.83%	42.00%
10	Baffled/unsure	95.37%	67.35%
11	Sad	94.91%	57.14%
12	Suspicious	94.44%	66.00%
13	Excited	94.44%	42.00%
14	Flirtatious	93.98%	84.00%
15	Shy	93.52%	56.00%
16	Neutral	92.59%	70.00%
17	Caring	92.59%	66.00%
18	Cheeky/playful	92.13%	34.69%
19	Enjoyment	92.13%	54.00%
20	Hopeful	89.81%	40.00%
21	Negatively surprised	88.89%	72.55%
22	Proud	88.43%	32.65%
23	Satisfied	85.65%	34.69%
24	Interested	82.41%	29.41%
25	Confident	81.94%	51.02%
26	Disgusted	79.17%	59.62%
27	Happy	79.17%	51.02%
28	Contempt	78.24%	52.00%
29	Embarrassment	78.24%	28.00%
30	Guilt	78.24%	26.53%

Discussion

Results revealed that the multiple choice response format for CAVEAT Pilot #2 was too easy for healthy non-clinical individuals, with response rates reaching ceiling on several emotions. A more difficult response format is required to reduce ceiling effects. Comparison of accuracy rates between CAVEAT Pilot #2 and CAVEAT Pilot #1 revealed that the narrower multiple choice format made even difficult emotions such as contempt, guilt and embarrassment much easier to recognise. However, despite a great increase in recognition rates (accuracy) in CAVEAT Pilot #2, the ranking of the emotions based on difficulty, largely remained quite similar between versions.

Overall, the very high recognition rates observed in this study suggested that the narrower option multiple choice response format is too easy for healthy controls, and that a more appropriate response format needed to be developed.

Study 3C

Study 3C aimed to determine an appropriate, middle range response format that is not too easy for healthy participants (as was CAVEAT Pilot #2) but also manageable for people with TBI. Thus, Study 3C had two aims: 1) to examine whether CAVEAT is sensitive to TBI, and 2) to establish an appropriate response format for the final form of CAVEAT that can be used with people with TBI and with healthy controls (i.e., not too difficult to be used in TBI groups and not too easy to be used with healthy controls).

This was approached in two steps. First, in order to establish a response format that can be completed by individuals with TBI (i.e., one that is not overly long or taxing), three response formats, were trialled with small subgroups of participants with TBI, i.e., multiple choice out of (1) four, (2) 23 and (3) 11 (the latter entailing 22 response choices divided into positive and negative emotions). Once an appropriate response format was established (i.e., TBI participants were observed to be able to complete the measure), it was administered to control participants to observe their performance to check for ceiling effects.

Method

Participants

Clinical sample

Ten individuals with TBI (9 males and 1 female), took part in this study, and were recruited from brain injury units in Sydney, Australia. All participants meet the following criteria: (1) sustained a moderate-severe TBI, measured as posttraumatic amnesia (PTA) greater than 1 day, (2) were at least 1 year post-injury, (3) were able to understand and adhere to instructions, and (4) had no identified aphasia or agnosia.

The participants were aged between 28 to 62 years (M age = 47.80 years, SD = 12.66), had experienced PTA ranging from 2 to 180 days (M = 51.90, SD = 49.74), and time post injury ranging from 3 to 19 years (M= 10.90, SD = 5.12). The participants had achieved an average 13 years (SD = 3.03) of education. Prior to the TBI, they had been employed in occupations ranging from skilled (n=3) to unskilled trade (n=2), professional and managerial (n=2), or part/full time study (n=2). One participant was unemployed. At the time of participating in this study, they were employed in occupations ranging from skilled (n=1) to unskilled trade (n=1), professional and managerial (n=1). Seven participants were unemployed.

Control sample

Six healthy individuals (5 males, 1 female) were recruited from the general community through advertising. Participants were aged from 29 to 62 years (M age=47.50, SD=11.84), had obtained a mean education level of 14.33 years (SD = 2.80 years), and were matched as closely as possible to the TBI participants in respect to sex, age, years of education, and pre-injury occupation (all ps>.17). There were no between-group differences on levels of depression, anxiety or stress as measured by DASS-21 (all ps>.09). At the time of the study, the controls participants were employed in occupations ranging from skilled trade (n=1), professional and managerial (n=3), or part/full time study (n=2). For both control and TBI groups, exclusion criteria included history of developmental, neurological (with the exclusion of TBI in the clinical group), psychiatric disorders, hearing impairments, uncorrected vision, or inability to communicate effectively.

Materials

Depression, Anxiety and Stress Scale (DASS-21; Lovibond & Lovibond, 1995) was administered to ascertain participant's self-reported symptoms of depressive mood, anxiety and stress.

The three different versions of the CAVEAT were administered;

Complex Audio-Visual Emotion Assessment Task (CAVEAT) Pilot #2 was re-administered to participants with TBI to determine how people with TBI and concomitant cognitive deficits would fare, given this version was too easy for healthy controls (see Study 3B). In this case it was administered by a clinician to each participant individually (compared to Study 3B where it was administered in a group). It had 30 emotions x four vignettes (120 items) with four response choices.

Complex Audio-Visual Emotion Assessment Task (CAVEAT) Pilot #3 had 23 emotions x four vignettes (92 items) with 23 response choices. This was an attempt to trial a constrained choice out of 23 emotions, rather than the 30 emotions used in CAVEAT #2 (92 instead of 120) but to expand the multiple choice options to 23 emotions rather 4 (which is still fewer than the 34 in CAVEAT#1). The rational was to trial a 'middle ground' in terms of difficulty between the two earlier versions that the previous studies revealed to be too difficult or too easy.

Complex Audio-Visual Emotion Assessment Task (CAVEAT) Pilot #4 had 22 emotions x four vignettes (88 items) and 22 response choices divided into positive and negative emotions based upon the ratings obtained in Study 3A. In this version eight of the least accurate emotions were removed, four from each valence leaving 88 vignettes representing 22 different emotions. Neutral was also removed ensuring the respondent had to make a selection between emotional expressions rather than opting for neutral as an ambiguous alternative. This version trialled the utility of implementing a broad-based decision based on valence, followed by a more fine-grained categorisation of the emotion. In this version for each vignette, participants were shown two columns of eleven descriptors (22 altogether) labelled at the top as either positive or negatively valanced emotions. Participants were first asked if the emotion was positive or negative. If they were correct they were then asked to choose which emotion of the eleven it corresponded to. If incorrect, they were corrected and referred to the appropriate column.

Procedure

The TBI group was randomly divided into three subgroups, each of the subgroups completing a different response format. All participants were informed of the study procedures, and gave written consent to participate in the study. The study procedures were conducted at the neuropsychology laboratory of the University of New South Wales and were approved by the Human Research Ethics Board of the University.

All procedures were administered individually on a computer screen, with the experimenter present in the room. Respondent viewed each video and asked to make a response (verbally indicate which emotion best described the emotion/feeling which was expressed by the target actor). If there were two actors present, the experimenter pointed out the target actor as the video starting. The response time was untimed and the next video would not start until they have made a response. If the respondent would say: 'I don't know' following a video, they were encouraged to make a guess. If they insisted that they did not have a response, the experimenter proceeded to the next item by saying: 'let's try another one'.

Data Analysis

Data were examined quantitatively (comparing TBI and control performance on CAVEAT and presence/absence of floor or ceiling effects) with Microsoft Excel 2010 and qualitatively (observing CAVEAT performance while completing the measure, such as participants request to repeat the video, reporting of forgetting, request for breaks, report of fatigue, etc.). Data for CAVEAT Pilot #2 and CAVEAT Pilot #3 were compiled into accuracy per emotions and examined visually, and data for CAVEAT Pilot #4 were analysed using two one-way ANOVAs to compare the two groups on their emotion recognition (i.e., CAVEAT performance), and the number of incorrect valence identifications made. The valence identification refers to the frequency of both groups incorrectly indicating that the target actor is feeling positively while he/she was feeling negatively (and vice versa) and subsequently being referred to the other column to make a selection. Error matrices outlining the incorrect labelling of the different emotions were calculated for 6 TBI and 6 control participants in the valence-correction response format (CAVEAT Pilot #4).

Results

CAVEAT Pilot #2 and CAVEAT Pilot #3

Preliminary pilot data from TBI participants completing CAVEAT Pilot #2 (30 emotions x 4 vignettes (120 items) with 4 choice format) CAVEAT Pilot #3 (23 emotions x 4 vignettes (92 items) with 23 choice format) and is reported in Table 4.3.

Table 4.3

Pilot data from TBI participants completing CAVEAT Pilot #2 (120 items, 4 choices per item) CAVEAT Pilot #3 (92 items 23 choices per item) and for each emotion ranked from highest accuracy to lowest.

CAVEAT Pilot #2 n=2		**CAVEAT Pilot #3 n=2**	
Emotion	**Accuracy**	**Emotion**	**Accuracy**
Excited	100.00%	Disinterested/Bored	100.00%
Satisfied	100.00%	Enjoyment	87.50%
Relieved	100.00%	Relieved	87.50%
Angry	100.00%	Angry	87.50%
Suspicious	100.00%	Fearful/anxious	87.50%
Annoyed	87.50%	Negatively surprised	75.00%
Positively surprised	87.50%	Happy	62.50%
Arrogant/cocky	87.50%	Suspicious	50.00%
Negatively surprised	87.50%	Positively surprised	50.00%
Enjoyment	87.50%	Neutral	50.00%
Fearful/anxious	87.50%	Annoyed	50.00%
Hopeful	75.00%	Amused	50.00%
Proud	75.00%	Disgusted	50.00%
Interested	75.00%	Caring	37.50%
Amused	75.00%	Baffled/unsure	37.50%
Flirtatious	75.00%	Shy	37.50%
Happy	75.00%	Contempt	37.50%
Disinterested/Bored	62.50%	Flirtatious	37.50%
Disgusted	62.50%	Confident	25.00%
Worried	62.50%	Sad	25.00%
Caring	62.50%	Proud	25.00%
Cheeky/playful	62.50%	Excited	25.00%
Baffled/unsure	50.00%	Interested	12.50%
Embarrassment	50.00%		
Guilt	50.00%		
Neutral	50.00%		
Confident	37.50%		
Contempt	37.50%		
Sad	37.50%		
Shy	25.00%		

Qualitative observations of the inspection of the left column of Table 4.3 suggests that limiting the multiple choice options to four was too easy for TBI participants as evident by their performance reaching a ceiling for five emotions. Conversely, the right column suggested that CAVEAT Pilot #3 (92 items 23 choices per item) was too challenging and taxing for TBI participants. While scanning the response sheet containing 23 emotions, they often reported forgetting how the target actor was feeling or who was the target actor, and asked to repeat the video. They were also observed to repeatedly scan the list, losing track of the different responses.

CAVEAT Pilot #4

Data from TBI participants and controls who completed CAVEAT Pilot #4 including 22 emotions x four vignettes (88 items) and with a valence-corrected choice of 11 responses is outlined in Table 4.4.

Table 4.4

Accuracy rates (percentages) for control and TBI groups completing CAVEAT Pilot #4 (88 items, valence corrected choice of 11 responses)

CONTROL group n=6		**TBI group n=6**	
Emotion	**Accuracy**	**Emotion**	**Accuracy**
Fearful/anxious	95.83%	Fearful/anxious	66.67%
Flirtatious	91.67%	Flirtatious	66.67%
Relieved	83.33%	Relieved	79.17%
Disinterested/Bored	70.83%	Disinterested/Bored	70.83%
Caring	66.67%	Caring	16.67%
Amused	62.50%	Amused	45.83%
Angry	62.50%	Angry	37.50%
Suspicious	58.33%	Suspicious	37.50%
Annoyed	54.17%	Annoyed	66.67%
Enjoyment	50.00%	Enjoyment	37.50%
Disgusted	50.00%	Disgusted	54.17%
Interested	50.00%	Interested	37.50%
Proud	50.00%	Proud	33.33%
Positively surprised	45.83%	Positively surprised	37.50%
Sad	45.83%	Sad	25.00%
Shy	45.83%	Shy	12.50%
Excited	45.83%	Excited	33.33%
Negatively surprised	41.67%	Negatively surprised	54.17%
Confident	41.67%	Confident	29.17%
Baffled/unsure	37.50%	Baffled/unsure	41.67%
Happy	33.33%	Happy	20.83%
Contempt	33.33%	Contempt	8.33%

Inspection of Table 4.4 suggests that the TBI group have lower accuracy than controls on most emotions. One-way ANOVA revealed that the between-group difference is approaching significance ($F_{1,10}$=4.91, p=.051). The accuracy rates of the control group were similar to the recognition rates in CAVEAT Pilot #1 (see Table 4.1) which also used a non-clinical population. Interestingly, the recognition of fear in both groups is the most accurate and the recognition of happiness is the least accurate.

Valence correction

A one-way ANOVA revealed that the two groups did not differ on the number of times they identified a valence incorrectly (e.g., incorrectly said that the target actor was expressing a positive emotion when they were expressing a negative or vice versa), $F_{1,10}=1.71$, $p=.22$.

Labelling errors

Average error scores (percentages) were calculated to examine the type of errors made by the two groups, and they are outlined in Table A.2, in Appendix 2 (the tables are included in the appendix due to their large size). Observing the error scores for the control (top panel) and TBI group (bottom panel) reveals that TBI participants, on average, chose many more descriptors for emotions than the controls, who mostly selected from a smaller range.

Discussion

This study aimed to establish whether CAVEAT is sensitive to TBI and to establish an appropriate response format to use in this population. The findings indicated that CAVEAT is sensitive to TBI, differentiating between the two groups in their performance on this measure. It also revealed that the optimal response format for individuals with TBI and healthy controls is the valence-correction limited choice response format. This format was not too easy for healthy controls and not too difficult for individuals with moderate-severe TBI. Importantly, the 4 multiple choice format of CAVEAT Pilot #2 which was too easy for uninjured adults was also too easy for the participants with TBI. On the other hand, CAVEAT Pilot # 3 with 23 response options generated confusion and requests for repetition. In that version TBI participants were often observed to spend quite a while scanning the list, at times requesting to watch the scene again, indicating that they forgot the scene, or which person they had to focus on (the target actor). This illustrated the working memory constraints experienced by the TBI group and suggested other cognitive impairments were impeding performance when participants were faced with too many response options (e.g., Adolphs, 2003; Decety & Jackson, 2004; Satpute & Lieberman, 2006). While non-social cognitive processes (such as working memory, processing speed, reasoning and new learning) are likely to be required in emotion recognition tasks, the aim in developing CAVEAT was to reduce the involvement of these cognitive abilities as much as possible. This is especially important since CAVEAT incorporates dynamic, multi-modal videos which may tax cognitive abilities more than static displays (Knox & Douglas, 2009). By excluding neutral expressions (which served as a 'default' option which participants might select when they are unsure of the target emotion) in CAVEAT Pilot #4, participants were 'forced' to select one of the other emotions, increasing recognition rates.

As noted by McDonald (2013), most social cognition tasks, also engage perceptual, language, memory and executive abilities, and the challenge for researchers in social cognition in TBI is to ensure that all tasks adequately control for these more general impairments. While not being able to remove the involvement of these other cognitive processes from CAVEAT, adapting the category specific, 11-item response format, attempted to minimise the engagement of these processes in the task (and the extent to which such abilities are tapped by CAVEAT was examined formally in Study 5).

In addition, examining the labelling errors made by the two groups revealed that the TBI group labelled emotions more widely and less systematically than control participants. Their pattern of responding suggested that they were selecting different emotion labels uncritically instead of following a pattern based upon similarity. Thus, selecting the narrower version response format by providing the valence correction/direction provided a middle ground which made the measure usable in both TBI and healthy controls. One limitation of this study is the small sample size used in each of the experimental conditions, and subsequently, results should be interpreted with caution.

Since the findings revealed that CAVEAT Pilot #4 was successful in assessing emotion recognition in both TBI and control participants, and was therefore adopted as the final version of CAVEAT, it will be referred to as CAVEAT in subsequent studies. This study also revealed that the recognition of fear in both groups is the most accurate and the recognition of happiness is the least accurate. This is inconsistent with previous research which reveals that happiness is usually recognised most accurately and fear the least accurately (Biehl et al., 1997; Palermo & Coltheart, 2004). This inconsistency is not surprising given the aims underlying CAVEAT development. Study 2 and 3 demonstrated just how large the difference in difficulty between recognition of happiness and fear is using ERT. In order to ameliorate this differential difficulty, the actors taking part in CAVEAT stimuli development were instructed to express fear more intensely, as if they were terrified. The generated accuracy and error rates revealed that this manipulation was successful. However, it is unclear, whether the low accuracy rates in happiness are due to the availability of a larger number of positive emotions, increasing its confusability with the other emotions, or whether the stimuli of happiness are just not capturing the emotion well. This was addressed in the next study.

Study 3D

This study compared performance of TBI and control group on a limited subset of CAVEAT, limited to the six basic emotions (fear, sadness, anger, disgust, happiness, and surprise) (e.g., Ekman & Friesen, 1976; Palermo & Coltheart, 2004). Examining the performance of a TBI group and matched controls on these six basic emotions, without the additional emotions included in the full set CAVEAT, allowed for a direct comparison to accuracy rates to those obtained using conventional emotion recognition tasks. The CAVEAT basic accuracy rates were compared to the norms obtained by Palermo and Coltheart (2004), who obtained the accuracy and response time of healthy participants on the six basic expressions sourced from five databases of commonly used emotion recognition measures such as Pictures of Facial Affect (Ekman & Friesen, 1976), and others (Gur et al., 2002; Mazurski & Bond, 1993; Tottenham et al., 2002; Watson & Clifford, 2002).

Method

Participants

Clinical sample

Sixteen individuals with TBI (13 males and 3 females), took part in this study, and were recruited from brain injury units in Sydney, Australia. All participants meet the following criteria: (1) sustained a moderate-severe TBI, measured as posttraumatic amnesia (PTA) greater than 1 day, (2) were at least 1 year post-injury, (3) were able to understand and adhere to instructions, and (4) had no identified aphasia or agnosia. The participants were aged between 18 to 69 years (M age = 45.25 years, SD = 16.58), had experienced PTA ranging from 10 to 189 days (M = 66.94, SD = 51.21), and time post injury ranging from 5 to 45 years (M= 17.06, SD = 12.52). The participants had achieved an average 13.44 years (SD = 3.65) of education. Prior to the TBI, they had been employed in occupations ranging from skilled (n=2) to unskilled trade (n=2), professional and managerial (n=8), or part/full time study (n=4). At the time of participating in this study, they were employed in occupations ranging from skilled (n=1) to unskilled trade (n=1), professional and managerial (n=4). Seven participants were unemployed, and 3 participants engaged in full time/part time study.

Control sample

Twelve healthy individuals (11 males, 1 female) were recruited from the general community through advertising. Participants were aged from 24 to 63 years (M age=45.83, SD=12.96), had obtained a mean education level of 14.58 years (SD = 1.88 years), and were matched as closely as possible to the TBI participants in respect to sex, age, years of education, and pre-injury occupation (all ps>.33). There were no between-group differences on levels of anxiety and stress as measured by DASS-21 (all ps>.32), but the TBI group displayed greater level of depressive symptoms compared to the control group ($F_{1,26}$=6.27, p=.02). To assure that the group difference between the depression subscale of the DASS did not influence results, a correlation between CAVEAT score and the depression subscale was examined, and it was not significant (p=.22), indicating that negative affect did not influence performance on CAVEAT. At the time of the study, the control participants were employed in occupations ranging from professional and managerial (n=7), part/full time study (n=3). Two participants were unemployed. For both control and TBI groups, exclusion criteria included history of developmental, neurological (with the exclusion of TBI in the clinical group), psychiatric disorders, hearing impairments, uncorrected vision, or inability to communicate effectively.

Materials

Depression, Anxiety and Stress Scale (DASS-21; Lovibond & Lovibond, 1995) was administered to ascertain participant’s self-reported symptoms of depressive mood, anxiety and stress.

CAVEAT BASIC subtest, including the vignettes pertaining to the six basic emotions (fear, anger, disgust, sadness, happiness and surprise) was administered to both groups. Surprise consisted of two 'positive surprise' and two 'negative surprise'. The vignettes were taken from the final version of CAVEAT (i.e. CAVEAT Pilot #4 used in Study 3C) and the vignettes were arranged on a new DVD in a semi-random order with the restrains of the same emotion, script or actor not appearing twice in a row. There were 24 vignettes all together (4 vignettes for each of the six emotions).

Procedure

The procedure was identical to this described in Study 3C, with the exception that the participants were viewing the vignettes corresponding to the six basic emotions, and were given a response form which listed the *six basic emotions* included in this measure, from which they had to make a selection. The task took approx. 15 min to complete.

Data Analysis

The analyses were conducted using IBM SPSS Statistics version 22.0. Bonferroni correction (adjusted $\alpha=.05/6=.008$) was used to adjust for the possibility of an inflated error rate of the simple-effects follow-up comparisons.

Results

CAVEAT performance for the TBI and control groups across the six basic emotions is shown in Table 4.5.

Table 4.5

CAVEAT performance for TBI and control groups across the six basic emotions on CAVEAT basic (left column), CAVEAT full set (the accuracy rates for the basic emotions were replicated below from CAVEAT#4 in Study 3C for convenience of a comparison; middle column), and accuracy rates on convention measures (adapted from Palermo and Coltheart (2004)

Emotion	**CAVEAT basic set (6 emotions)**		**CAVEAT full set (22 emotions)**		**Conventional measures (norms from Palermo & Colheart, 2004)**	**Difference between CAVEAT basic and Palermo & Colheart (2004) norms**
	Control (n=12)	**TBI (n=16)**	**Control (n=6)**	**TBI (n=6)**	**Control (n=24)**	
Fearful/anxious	97.92%	85.94%	95.83%	66.67%	51.7%	46.22%
Angry	95.83%	81.25%	62.50%	37.50%	82.9%	12.93%
Happy	85.42%	85.94%	33.33%	20.83%	99.1%	-13.68%
Disgust	75.00%	51.56%	50.00%	54.17%	68.2%	6.80%
Sad	72.92%	51.56%	45.83%	25.00%	62.0%	10.92%
Surprise	72.92%	76.56%	41.67% (neg sur) 45.83% (pos.sur)	54.17% (neg.sur) 37.50% (pos.sur)	85.0%	-12.08%

Note. Neg. sur; negative surprise; pos.sur; positive surprise. The difference between CAVEAT basic and the norms from conventional measures (Palermo & Colheart, 2004) was calculated by subtracting the accuracy rates for the control group obtained on the CAVEAT basic set from the rates obtained in the normative study by Palermo & Colheart (2004), e.g., for fear, 97.92%-51.7%=46.22%.

Emotion recognition

A 2 (group) x 6 (emotion type) ANOVA revealed that the TBI group performed more poorly on overall emotion recognition than matched controls ($F_{1,26}$ =7.88, p<.01, ηp^2= .23). There was a main effect of emotion ($F_{1,26}$ =12.64, p<.001, ηp^2= .33) indicating that some emotions were recognised more accurately than others. There was a trend towards significance in the group x emotion interaction ($F_{1,26}$ =.2.34, p=.05, ηp^2= .08) indicating that the performance on the individual emotions was affected by group membership. Follow-up simple effect comparisons revealed that interaction was driven by the TBI group performing more poorly on disgust (p<. 008). There was a trend in poorer performance of the TBI group on sadness, anger, and fear, but those failed to reach the conservative Bonferroni correction (α=.05/6=.008).

Inspection of Table 4.5 suggests that the accuracy rates of the control group on the six basic emotions obtained in this study are mostly similar to the rates reported in studies using conventional measures of the six emotions. As outlined in the right column, for all emotions with the exception of fear, the difference between the CAVEAT basic set and the conventional measures (Palermo & Coltheart, 2004) is within 15%. Inspection also revealed that fear was recognised correctly by the control group 97.92% of the time, which is 46.22% higher than the recognition rates obtained when using conventional measures. Moreover, comparing the accuracy rates between the basic subset (6 emotions) and the full subset (22 emotions) suggests that the recognition rates of the six emotions decrease when they are examined in a full set of 22 emotions, again, with the exception of fear in the control sample, which remains very high.

Labelling Errors

Average error scores were calculated to examine the type of errors made by control and TBI participants for the six emotions (see Table 4.6). Visual inspection of the error scores revealed that in both groups, some facial expressions were confused with others (e.g., sadness, disgust and surprise), while other emotions were rarely confused.

Table 4.6

Percentage of error types for TBI (n=16) and control participants (n=12) for each of the six emotions. The correct responses are in bold. For example, on average, the control group correctly labelled fearful expressions as fear 85.94% of the time, and incorrectly labelled them as surprise 3.13% of the time. Anger, disgust and fear were never labelled as happiness (0%0), by both groups.

		Label given by participant (%)					
Group	**Actual Emotion**	**Angry**	**Disgusted**	**Fearful**	**Happy**	**Sad**	**Surprised**
TBI	**Angry**	**81.25**	15.63	1.56	0.00	0.00	1.56
	Disgusted	12.50	**51.56**	9.38	0.00	9.38	17.19
	Fearful	1.56	1.56	**85.94**	0.00	7.81	3.13
	Happy	0.00	1.56	1.56	**85.94**	0.00	10.94
	Sad	14.06	3.13	25.00	3.13	**51.56**	3.13
	Surprised	3.13	1.56	1.56	15.63	1.56	**76.56**
Controls	**Angry**	**95.83**	4.17	0.00	0.00	0.00	0.00
	Disgusted	4.17	**75.00**	6.25	0.00	10.42	4.17
	Fearful	0.00	0.00	**97.92**	0.00	2.08	0.00
	Happy	0.00	0.00	0.00	**85.42**	0.00	14.58
	Sad	10.42	2.08	14.58	0.00	**72.92**	0.00
	Surprised	2.08	4.17	2.08	12.50	6.25	**72.92**

Discussion

This study compared performance of TBI and control group on a limited subset of six basic emotions from CAVEAT. Participants viewed a smaller version CAVEAT and were asked to select which emotion out of the basic six (fear, sadness, anger, disgust, happiness and surprise), best described the emotion experienced by the target actor in each scene. Consistent with prior research (e.g., R. E. Green et al., 2004; Hopkins et al., 2002; McDonald, 2003; McDonald & Flanagan, 2004; Milders et al., 2003; Spell & Frank, 2000), the findings indicated that the TBI group was performing more poorly than matched controls on recognising the six basic emotions, overall. Further, while both groups found some emotions more difficult than others, the TBI group was especially poor in recognising disgust (with trends in the remaining negative emotions: sadness, anger, and fear).

The findings also indicated that the recognition rates of the six basic emotions included in CAVEAT are largely similar to those reported in the literature (Palermo & Coltheart, 2004). An exception is a substantially higher accuracy of recognising fear, which was observed in both groups. This increase is consistent with the attempt during stimuli development to increase the intensity of fear, in order to decrease task difficulty of this emotion. Accordingly, the accuracy rate of fear in the basic subset was 97.9% for controls and 85.9% for TBI group. These rates slightly decreased to 95.83% and 66.67%, respectively when completing the full CAVEAT (Study 3C), however, still remaining substantially higher than accuracy rates observed on the conventional static photographs of fear (e.g., 51.7% in the Palermo and Coltheart (2004) study).

Examining the recognition rates of happiness on the CAVEAT basic set indicated that this emotion is recognised well by both groups, but recognition rates substantially decrease when the happy vignettes are viewed alongside the full range of emotions. In the control and TBI group, the accuracy rates decreased from 85.42% and 85.94% (in the CAVEAT basic subset), to 33.33% and 20.83% (in the full 22-emotion subset), respectively. This suggests that when participants are provided with a larger number of emotions to make a selection from in the positive category, they are less likely to label happy expressions as happiness. This indicates that the decrease in the recognition accuracy of happiness in the full 22-emotion CAVEAT set obtained in Study 3C was not due to stimuli not capturing the emotion, but due to the introduction of more labels to choose from in the positive category (which leads to higher confusability with the other emotions) and the increase in fear intensity.

While the accuracy for the basic emotions obtained in this study is mostly similar to those reported by Palermo and Coltheart (2004), some differences are consistent with the fact that CAVEAT consists of dynamic, multimodal, natural expressions of emotion, rather than static, unimodal and posed pictures as the conventional measures. For example, it is possible that the slightly lower recognition rates of happiness observed in CAVEAT basic correspond to the fact that it is easier to recognise happiness from a static picture (with a smile being a strong cue assisting correct labelling), than from a dynamic multimodal video, which incorporates a number of cues that make recognition more difficult. This possibility is supported by the similarity in the recognition of happiness in CAVEAT basic and TASIT (McDonald et al., 2003), which stand at 85.42% and 93%, respectively, for healthy controls.

Examining the labelling errors of the six emotions in CAVEAT basic, reveals that the six emotions have low confusability rates in both groups, although as expected, the TBI still makes more labelling errors than the control group. In addition, the confusability rates are considerably lower than the error rates from the ERT which are discussed in Study 1. This is not surprising since Study 1 examined labelling errors across the nine intensities of the ERT, which is likely to have increased the confusability of the different emotions with each other. The high accuracy with which the six basic emotions included in CAVEAT are recognised, together with the low confusability of these emotions with other emotions indicates that the CAVEAT stimuli, at least the basic ones, indeed measure the emotion they intend to measure.

Summary and Concluding Discussion

Overall, the four studies described in this chapter provided an empirically driven final version of CAVEAT with an appropriate response format, which was both sensitive to TBI, and was appropriate to use in TBI and healthy controls. In addition, examining recognition rates for the six basic emotions included in the CAVEAT demonstrated that the accuracy on the six emotions is mostly consistent with the literature, indicating that CAVEAT stimuli allow an adequate assessment of emotion recognition for the six basic emotions as well as a wide range of others. The validity and reliability of CAVEAT is examined in the following study.

CHAPTER 5

Study 4. Reliability and Validity of the Complex Audio Visual Emotion Assessment Task (CAVEAT)

Chapter 4 outlined the development and pilot testing of CAVEAT, a new test of emotion recognition, aiming to establish its final form. The present study aimed to examine its reliability and validity as a potential clinical tool. It is well established that cognitive processes, including emotion perception, need to be assessed using tools which demonstrate adequate psychometric properties. Using tools with inadequate validity and reliability will limit the conclusions that can be made about the underlying processes being measured. Reliability refers to the consistency of scores obtained on the test, i.e. the extent to which scores are stable from one occasion to the next or the extent to which all items consistently measure the same underlying construct. Validity is defined as the extent to which a test measures what it is designed to measure. Specifically, construct validity refers to the extent to which a test is a valid measure of a defined theoretical construct. It commonly includes convergent validity, i.e., how well the test is correlated with other tests of similar constructs, and discriminant validity, i.e., how well the test discriminates between groups who are known to differ on the construct being measured (Tate, 2010). Since CAVEAT was developed as a measure of emotion recognition, its construct validity needs to be established in relation to other measures of emotion recognition, as well as other social cognition related constructs[5]. This is described below.

[5] Another important aspect of CAVEAT validity is whether it predicts real life social functioning, and associations between CAVEAT performance and social functioning will be indicative of the measure's predictive/ecological validity. While this was not directly examined in this study, it will be addressed in the next chapter.

Reliability

CAVEAT's reliability was examined by assessing its internal consistency, i.e. the homogeneity of all items within the test (Tate, 2010). Internal consistency provides not only evidence for the reliability of the measure, but also initial evidence for its construct validity since high internal consistency indicates the stability of the underlying construct/s being measured.

Convergent validity

Emotion perception constructs

Two tests were selected to provide an examination of CAVEAT's convergent validity, the Emotion Evaluation Test (EET) from TASIT (McDonald et al., 2002) and the Reading the Mind in the Eyes Test (RMET; Baron-Cohen, Wheelright, Hill, Raste, & Plumb, 2001). TASIT was expected to correlate strongly with CAVEAT as both measures use audiovisul stimuli to depict dynamic, genuine, multi-modal displays of emotion. The RMET is commonly described as a test of Theory of Mind (ToM), which refers to the ability to understand other's emotions, thoughts and motivations, and to understand their behaviour accordingly (Bibby & McDonald, 2005; Channon, Pellijeff, & Rule, 2005). None-the-less, the RMET requires judgements to be made of a range of emotional states and, as such, taps similar abilities to the CAVEAT. Thus, it was hypothesised that CAVEAT performance will positively correlate with TASIT EET and RMET scores. These correlations will be indicative of its concurrent validity.

Social cognition related constructs

Two additional interrelated constructs have been implicated in emotion perception deficits following TBI; alexithymia and empathy.

Alexithymia is a multifaceted construct encompassing difficulty identifying and describing feelings, externally oriented thinking, and limited imaginal capacity (Taylor, Bagby, & Parker, 1997). Alexithymia has been associated with dysfunction in a number of neural structures such as the frontal lobes, the right hemisphere, and corpus callosum (Hornak, Rolls, & Wade, 1996; Houtveen, Bermond, & Elton, 1997; Mandal et al., 1999). Individuals with TBI have been shown to have higher incidence of alexithymic symptoms compared to healthy adults with similar demographic characteristics (Henry, Phillips, Crawford, Ietswaart, & Summers, 2006; McDonald et al., 2011). These led some researchers to argue that acquired alexithymia in TBI reflects a generalised deficit in processing emotional stimuli that encompasses emotion perception deficits, and subsequently, alexithymia and emotion recognition were proposed to constitute a different facet of a single emotion processing disorder (Henry et al., 2006; Wood &Williams, 2007). Moreover, alexithymia was proposed to explain not only why many individuals with TBI have difficulties in emotion recognition and expression, but also loss of empathy, namely, why following TBI many lack the ability to understand another person’s feelings (Preston & De Waal, 2002; Wood & Williams, 2008).

Empathy is a broad construct, which encompasses emotional and cognitive components, that draw upon separate but overlapping neurological substrates (Decety & Jackson, 2004; Heberlein & Saxe, 2005; Preston & De Waal, 2002; Shamay-Tsoory & Aharon-Peretz, 2007). Emotional Empathy, which refers to the ability to vicariously experience the emotions of others (Mehrabian, 2000), has been associated with inferior frontal gyrus and the insula (Schulte-Rüther, Markowitsch, Fink, & Piefke, 2007; Shamay-Tsoory & Aharon-Peretz, 2007; Singer et al., 2004). Cognitive empathy, which refers to the capacity to comprehend the situation of another person in a way that allows mutual sharing and understanding (Hogan, 1969), has been linked to the ventromedial prefrontal cortex (Shamay-Tsoory & Aharon-Peretz, 2007). Since these structures are highly vulnerable to mechanisms of TBI, similarly to alexithymia, emotional and cognitive components of empathy are likely to be compromised in TBI (Shamay-Tsoory & Aharon-Peretz, 2007). Relationship between emotion recognition and self-reported changes in the experience of emotions has been well established (Croker & McDonald, 2005; Hornak et al., 1996), as well as the relationship between high alexithymia and low empathy (Williams & Wood, 2010). Thus, as a measure of complex emotion recognition, CAVEAT is expected to correlate with measures of alexithymia and emotional empathy.

Discriminant validity

Due to the documented difficulties TBI population has with emotion recognition (R. E. Green et al., 2004; Hopkins et al., 2002; McDonald & Flanagan, 2004), it is expected that on average, the TBI group would perform more poorly than the control group on CAVEAT. If CAVEAT can discriminate between the TBI and control groups, it will demonstrate discriminant validity, providing further support to its construct validity.

Neuropsychological constructs

Given the dynamic and complex nature of social perception stimuli used in the CAVEAT, it was expected that cognitive abilities, such as working memory, processing speed and executive functioning may substantially affect emotion recognition ability. These cognitive abilities are frequently reported to be compromised following moderate-severe TBI (Crawford et al., 1997; R. E. Green et al., 2004; Slovarp et al., 2012), and have been implicated in social cognition (McDonald et al., 2006; Yim et al., 2013). Thus, selected tests were administered to reflect the common cognitive deficits associated with TBI, especially focusing on these constructs. Similarly, in light of the evidence suggesting higher incidence of negative affect following TBI (J. M. Silver, Kramer, Greenwald, & Weissman, 2001; Wood, Williams, & Lewis, 2010), and to reduce the possibility that it might influence results, participant's socio-emotional functioning was also assessed.

Method

Participants

Clinical sample

Thirty two individuals with TBI (25 male, 7 female), took part in this study, and were recruited from brain injury organisations in Sydney, Australia. All participants meet the following criteria: (1) sustained a moderate-severe TBI, measured as posttraumatic amnesia (PTA) greater than one day, (2) were at least one year post-injury, (3) were able to understand and adhere to instructions, and (4) had no identified aphasia or agnosia. The participants were aged between 22 to 67 years (M age = 47.81 years, SD = 13.44), had experienced PTA ranging from 2 to 189 days (M = 55.41, SD = 48.89) and had incurred their injuries from 3 to 43 years (M= 14.84, SD = 9.89) previously. Their injuries were sustained as a consequence of motor vehicle accidents (n =19), falls (n =8), assault (n = 3), and a sporting injury resulting in an accidental blow to the head (n = 1). The participants had achieved an average 14.02 years (SD=2.73) of education.

Prior to the TBI, they had been employed in occupations ranging from skilled (n=7) to unskilled trade (n=3), professional (n=11), managerial (n=4), or part/full time study (n=5). Two participants were unemployed. At the time of participating in this study, they were employed in occupations ranging from skilled (n=3) to unskilled trade (n=5), professional (n=3), managerial (n=3), or part/full time study (n=2). Sixteen participants were unemployed.

As typical of the TBI population, the injuries were heterogeneous, and included contusions, skull fractures, and intracerebral and subdural or subarachnoid haemorrhages. CT scans described injuries that were left hemisphere-focused (n=3), right hemisphere-focused (n=9), or bilateral (n = 14). Specific frontal lobe injuries were reported in 16 participants. For four participants, CT scan readings did not identify the injury site, or were unavailable.

Control sample

Thirty two healthy individuals (25 male, 7 female), were recruited from the general community through advertising. Participants were aged from 19 to 66 years (M age=45.22, SD=14.01), had obtained a mean education level of 14.99 years (SD = 2.33 years), and were matched as closely as possible to the TBI participants in respect to sex, age, years of education, and pre-injury occupation. At the time of the study, the controls participants were employed in occupations ranging from skilled trade (n=2), professional (n=11), managerial (n=6), or part/full time study (n=9). Four participants were unemployed. For both control and TBI groups, exclusion criteria included history of developmental, neurological (with the exclusion of TBI in the clinical group), or psychiatric disorders, hearing impairments, uncorrected vision, or inability to communicate effectively. The TBI and control groups participated in another study in our laboratory, which will be described in the following chapter. The demographic information as well as scores on neuropsychological and social cognition measures are outlined in Table 5.1.

Materials

The Complex Audio Visual Emotion Assessment Task (CAVEAT). The CAVEAT is an audio-visual assessment tool designed for clinical assessment of emotion recognition ability in healthy and clinical populations, and includes 88 videos of 22 emotions (4 videos for each emotion). The development of its final form is outlined in the previous chapter.

Social cognition measures

TASIT (McDonald et al., 2002), Part 1 – Emotion Evaluation Test (EET). The EET consists of 28 videotaped vignettes of actors expressing one out of six emotions alongside a neutral expression (4 exemplars of each). After viewing each vignette, the respondent is asked to select which emotion from the selection provided best matches how the target actors was feeling. TASIT was shown to be sensitive to social cognition difficulties and to have strong psychometric properties (McDonald et al., 2006b; McDonald et al., 2004).

Reading the Mind in the Eyes Test (RMET; Baron-Cohen, Wheelwright, Hill, Raste, & Plumb, 2001) consists of 36 photographs of eye-regions. After viewing each photograph, the respondent is asked to select which emotion out of four best describes what the person in the picture is thinking or feeling. This measure was shown to be sensitive to the more subtle social cognition difficulties broadly referred to as ToM, and to have good psychometric qualities (Baron-Cohen, Wheelwright, et al., 2001).

The *Balanced Emotional Empathy Scale* (BEES; Mehrabian, 2000) was used as a measure of emotional empathy. The BEES was designed to distinguish individuals who experience more of the feelings of other people from those who are less responsive to the emotional expressions and experiences of others. The BEES contains 30 items which participants endorse on a 9-point Likert-type scale, ranging from very strong agreement to very strong disagreement. The BEES has been used with a number of clinical populations (Danziger, Prkachin, & Willer, 2006; Eslinger, Parkinson, & Shamay, 2002), including TBI (Wood & Williams, 2008), and has established psychometric qualities (Mehrabian, 1997).

Toronto Alexithymia Scale (TAS-20; Bagby, Parker, & Taylor, 1994; Bagby, Taylor, & Parker, 1994) is a self-report questionnaire assessing features of Alexithymia, which refers to difficulty identifying and describing feelings, and externally oriented thinking. A total score can range from 20–100, with a score ≥61 confirms alexithymia; 51–60 indicative of ‘possible’ alexithymia; and ≤51 indicates absence of alexithymia. Simialrly to the other measures, the TAS-20 has been shown to have adequate reliability and validity (Bagby, Parker, et al., 1994; Bagby, Taylor, et al., 1994; Taylor, Bagby, & Parker, 2003).

Neuropsychological measures

A number of measures of neuropsychological functioning were selected to reflect the common cognitive deficits associated with TBI, especially focusing on processing speed, working memory and executive functioning.

Information processing speed was assessed using the *Digit Symbol coding (DSC)* subtest of WAIS-III (Wechsler, 1997b). Working memory was assessed using *Digit Span (DS)* subtest of WAIS-III (Wechsler, 1997b). Executive functioning was assessed via *Matrix Reasoning* subtest of WAIS-III (Wechsler, 1997b), the *Controlled Oral Word Association Test* (COWAT CFL; Ruff, Light, Parker, & Levin, 1996), *Trails*

A and B (Reitan, 1992), and *Hayling-Brixton test* (Burgess & Shallice, 1997). These three tests combined provided an estimate of individuals' executive functioning.

Emotional functioning

Emotional functioning was assessed using the *Depression Anxiety and Stress Scale (DASS-21; Lovibond & Lovibond, 1995).* DASS21 was administered to all participants to assess their psychological status across self-reported symptoms of depression, anxiety and stress and in order to insure that it does not influence their performance on the CAVEAT and other measures of social cognition.

Procedure

The participants were informed of the study procedures and gave written consent to participate in the study. All procedures were approved by the Human Research Ethics (HREC) Board of the University of New South Wales, and conducted at the neuropsychology laboratory at the University. Participants were administered the DASS-21 (Lovibond & Lovibond, 1995), followed by the CAVEAT, and then neuropsychological measures, unless these were administered on a prior occasion, for those participants who had participated in a research in our laboratory recently. All measures were administered in a single session, unless the neuropsychological measures were completed previously.

Data Analysis

The data were analysed using SPSS version 22. Between group differences were analysed using an ANCOVA with group (TBI vs. Control) as one factor and CAVEAT performance as the dependent variable. Partial correlations were computed between

CAVEAT and the other constructs. The covariates used in the analyses are outlined below.

Results

Demographic, clinical, and neuropsychological features

Demographic, clinical, and neuropsychological features are displayed in Table 5.1. There were no significant difference between the TBI and control groups on distribution of gender [$\chi 2$ (1, n=64) = 0, p =.62, phi=1.00], pre-injury occupation [χ^2 (4, n=64)= 7.71, p =.10, phi=.35], age ($F_{1,62}$=.57, p=.45), and years of education ($F_{1,62}$=2.33, p=.13). However, there were between group differences on DASS-21, with TBI group, on average, reporting higher levels of depressed mood ($F_{1,62}$ =4.30, p=.04), anxiety ($F_{1,62}$ =11.38, p=.001), and stress ($F_{1,62}$ =10.16, p=.002).

Further, as evident from inspection of Table 5.1, the two groups differed on their performance on most measures of neuropsychological functioning, except Matrix Reasoning (where the results showed a trend toward significance) with TBI participants performing significantly lower than matched controls. The scores on the seven measures of neuropsychological functioning were combined into a single factor of attention/executive processing, which was extracted by Principal Component Analysis (PCA), and the depression, anxiety and stress scores were combined into a single DASS score (by averaging the three subscales). To ensure that these variables did not influence results, the attention/executive processing and emotional functioning variables were subsequently entered in the analyses as covariates.

Table 5.1

Demographics and measures of socio-emotional and neuropsychological functioning of TBI (n=32) and Control (n=32) group

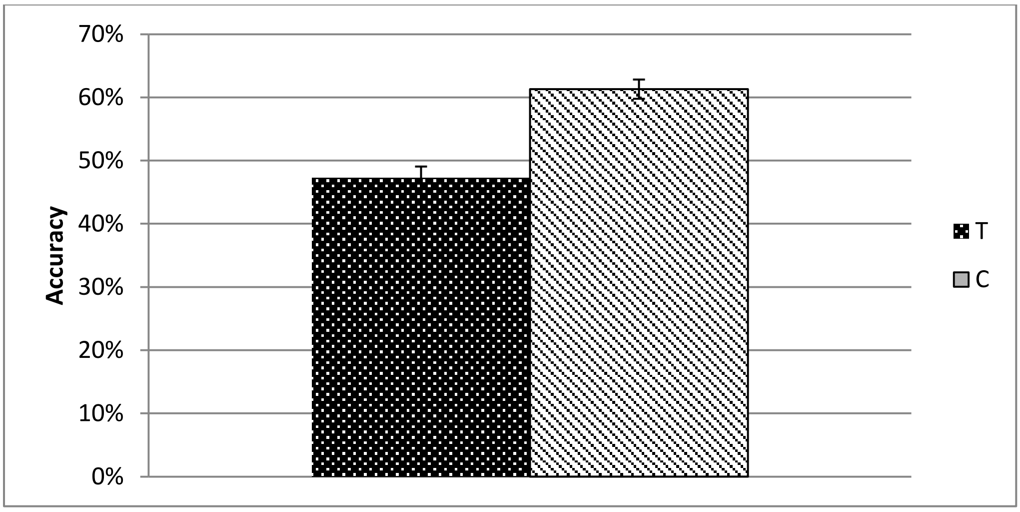
	TBI group		Control group		Between-group differences
	M (SD)	**Range**	**M (SD)**	**Range**	
Sex	m=25, f=7		m=25, f=7		p =.62
Age	47.81 (13.44)	22-67	45.22 (14.01)	19-66	p=.45
Educ. Level (years)	14.02 (2.73)	9-22	14.99 (2.33)	11-20	p=.13
PTA (days)	55.41 (48.89)	2-189	N/A	N/A	
Neuropsychological measures					
• **DS**	9.94 (2.81)	6-17	13.06 (3.30)	7-19	p<.001*
• **DSC**	8.81 (2.91)	3-15	11,16 (2.24)	8-17	p<.001*
• **MR**	11.94 (3.23)	4-17	13.41 (2.75)	7-18	p=.054
• **COWAT (CFL)**	52.03 (12.02)	36-85	69.10 (13.77)	47-93	p<.001*
• **Trails A**	38.04 (14.62)	19-79	27.13 (7.90)	13-44	p<.001*
• **Trails B**	94.34 (50.50)	41-297	59.60 (16.93)	30-99	p<.001*
• **Haylings-Brixton**	16.09 (3.62)	7-20	17.71 (2.40)	13-23	p=.026*
DASS-21					
• **Depression**	9.31 (9.08)	0-34	5.38 (5.80)	0-20	p=.04*
• **Anxiety**	6.31 (7.28)	0-28	1.75 (2.37)	0-10	p=.001*
• **Stress**	14.50 10.73)	0-40	7.38 (6.70)	0-26	p=.002*
Social cognition measures					
• **TASIT EET**	22.65 (3.33)	14-27	25.40 (2.10)	20-28	p<.001*
• **RMET**	23.60 (5.06)	11-31	28.88 (4.23)	15-34	p<.001*
• **TAS-20**	55.25 (9.18)	37-74	38.19 (7.30)	28-51	p<.001*
• **BEES**	33.78 (26.05)	-29-84	49.34 (25.10)	-17-99	p=.01*

M, mean; SD, Standard deviation; f, female, m, male; PTA; post traumatic amnesia. The p values for the significant group differences are reported. Neuropsychological measures are reported in scaled scores with the exception of Trails A and B (for which numbers represent time in seconds), and COWAT (numbers represent total num of words generated). The p values represent between-group differences in social cognition measures are those generated from One-way ANOVAs, which are different to the ANCOVAs reported in a later section.

Performance on CAVEAT

The CAVEAT performance for TBI and control groups is outlined in Figure 5.1. Inspection suggests that the TBI group performed more poorly on CAVEAT than matched controls. While the control group total recognition rates (averaged across the 22 emotions) is at 61.3%, the TBI recognition rate is at 47.3%. The data reveals no indication of floor or ceiling effects.

Figure 5.1. Total CAVEAT performance (averaged across all 22 emotions) for the control and TBI groups.



Note. T; TBI, C; controls. The error bars represent standard error of the mean.

Reliability

Inter-item correlations for CAVEAT items ranged from -.48 to .57. The Cronbach's Alpha for CAVEAT items was .85. Following Anastasi and Urbina (1997) recommendations, when Cronbach's Alpha is calculated for a reliability analysis, high values ranging between r=.8-.9 are required, and according to the George and Mallery (2003) guidelines, these reliabilities range between good (>.8) to excellent (>.9).

Construct validity

Discriminant validity. ANCOVA using the DASS score and cognitive ability (the extracted factor of attention/executive functioning) as covariates revealed a significant main effect of group ($F_{1,54}$=15.60, p<.0001, ηp^2=.22). This indicated when negative affect and cognitive ability are held constant, the TBI group performed significantly poorer on CAVEAT than matched controls.

Convergent validity. Partial correlations on the whole sample, controlling for cognitive ability, and the three DASS-21 subscales, revealed significant positive correlations between CAVEAT performance and both TASIT emotion recognition (r=.47, p<.0001) and the RMET (r=.50, p<.0001), indicating that higher accuracy on CAVEAT was associated with higher accuracy on these two tests. A positive correlation between CAVEAT and BEES (r=.35, p=.004), indicated that individuals who rated themselves as having higher emotional empathy, also performed better on CAVEAT. There was also a negative correlation between CAVEAT and TAS-20 (r= -.34, p<.01), indicating that individuals who rated themselves as more Alexithymic (i.e., having more difficulty with identifying and describing feelings and externally oriented thinking), performed more poorly on CAVEAT. A negative correlation between CAVEAT and PTA (r= -.35, p<.05), indicating that longer PTA (and more severe TBI) was associated with worse emotion recognition. The correlations were re-run in the TBI and control groups separately, and the results of the correlations with CAVEAT were the same as reported above, with the exception that the correlation with BEES did not reach significance in the TBI group and TAS did not reach significance in the control group.

The correlations are outlined in Table 5.2.

Table 5.2.

Table of Partial correlations (controlling for cognitive ability and DASS scores) between CAVEAT, TASIT emotion recognition test (EET), Reading the Mind in the Eyes test (RMET), TAS-20 and BEES.

Variable	CAVEAT	PTA	TASIT EET	RMET	TAS-20	BEES
CAVEAT	1	-.35*	.47**	.50**	-.34**	.35**
PTA		1	-.41**	-.39**	.38**	-.14
TASIT EET			1	.41**	-.13	.24*
RMET				1	-.26*	.20
TAS-20					1	-.03
BEES						1

NS = not significant (p>.05), *correlation is significant at p<.05 level, **significant at p<.01 level, all correlations are one-tailed. PTA includes information about group membership (PTA=0 for control participants) and injury severity.

Discussion

CAVEAT is a novel test of emotion recognition which was designed to fill a gap in the literature by addressing several of the limitations of conventional emotion perception measures. This study aimed to establish the psychometric properties of CAVEAT, by examining performance of a TBI group and a group of healthy controls in order to provide estimates of reliability (internal consistency) and validity. With regard to the former, CAVEAT was shown to have a strong internal consistency, demonstrating that it is a reliable measure, with items that are highly homogenous.

The construct validity of CAVEAT was assessed by administering it, along with a number of well-established measures of social cognition, to a sample of individuals with TBI and matched controls. As a dynamic, complex, naturalistic set of stimuli, it was expected that CAVEAT performance would rely on a number of cognitive processes, such as processing speed, working memory and executive functioning (McDonald et al., 2006). Consequently, selected neuropsychological tests, alongside a measure of emotional functioning were also administered and used as covariates in the analyses to ensure that variance associated with these factors was taken into account when analysing results.

Examining CAVEAT performance between groups revealed that the TBI group performed more poorly on CAVEAT than the matched controls, even when cognitive ability and negative affect were controlled for. This is consistent with the large number of studies now published that report that people with TBI perform more poorly on measures of emotion recognition (e.g. Babbage et al, 2011). The fact that the emotion recognition deficits were present when cognitive ability and negative affect were controlled for strengthens the robustness of the finding of emotion recognition difficulty in TBI suggesting that emotion recognition can be impaired on its own right, rather than being simply reflective of cognitive difficulties.

As predicted, even when cognitive ability and mood/negative affect were controlled for, CAVEAT was shown to be associated with the two selected measures of emotion perception, TASIT EET and the RMET. This demonstrated that CAVEAT indeed assesses social cognition. Further evidence for its concurrent validity was provided by finding significant correlations between CAVEAT and self-reported emotional empathy (BEES; Mehrabian, 2000) and alexithymia (TAS-20; Bagby, Parker, et al., 1994; Bagby, Taylor, et al., 1994). Individuals who rated themselves as having higher emotional empathy performed better on CAVEAT, and reported lower level of difficulty with identifying and describing feelings and externally oriented thinking. This is consistent with research showing strong links between emotion recognition, alexithymia, and low empathy (Croker & McDonald, 2005; Hornak et al., 1996; Williams & Wood, 2010).

CAVEAT was also shown to discriminate between groups that are expected to have differences in their ability to recognise emotions (demonstrating discriminant validity), with individuals with TBI performing more poorly than matched controls, even when negative affect and cognitive ability were controlled for.

Despite the importance of these findings, this study is not without limitations. While these findings provided some preliminary evidence for CAVEAT's validity and reliability, other research, on larger samples of both healthy controls of widely varying ages as well as different clinical populations is needed to confirm its psychometric qualities. Moreover, while this study provided evidence for CAVEAT's convergent validity, demonstrating that it is associated with tests measuring similar constructs (such as social cognition, alexithymia and empathy), it did not assess divergent validity, i.e. the extent to which it is superficially a measure of emotion perception and not also sensitive to other dissimilar constructs. Indeed, divergent validity is difficult to operationalise in view of the finding that CAVEAT performance is correlated to numerous measures of attention/processing speed and executive processes. This is not unexpected. The stimuli in CAVEAT are complex and change over time, making it likely that a range of cognitive processes are required to process them efficiently. Finding cognitive abilities that are not involved will be challenging. One such ability, might be immediate attentional span as measured by digit-span forward subtest of the WAIS-III (Wechsler, 1997b). An additional important facet of validity is ecological validity, i.e. the ability of a test to predict real life function. Ecological validity of CAVEAT is examined in the next chapter, in Study 5.

The high internal consistency of CAVEAT provided confidence in the reliability of the measure. However, this also raises questions over the extent to which CAVEAT measures a single uniform ability, i.e. emotion perception, or a set of inter-related abilities, such as the ability to process negative versus positively valanced emotions, or social versus non-social emotions. Having such high internal consistency would suggest that it is, indeed, only measuring one construct, which is emotion recognition, and this hypothesis will be examined in greater detail in the following study. It is important to note that the high reliability also indicates that there might be some redundancy between the items, suggesting that a short version of the CAVEAT that includes fewer items might prove to have similar validity to the full version while providing a briefer, more clinically practical measure. One benefit of such an approach is the possibility of developing two, short but equivalent, parallel measures which would have many clinical uses (such as when repeated testing is required). This work would require further testing of alternate forms reliability and is not within the scope of the current thesis. Indeed, there is also need for test-retest reliability studies to be conducted on CAVEAT in order to provide a comprehensive overview of its reliability but this, also, is outside the scope of the current thesis although is envisaged for future research on this instrument.

Overall, these initial findings indicate that CAVEAT has adequate psychometric properties that make it satisfactory as a clinical test for assessing emotion perception. There is some evidence for its validity and reliability indicating that it can be used with healthy controls and individuals with TBI. This suggests that it might also be suitable to use with other clinical populations, however, this is yet to be established. Because CAVEAT samples a wider range of emotions than most conventional tests and uses stimuli that share many features with natural emotions (multi-modal, dynamic, genuine) it is a potentially useful tool to expand understanding of emotion recognition difficulties in TBI and other clinical populations. In the following study CAVEAT performance is used to investigate the extent to which different types of emotions (positive vs. negative, social vs. non-social etc.) are differentially impaired in people with TBI compared to demographically matched control participants.

CHAPTER 6

Study 5. Amused, flirting or simply baffled? Is recognition of all emotions affected by TBI[6]?

Studies 1 and 2 revealed that when task difficulty is taken into account, people with TBI show an overall impairment in emotion recognition, rather than a selective impairment in recognising some emotions compared to others (such as negative compared to positive). While demonstrating that methodological shortcomings of the conventional emotion recognition measures may confound the conclusions regarding emotion recognition deficits in TBI, these two studies were limited to examining group differences across a limited set of posed, uni-modal emotions which are included in the ERT.

Subsequently, Study 3 described the development and pilot testing of CAVEAT, which was designed to directly address the limitations of the conventional emotion recognition measures. It was followed by Study 4, which revealed that CAVEAT has adequate psychometric properties which make it satisfactory to be used as a clinical tool for assessing emotion perception. As noted in the Introduction, literature to date has largely focused on an assessment of a limited number of emotions such as the basic six. However research examining whether people with moderate- severe TBI vary in their capacity to recognise emotions conceptualised according to other theoretical frameworks, such as different dimensions (for example social vs. non-social, positive vs. negative, approach vs. avoidance, and complex vs. basic), is limited.

[6] Study submitted for publication as: Rosenberg, H., McDonald, S., Rosenberg, J., Westbrook, R. F. (Submitted). Amused, flirting or simply baffled? Is recognition of all emotions affected by Traumatic Brain Injury (TBI)?

Examining emotion recognition across a wider range of emotions than the basic six is important, since the human experience expands well beyond six emotions, and it unclear if and how the recognition of other emotions is affected by TBI. For example, social emotions might be predicted to be more difficult to recognise than non-social emotions for people with TBI because they necessitate reference to mental states. Understanding mental states is an area of social cognition that is especially vulnerable to TBI (Martin-Rodriguez & Leon-Carrion, 2010). Alternatively, it could be speculated that more complex, i.e., subtle, emotions pose greater difficulty for people with TBI than the less ambiguous ‘basic ‘emotions due to the cognitive impairments typically experienced as a result of TBI, including difficulties with processing speed, working memory, and executive function.

As emotion recognition is a fundamental social skill, impairment in emotion perception should predict social functioning after TBI. However, the evidence is yet to be established. One study examined recognition of static emotional displays in face and also voice (separately) (Milders et al., 2008) and found no association between emotion perception and severity of behavioural problems and social functioning following TBI. However, another, using naturalistic audiovisual displays of the six basic emotions showed that impairment predicted poor social performance of people with TBI *in vivo* (McDonald et al., 2004). The divergence of these findings may reflect the use of more naturalistic displays of emotions in the latter study. It is also possible that the relation between everyday functioning and emotion perception accuracy will be more clearly established if tasks assessing emotion perception tap a broader range of emotions including ‘social’ and ‘complex’ emotions.

To address these gaps in the literature, the following study had three aims. First, it aimed to examine the nature of emotion recognition difficulties in TBI by using CAVEAT, which was developed to embrace emotions sampled from all dimensions of emotions with particular focus on negative versus positive (which overlaps considerably with approach vs. avoidance), social versus non-social and basic versus complex. It aimed to determine whether TBI results in an overall deficit in emotion recognition, or a specific impairment in the ability to recognise some emotions compared to others. Emotional expressions in the real world are conveyed via a number of modalities (e.g., face, voice, gestures) and are dynamic, shifting and changing rapidly. Consequently, the CAVEAT used naturalistic audiovisual vignettes in order to examine emotional recognition as it is more likely to occur in real life.

The second aim was to determine whether emotion recognition deficits are a direct consequence of brain injury or an indirect effect due to impairments in other cognitive processes, in particular, processing speed, working memory, and non-verbal reasoning. This question has been examined, with mixed outcomes; some studies reporting clear associations (McDonald et al., 2006; Yim et al., 2013), while others have found none (Spikman et al., 2012).

Hypothetically, the CAVEAT stimuli, being both complex and dynamic will make demands upon executive functioning, processing speed and working memory. Alternatively, it is possible that the processing of even such complex social stimuli represents a modular cognitive ability that is directly impacted by brain injury. In this case CAVEAT performance will be uniquely predicted by brain injury and/or injury severity.

Thirdly, in light of the documented reduction in social functioning following TBI (Temkin et al., 2009), it was hypothesised that CAVEAT performance would predict psychosocial functioning indexed by self-ratings on selected measures of social and everyday functioning, and self-reported number of friends.

Method

Participants

The clinical and control samples in this study (25 male, 7 female), are identical to those described in Study 4.

Materials

The Complex Audio Visual Emotion Assessment Task (CAVEAT)

The CAVEAT consists of 88 audiovisual vignettes of everyday scenarios involving one or two actors engaged in an ambiguous conversation (which gives no clue as to the emotions involved). The duration of vignettes ranged from 10-30 sec. The target actor in each vignette displayed one of 22 possible emotions. These included the six basic emotions: happiness, surprise (both positive and negative), anger, fear, sadness and disgust as defined by conventions in emotion recognition research (Ekman & Friesen, 1976). The remaining 16 were classified as complex. Together these 22 emotions made up an equal number of positive and negative emotions (11 of each) and a range of exemplars from the social versus non-social emotion categories. There were four vignettes for each emotion, resulting in a total of 88 vignettes. The CAVEAT takes approx. 40 minutes to administer to healthy controls. The full description of CAVEAT stimuli is outlined in Study 3 (Chapter 4).

As described in Study 3A, in order to confirm category membership, the emotions were rated as belonging to one or other subcategory (e.g., as positive vs. negative and social vs. non-social). See Chapter 4 for details on methodology.

Measure of Mood

The *Depression Anxiety and Stress Scale (DASS-21; Lovibond & Lovibond, 1995).* DASS21 was administered to all participants to assess their self-reported symptoms of depression, anxiety and stress.

Measures of cognitive ability

Measures of neuropsychological functioning were taken from the Wechsler Scale of Adult Intelligence 3rd Edition (WAIS-III; Wechsler, 1997b) in order to measure the cognitive abilities of (i) immediate attention span, or 'working memory' (*Digit Span (DS)* which requires the individual to repeat an orally presented sequence of numbers in a particular order and manipulate them, (ii) processing speed (*Digit Symbol coding (DSC)* which requires the individual to write an associated symbol next to each digit as quickly as they can) and (iii) non-verbal reasoning and non-verbal concept formation (*Matrix Reasoning: MR)*, which requires the individual to find an appropriate piece to complete a matrix).

Measures of everyday and social functioning

The Frontal Systems Behavior Scale (FrSBe; Grace & Malloy, 2001), Apathy and *Disinhibition* subscales were administered to measure self-reported apathy (such as problems with inattention, psychomotor retardation, spontaneity, drive, persistence, loss of energy and interest, lack of concern for self-care and/or blunted facial expression), and disinhibition (such as inhibitory control of actions and emotions, including impulsivity, hyperactivity, social inappropriateness, emotional liability, explosiveness and irritability). The *Sydney Psychosocial Reintegration Scale (SPRS*; Tate, Hodgkinson, Veerabangsa, Pfaff, & Simpson, 2002) is designed to measure psychosocial functioning in individuals with TBI currently and at time of injury. The *Interpersonal Relationships subscale* of the SPRS was administered to ascertain the self-reported level of current competency in interpersonal functioning. *Number of friends.* At the clinical interview conducted prior to administering the other self-report measures, the TBI participates were asked how many people are in their circle of close friends currently.

Procedure

All participants were informed of the study procedures, and gave written consent to participate in the study. The study procedures were conducted at the neuropsychology laboratory of the University of New South Wales and were approved by the Human Research Ethics Board of the University. The order of presentation of the CAVEAT was counterbalanced, with two versions available for alternate participants. In each the vignettes were presented in a semi-randomised order with the restriction that no actors, scripts or emotions appeared consecutively.

Participants viewed a DVD with the 88 vignettes, each lasting from 10-30 sec. For each vignette, participants were shown two columns of eleven descriptors (22 altogether) labelled at the top as either positive or negatively valanced emotions. Participants were first asked if the emotion was positive or negative (i.e. asked if the target actor in the scene was feeling positive or negative). If they were correct, they were then asked to choose which emotion of the eleven it corresponded to. If incorrect, they were corrected and referred to the appropriate column to make a selection of which emotion best matches how the target actor was feeling.

Data Analysis

All analyses were conducted using IBM SPSS Statistics version 22.0. To control for the possibility of an inflated error rate due to multiple-comparisons, Bonferroni corrections were applied to the analyses, when appropriate, and as outlined in each section.

Results

Demographic, clinical, and neuropsychological features

Demographic, clinical, and neuropsychological features are displayed in Table 6.1. There were no significant difference between the TBI and control groups on distribution of gender [$\chi 2$ (1, n=64) = 0, p =.62, phi=1.00], pre-injury occupation [χ^2 (4, n=64)= 7.71, p =.10, phi=.35], age ($F_{1,62}$=.57, p=.45), or years of education ($F_{1,62}$=2.33, p=.13). The TBI group performed significantly more poorly on DS ($F_{1,62}$ =16.71, p<.0001) and DSC ($F_{1,62}$ = 25.84, p<.0001), but not MR ($F_{1,62}$ =3.84, p=.06). There were between group differences on DASS-21, with TBI group reporting higher levels of depressed mood ($F_{1,62}$ =4.30, p=.04), anxiety ($F_{1,62}$ =11.38, p=.001), and stress ($F_{1,62}$ =10.16, p=.002). In light of the group differences on DASS-21 scores, and the fact that, in the combined group, the DASS anxiety score correlated with CAVEAT performance (with a trend with the depression and stress subscales), the total DASS-21 score was entered as a covariate in the between-group analyses to assure that negative affect did not influence the results.

Table 6.1.

Demographics and measures of socio-emotional functioning of TBI (n=32) and Control (n=32) group.

	TBI group		Control group		Between-group differences
	M (SD)	**Range**	**M (SD)**	**Range**	
Sex	m=25, f=7		m=25, f=7		
Age	47.81 (13.44)	22-67	45.22 (14.01)	19-66	
Educ. Level (years)	14.02 (2.73)	9-22	14.99 (2.33)	11-20	
DASS-21					
• **Depression**	9.31 (9.08)	0-34	5.38 (5.80)	0-20	p=.04
• **Anxiety**	6.31 (7.28)	0-28	1.75 (2.37)	0-10	p=.001
• **Stress**	14.50 (10.73)	0-40	7.38 (6.70)	0-26	p=.002
PTA (days)	55.41 (48.89)	2-189	N/A	N/A	

Note. M, mean; SD, Standard deviation; f, female, m, male; PTA; post traumatic amnesia. The p values for the significant group differences are reported.

Emotion recognition

CAVEAT performance for both groups across the 22 emotions is shown in Figure 6.1.

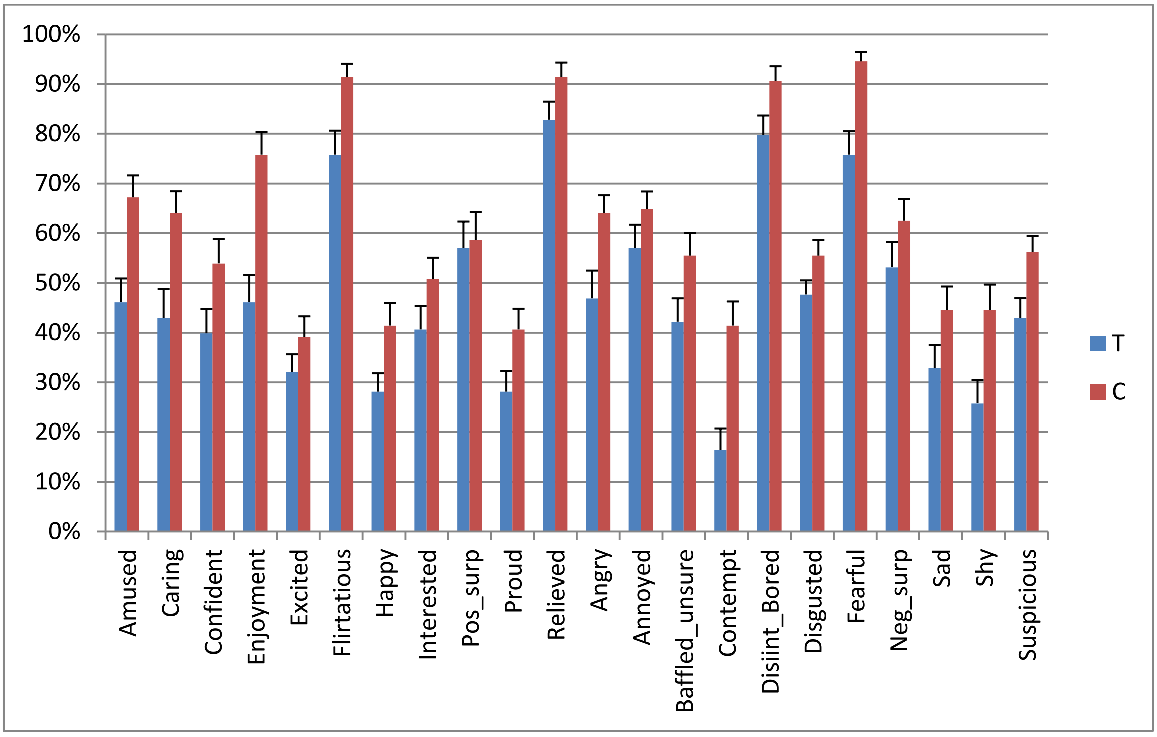


*Figure 6.1***.** Emotion recognition accuracy on the 22 emotions included in the CAVEAT for the TBI (n=32) and control group (n=32). The error bars represent standard error of the mean. T, TBI; C, control; pos_surp, positive surprise; neg_surp, negative surprise; Disint_Bored, disinterested/bored.

Two (group) x 22 (emotion type) ANCOVA with the DASS-21 total score as a covariate revealed that the TBI group performed more poorly on overall emotion recognition than matched controls ($F_{1,59}$ =28.23, p<.0001, ηp^2= .32). There was a main effect of emotion ($F_{1,21}$ =15.00, p<.001, ηp^2= .20) indicating that some emotions were recognised more accurately than others. However, the group x emotion interaction was not significant ($F_{1,21}$ =.1.03, p<.42, ηp^2= .02).

To confirm that there were no differences between the various dimensions identified in the literature, planned follow-up comparisons were conducted using 2 (group) x emotion dimension ANCOVAS, again including the DASS-21 total score as a covariate. The emotion dimensions were as previously described i.e., (1) positive vs. negative (which overlap with approach vs. withdrawal); (2) social vs. non-social (3) basic vs. complex. The emotions included in each of the categories are outlined in Table 6.2.

Table 6.2. Emotions included in the valence, basic vs. complex, and social vs. non-social categories.

Valence (overlapped with approach tendency)		**Basic vs. complex**		**Social vs. non-social** (top most reliable emotions which were included in the analysis)	
Positive	**Negative**	**Basic**	**Complex**	**Social**	**Non-social**
Amused	Angry	Fearful	Amused	Caring	Baffled/unsure
Caring	Annoyed	Sad	Caring	Flirtatious	Relieved
Confident	Baffled/unsure	Happy	Confident	Shy	Enjoyment
Enjoyment	Contempt	Positively surprised	Enjoyment		
Excited	Disinterested/Bored	Negatively Surprised	Excited		
Flirtatious	Disgusted	Disgusted	Flirtatious		
Happy	Fearful/anxious	Angry	Interested		
Interested	Negatively Surprised		Proud		
Positively surprised	Sad		Relieved		
Proud	Shy		Annoyed		
Relieved	Suspicious		Baffled/unsure		
			Contempt		
			Disinterested/Bored		
			Shy		
			Suspicious		

Examining emotion recognition across these different dimensions, revealed that while the TBI group was performing more poorly than the control group across the three dimensions (all group main effects, $ps<.001$), all the group x emotion interactions were not significant ($ps> .05$), indicating that the TBI group followed the same pattern as the control group in finding the same emotions difficult.

Valence correction

Group differences in the valence classification were examined with a 2(group) x 22 (emotion) mixed ANOVA. The analysis revealed a significant main effect of group ($F_{1,63}=16.47$, $p<.001$, $\eta p^2=.21$), indicating that the TBI group identified the valence incorrectly (e.g., incorrectly said that the target actor was expressing a positive emotion when they were expressing a negative or vice versa), more often than controls. The emotion main effect was significant ($F_{1,63}=31.66$, $p<.001$, $\eta p^2=.34$), indicating that overall, some emotions were more difficult for all participants to identify as belonging to a certain valence correctly, however, this was not affected by group membership, as indicated by non-significant group x emotion interaction ($F_{1,63}=1.37$, $p=.19$, $\eta p^2=.22$). This suggested that the TBI group was performing more poorly in identifying the valence of emotions, but not differential poorer on some emotions, compared to controls. Group differences in valence classification are outlined in Table 6.3.

Table 6.3

Number of incorrect valence identifications in TBI (n=32) and Control (n=32) group.

Emotion	Group	Mean	SD	Min	Max
Amused	TBI	.01	.04	.00	.25
	Control	.05	.12	.00	.50
Caring	TBI	.07	.11	.00	.25
	Control	.02	.06	.00	.25
Confident	TBI	.28	.21	.00	.75
	Control	.16	.19	.00	.50
Enjoyment	TBI	.01	.04	.00	.25
	Control	.00	.00	.00	.00
Excited	TBI	.05	.12	.00	.50
	Control	.04	.09	.00	.25
Flirtatious	TBI	.02	.10	.00	.50
	Control	.00	.00	.00	.00
Happy	TBI	.05	.11	.00	.25
	Control	.01	.04	.00	.25
Interested	TBI	.34	.26	.00	.75
	Control	.27	.21	.00	.75
Positive surprise	TBI	.03	.11	.00	.50
	Control	.02	.07	.00	.25
Proud	TBI	.09	.14	.00	.50
	Control	.07	.11	.00	.25
Relieved	TBI	.05	.10	.00	.25
	Control	.02	.06	.00	.25
Angry	TBI	.02	.10	.00	.50
	Control	.00	.00	.00	.00
Annoyed	TBI	.03	.08	.00	.25
	Control	.00	.00	.00	.00
Baffled/unsure	TBI	.15	.20	.00	.75
	Control	.14	.17	.00	.50
Contempt	TBI	.03	.08	.00	.25
	Control	.01	.04	.00	.25
Disinterest/bored	TBI	.05	.13	.00	.50
	Control	.01	.04	.00	.25
Disgusted	TBI	.02	.07	.00	.25
	Control	.00	.00	.00	.00
Fear	TBI	.00	.00	.00	.00
	Control	.00	.00	.00	.00
Negative surprise	TBI	.09	.14	.00	.50
	Control	.08	.15	.00	.50
Sad	TBI	.16	.21	.00	.75
	Control	.05	.13	.00	.50
Shy	TBI	.25	.18	.00	.75
	Control	.21	.11	.00	.50
Suspicious	TBI	.11	.15	.00	.50
	Control	.07	.11	.00	.25
Total (22 emotions)	TBI	.09	.04	.02	.18
	Control	.06	.02	.01	.10

Numbers reported out of 4. For example, Mean of .25 for Shy emotion indicates that the TBI group incorrectly judged the valence of 'shy' vignette as positive rather than negative 1 out of 4 times.

Labelling Errors

Average error scores (percentages) were calculated to examine the type of errors made by the two groups. The error scores are outlined in Table 6.4. Observing the error scores for the control (top panel) and TBI group (bottom panel) reveals that TBI participants, on average, chose many more descriptors for emotions than the controls, who mostly selected from a smaller range. For example, while the errors the control group made in recognising ‘flirtatious’ were limited to four emotions; interested, confident, happy and amused, the TBI group incorrectly labelled ‘flirtatious’ as more than nine different emotions. Similarly, ‘fear’ was mislabelled as three other emotions by controls but as seven others by the TBI group.

Table 6.4

Percentage of error types across the 22 emotions of CAVEAT when incorrect responses were chosen. Control group (N= 32: top panel) and TBI group (N= 32: bottom panel)

CONTROL GROUP									
				Incorrect Label					
Emotion	**1st**	**2nd**	**3rd**	**4th**	**5th**	**6th**	**7th**	**8th**	**other**
Fearful/anxious	71% - Sad	14% - Negatively surprised	14% - Baffled/unsure						
Relieved	55% - Positively surprised	27% - Proud	9% - Interested	9% - Contempt					
Flirtatious	36% - Interested	36% - Confident	18% - Happy	9% - Amused					
Disinterested/Bored	33% - Contempt	17% - Annoyed	17% - Suspicious	8% - Sad	8% - Angry	8% - Baffled/unsure	8% - Negatively surprised		
Enjoyment	52% - Happy	35% - Relieved	6% - Caring	3% - Positively surprised	3% - Proud				
Amused	62% - Happy	17% - Positively surprised	7% - Confident	7% - Enjoyment	2% - Caring	2% - Relieved	2% - Excited		
Annoyed	42% - Contempt	36% - Angry	7% - Negatively surprised	7% - Disgusted	4% - Disinterested/Bored	4% - Baffled/unsure			
Angry	52% - Annoyed	39% - Contempt	4% - Negatively surprised	4% - Disgusted					
Caring	28% - Positively surprised	22% - Flirtatious	22% - Confident	17% - Happy	9% - Interested	2% - Negatively surprised			
Negatively surprised	42% - Baffled/unsure	15% - Suspicious	13% - Fearful/anxious	13% - Annoyed	10% - Disgusted	4% - Contempt	2% - Positively surprised	2% - Sad	
Positively surprised	64% - Excited	13% - Happy	8% - Interested	8% - Enjoyment	6% - Amused	2% - Relieved			
Suspicious	36% - Baffled/unsure	20% - Negatively surprised	13% - Disgusted	13% - Annoyed	11% - Contempt	4% - Fearful/anxious	4% - Angry	2% - Disinterested/Bored	
Disgusted	26% - Baffled/unsure	23% - Annoyed	19% - Negatively surprised	11% - Fearful/anxious	7% - Contempt	7% - Sad	5% - Suspicious	2% - Disinterested/Bored	
Baffled/unsure	37% - Fearful/anxious	19% - Shy	14% - Suspicious	11% - Negatively surprised	7% - Disinterested/Bored	5% - Annoyed	4% - Contempt	2% - Confident	2%
Confident	27% - Interested	20% - Proud	19% - Relieved	15% - Positively surprised	7% - Excited	5% - Happy	3% - Caring	2% - Annoyed	2%
Interested	84% - Positively surprised	8% - Relieved	3% - Happy	3% - Confident	2% - Caring				
Sad	31% - Baffled/unsure	31% - Annoyed	18% - Fearful/anxious	8% - Shy	4% - Disinterested/Bored	4% - Negatively surprised	1% - Disgusted	1% - Contempt	
Shy	41% - Fearful/anxious	30% - Baffled/unsure	10% - Suspicious	8% - Sad	7% - Negatively surprised	3% - Annoyed	1% - Disgusted		

Table 6.4 *(Continued)*

CONTROL GROUP									
	Incorrect Label								
Emotion	**1st**	**2nd**	**3rd**	**4th**	**5th**	**6th**	**7th**	**8th**	**other**
Happy	27% - Proud	19% - Excited	15% - Positively surprised	11% - Interested	9% - Confident	7% - Enjoyment	5% - Relieved	5% - Amused	3%
Contempt	49% - Annoyed	27% - Disgusted	16% - Angry	5% - Negatively surprised	3% - Suspicious				
Proud	33% - Confident	25% - Happy	9% - Enjoyment	9% - Positively surprised	8% - Relieved	7% - Amused	7% - Interested	3% - Excited	
Excited	37% - Positively surprised	24% - Happy	14% - Confident	10% - Interested	5% - Enjoyment	5% - Relieved	3% - Proud	1% - Negatively surprised	

TBI GROUP									
	Incorrect Label								
Emotion	**1st**	**2nd**	**3rd**	**4th**	**5th**	**6th**	**7th**	**8th**	**other**
Fearful/anxious	35% - Sad	23% - Baffled/unsure	19% - Negatively surprised	13% - Suspicious	3% - Shy	3% - Disinterested/Bored	3% - Disgusted		
Relieved	68% - Positively surprised	9% - Interested	9% - Happy	5% - Amused	5% - Excited	5% - Caring			
Flirtatious	23% - Happy	23% - Interested	16% - Confident	10% - Excited	10% - Proud	6% - Enjoyment	6% - Amused	3% - Positively surprised	3%
Disinterested/Bored	23% - Baffled/unsure	23% - Negatively surprised	15% - Annoyed	15% - Contempt	8% - Suspicious	8% - Angry	4% - Fearful/anxious	4% - Sad	
Enjoyment	39% - Happy	30% - Relieved	7% - Positively surprised	4% - Amused	4% - Proud	4% - Confident	4% - Interested	3% - Excited	3%
Amused	48% - Happy	20% - Positively surprised	10% - Excited	7% - Enjoyment	6% - Confident	3% - Interested	3% - Flirtatious	1% - Relieved	1%
Annoyed	38% - Negatively surprised	20% - Angry	13% - Contempt	9% - Disgusted	9% - Disinterested/Bored	5% - Suspicious	4% - Baffled/unsure	2% - Fearful/anxious	
Angry	56% - Annoyed	21% - Contempt	6% - Fearful/anxious	4% - Negatively surprised	4% - Baffled/unsure	4% - Disgusted	3% - Suspicious	1% - Disinterested/Bored	
Caring	32% - Flirtatious	16% - Positively surprised	16% - Confident	15% - Happy	10% - Interested	7% - Relieved	1% - Enjoyment	1% - Proud	1%
Negatively surprised	53% - Baffled/unsure	17% - Suspicious	8% - Disgusted	8% - Annoyed	5% - Fearful/anxious	3% - Shy	2% - Sad	2% - Disinterested/Bored	2%
Positively surprised	51% - Excited	24% - Happy	7% - Enjoyment	7% - Interested	5% - Amused	4% - Relieved	2% - Proud		
Suspicious	33% - Baffled/unsure	18% - Annoyed	16% - Negatively surprised	14% - Fearful/anxious	8% - Disgusted	5% - Contempt	1% - Confident	1% - Amused	3%
Disgusted	31% - Baffled/unsure	22% - Negatively surprised	19% - Annoyed	9% - Suspicious	6% - Fearful/anxious	6% - Disinterested/Bored	3% - Sad	3% - Contempt	

Table 6.4 *(Continued)*

					TBI GROUP				
					Incorrect Label				
Emotion	**1st**	**2nd**	**3rd**	**4th**	**5th**	**6th**	**7th**	**8th**	**other**
Baffled/unsure	20% - Suspicious	16% - Negatively surprised	15% - Fearful/anxious	12% - Disinterested/Bored	12% - Shy	11% - Annoyed	7% - Sad	3% - Contempt	4%
Confident	31% - Interested	25% - Relieved	17% - Positively surprised	7% - Happy	7% - Amused	7% - Proud	4% - Caring	1% - Baffled/unsure	3%
Interested	72% - Positively surprised	8% - Relieved	7% - Caring	5% - Amused	4% - Happy	3% - Excited	1% - Flirtatious		
Sad	21% - Annoyed	20% - Baffled/unsure	15% - Fearful/anxious	12% - Shy	9% - Disinterested/Bored	7% - Negatively surprised	6% - Contempt	4% - Suspicious	6%
Shy	30% - Fearful/anxious	29% - Baffled/unsure	12% - Negatively surprised	9% - Sad	7% - Suspicious	6% - Annoyed	4% - Disinterested/Bored	1% - Disgusted	2%
Happy	22% - Positively surprised	15% - Excited	13% - Proud	13% - Interested	11% - Confident	10% - Amused	5% - Relieved	5% - Enjoyment	5%
Contempt	50% - Annoyed	19% - Disgusted	8% - Negatively surprised	8% - Angry	6% - Suspicious	4% - Disinterested/Bored	3% - Baffled/unsure	1% - Fearful/anxious	1%
Proud	25% - Positively surprised	24% - Confident	21% - Happy	9% - Enjoyment	7% - Interested	7% - Excited	4% - Relieved	4% - Amused	
Excited	49% - Positively surprised	18% - Happy	13% - Interested	8% - Relieved	7% - Confident	2% - Proud	1% - Enjoyment	1% - Amused	

Correlations

One-tailed Pearson correlations were conducted to examine whether overall performance on CAVEAT was correlated to performance on MR, DSC and DS tests of cognitive ability. In this and subsequent analysis, PTA was included as a group variable, and as a measure of injury severity (PTA=0 for control group, and in the TBI group, higher values indicate greater injury severity). In this and the regression analysis, Bonferroni correction (adjusted $\alpha=.05/6=.008$) was used for multiple comparisons.

Analysis revealed a significant negative correlation between emotion recognition accuracy, as measured by CAVEAT and PTA ($r=-.55$, $p<.0001$), indicating more severe TBI (as evident by longer PTA) was associated with worse ability to recognise emotions. There was a significant positive correlation between CAVEAT score and Matrix Reasoning ($r=.55$, $p<.001$), Digit Symbol Coding ($r=.47$, $p<.001$) and Digit Span ($r=.57$, $p<.001$). The correlational data are shown in Table 6.5.

Table 6.5

Table of correlations between total CAVEAT accuracy (overall emotion recognition), PTA, depression, anxiety, stress, and neuropsychological measures (MR, DSC and DS)

Variable	CAVEAT	PTA	DASS	MR	DSC	DS
CAVEAT	1.00	-0.55*	-0.27 T	0.55*	0.47*	0.57*
PTA		1.00	0.07	-0.21 T	-0.42*	-0.38*
DASS			1.00	-0.21 T	-0.17	-0.17
MR				1.00	0.36*	0.56*
DSC					1.00	0.50*
DS						1.00

Note. NS = not significant (p>.008), correlation is significant at the* p<.008 (Bonferroni adjusted), T=trend (p<.05).All correlations are one-tailed. PTA includes information about group membership (PTA=0 for control participants) and injury severity. MR=matrix reasoning, DSC=digit-symbol coding, DS=digit span.

Regression analysis

To determine whether CAVEAT performance could be accounted for by cognitive difficulties, MR, DCS and DS scores along with group membership and injury severity (as measured by PTA) were entered as predictors for CAVEAT into a simultaneous regression analysis. The DASS score was also entered. A significant model emerged ($F_{5,56}$ =14.30, p<.001). The model explained 56.1% of the variance in CAVEAT performance. The regression analysis is outlined in Table 6.6.

Table 6.6

The unstandardized and standardised regression coefficients for the variables entered into the model.

Variable	B	SE B	Β	*p*
PTA	-.001	.000	-.370	<.001*
DASS	-.002	.002	-.131	.157
Matrix reasoning	.012	.004	.307	.007*
Digit symbol coding	.003	.004	.087	.422
Digit Span	.007	.004	.192	.112

Note. *Significant at the Bonferroni adjusted (α=.05/5=.01)

The regression analysis revealed that PTA (t=-3.70, p<.001) and Matrix Reasoning (t=2.82, p=.007) were both significant unique predictors of emotion recognition.

Measures of psychosocial functioning

To determine whether emotion recognition is associated with psychosocial functioning, CAVEAT performance was correlated with measures of psychosocial functioning and number of friends in the TBI group (n=32). Data from correlational analysis are outlined in Table 6.7. DASS scores were not correlated with CAVEAT performance in the TBI group alone (ps>.07), so were not controlled for in this analysis.

Table 6.7

Correlational analysis in the TBI group (n=32)

	CAVEAT	FrSBe_A	FrSBe_D	SPRS_Interp	# friends
CAVEAT	1	-.32*	-.10	-.27	.43*
FrSBe_A		1	.19	-.39*	-.18
FrSBe_D			1	-.32*	-.02
SPRS_Interp				1	-.18
# friends					1

Note. One-tailed Pearson correlations. NS = not significant (p>.05). *Correlation is significant at the p<.05 level, **correlation is significant at the p=.01 level. All correlations are one-tailed. FrSBe_A= FrSBe Apathy T-score, FrSBe_D= FrSBe Disinhibition T-score, SPRS_Interp= SPRS Interpersonal, # friends= number of friends

As apparent in Table 6.7, there was a significant negative correlation between CAVEAT score and FrSBe apathy scale (r=-.32, p=.04), indicating that higher emotion recognition scores are associated with lower self-reported apathy. There was a positive correlation between the CAVEAT score and self-reported number of friends (r=.43, p=.03), with higher emotion recognition accuracy associated with greater number of friends. There was also a negative correlation between SPRS integration scale and FrSBe apathy (r=-.39, p=.2), and FrSBe disinhibition (r=-.32, p=.04) subscales, indicating that higher apathy and disinhibition were associated with better psychosocial functioning.

Discussion

This study investigated emotion recognition ability in individuals with TBI, when faced with 22 different emotional expressions sampled from different dimensions of emotion. By using a larger range of emotions than the six basic emotions normally studied, it was possible to provide a more comprehensive examination of positive vs. negative emotions (11 of each). It was also possible to look at basic versus complex and non-social versus social emotions. Consistent with studies 1 and 2, the TBI group was performing more poorly on overall emotion recognition, without selective impairments in recognising some emotions compared to others. These findings strengthen the argument that TBI results in a general deficit in emotion recognition, rather than a selective impairment in recognising some emotions compared to others. The failure to detect an impairment specific to negative emotions, the so-called valence effect, is consistent with a number of other studies (Ietswaart et al., 2008; McDonald & Saunders, 2005; Rosenberg et al,, 2014; Rosenberg et al., 2015).

This study also revealed that individuals with TBI are similarly impaired in their recognition of social versus non-social and complex versus basic emotions. This is also consistent with the findings by Ietswaart et al. (2008) who found that people with TBI (of mild to moderate severity) displayed overall difficulties in emotion recognition including impaired recognition of complex morphed hybrid emotions, rather than a selective impairment in recognising some emotions compared to others.

While evidence for a selective impairment of a particular dimension of emotion was not found, the data support the view that emotion perception (regardless of emotion type) reflects a specialised cognitive system/s. This ability was selectively impaired in people with TBI, more so in those with more severe injuries, and was not accounted for by impairments in working memory, processing speed or non-verbal reasoning, although the latter ability did make an additional unique contribution. This finding expands our previous work (Rosenberg, Dethier, et al., 2014; Rosenberg, McDonald, et al., 2015) which found that injury severity was the sole predictor of performance on an emotion perception task entailing the six basic emotions across a range of intensities (and difficulty levels). The finding that non-verbal processes were additionally important to accuracy on CAVEAT may reflect its audiovisual format. Dynamic, multi-modal displays of emotions may tax cognitive abilities more than static displays that are typically used (Knox & Douglas, 2009). Indeed, another study that used similar audiovisual displays of emotion taken from TASIT (McDonald et al., 2002), reported associations between emotion perception and other cognitive skills including premorbid intellectual ability, working memory, reasoning and new learning (McDonald et al., 2006).

While CAVEAT performance had some association with formal neuropsychological measures, it was associated with self-reported apathy and reported number of friends. In contrast, there was no association between CAVEAT performance and self-reported disinhibition. The negative association between CAVEAT performance and self-reported apathy suggests that emotion recognition predicts real life everyday functions such as problems with inattention, psychomotor retardation, spontaneity, drive, persistence, loss of energy and interest, lack of concern for self-care and/or blunted facial expression, all common characteristics of apathy. Since apathy is commonly described as loss of, or diminished goal directed behaviour as evident by difficulties to initiate and/or respond appropriately across three domains, such as behaviour, cognition and emotion (Mulin et al., 2011), the crucial role of intact emotion recognition is hardly surprising.

The positive association between emotion recognition and number of friends post TBI is consistent with previous literature. It has been previously reported that individuals with severe TBI (PTA of more than 7 days) do experience a significant decrease in number of friends (Oddy et al., 1978). These findings extend on this by suggesting that one of the contributors to fewer friends may be problems with impaired emotion recognition. This makes sense in light of research revealing that conversations of patients with TBI were rated as significantly more effortful, less interesting, and most importantly, less appropriate, than those of healthy controls (Bond & Godfrey, 1997).

In addition, examining the labelling errors made by the two groups revealed that the TBI group labelled emotions more widely and less systematically than control participants. Their pattern of responding suggested that they were selecting different emotion labels uncritically instead of following a pattern based upon similarity. This contrasted with the control group, who confused some emotions with a small group of similar emotions. Qualitative observation of the participants while completing the measure revealed that several TBI participants followed an 'elimination' style of responding, going through each emotion sequentially and verbalising a response such as: 'no, not happy, not amused, not excited, maybe flirtatious..'. This behaviour was not observed in the control group and strongly suggested that some participants with TBI were perplexed when trying to identify the emotion they were faced with.

Further, the findings indicate that the TBI group was poorer in identifying the valence of emotions, although they followed the pattern displayed by the control group, finding the same emotions difficult. This suggests that people with TBI might be experiencing difficulties in both the superordinate level (in identifying the valence of the emotion), and the subordinate level (when they are guided into the correct valence following the initial categorisation and asked to select the emotion corresponding to how the target actor is feeling). This is consistent with the social cognition difficulties experienced by people with TBI.

This study is not without limitations. First, this study did not provide a systematic examination of two other important dimensions in emotions, that is, dominance and arousal despite their potential relevance. It was simply outside the scope of a single study to examine these also, but future research may fruitfully do so. An additional limitation of this study was that social functioning was measured via self-report, and no proxy reports were collected. This raises the concern that people with moderate-severe TBI may have limited self-awareness and insight into their social and behavioural difficulties and may not be reliable informants (Hart, Sherer, Whyte, Polansky, & Novack, 2004; Spikman & van der Naalt, 2010). Proxy reports of family or friends of the people with TBI sample in this study would certainly have strengthened information about their psychosocial difficulties. Despite these concerns, the fact that significant correlations were obtained between emotion perception and self-reported functioning and in the hypothesised directions, suggests that the people with TBI in this study were able to reliably report on at least some facets of their social functioning.

Overall, these findings have important implications for extending our understanding of the complex interplay between brain impairment, cognitive processes and psychosocial functioning. Most importantly, as the previous studies, they indicate that individuals with moderate-severe TBI are impaired in their general ability to ascertain the emotions of others, but do not have a selective impairment in recognising some emotions over others. Impairment appears to be a direct consequence of brain injury as well as secondary to reduced non-verbal processing. Emotion recognition deficits predicted self-reported problems with apathy and the current number of close friendships. This adds to the rapidly accumulating literature that details emotion recognition deficits as a common consequence of a range of neurological conditions and TBI in particular, and emphasises the need to systematically include those difficulties among the cognitive and physical remediation targets post TBI.

CHAPTER 7

General Discussion

This thesis investigated emotion recognition following moderate-severe TBI. While emotion perception deficits in TBI have received an increasing amount of attention over the past few decades, as outlined in the Introduction, there are still a number of issues that remain to be addressed. Thus, the primary aims of this thesis were as follows; 1) to clarify whether people with TBI are poorer in recognising some emotions compared to others, and specifically whether the valence effect largely reported in the literature is a true consequence of TBI, or an artefact of the conventional emotion recognition measures used; 2) to examine the role of neuropsychological functioning in emotion recognition, in light of the dynamic nature of the tasks used in this thesis, and 3) to explore the utility of the CAVEAT as a clinical tool, examining its validity and reliability, and to investigate the relationship between emotion recognition as measured by the CAVEAT and social functioning, i.e., the CAVEAT's ecological validity.

These aims were addressed by using an existing task (ERT; Montagne, Kessels, et al., 2007) to examine the recognition of the six basic emotions at different intensity levels (Study 1 and 2), and by applying a new task, the CAVEAT, in order to investigate emotion recognition more widely (Study 5). CAVEAT development was outlined in study 3, and an exploration of its psychometric qualities was described in Study 4. Together, the five studies presented in this thesis represent an empirically driven investigation to examine emotion recognition in moderate-severe TBI. For convenience, these are summarised below.

Study 1 examined emotion recognition for the six basic emotions across low, medium and high intensities in individuals with TBI compared to matched control participants using the ERT (Montagne, Kessels, et al., 2007). Consistent with prior research (e.g., Babbage et al., 2011; Ietswaart et al., 2008), people with TBI were poorer in emotion recognition than their non-injured peers. Overall, the TBI group was performing more poorly than controls in recognising facial expressions of anger, followed by disgust, and happiness. There was also a trend for poorer recognition of surprise, sadness, and fear, compared to controls, although these effects failed to reach significance. Moreover, individuals with TBI were more impaired on the overall recognition of the negative, compared to the positive emotions, reinforcing the valence effect found in prior research. However, by examining emotion recognition across varying intensities, it became apparent that different emotions varied widely as to how easily they were recognised by both people with TBI and individuals without injuries. Importantly, the findings indicated that differential difficulty across categories of emotions is a feature of the stimuli themselves rather than a particular problem that arises as a consequence of TBI. In particular, happiness was so easy as to lead to clear ceiling effects in both TBI and control groups at most levels of intensity. In contrast, fear was so difficult that there were obvious floor effects, especially at the more subtle levels of intensity.

Taken together, these findings contradict the claim that it is specifically negative emotions that are impaired by TBI, but rather suggest that particular facial configurations may be more ambiguous, and therefore more difficult, for both people with TBI and non-injured, healthy adults to ascertain. The differential difficulty of each emotion resulted in floor and ceiling effects that made a direct comparison across the six basic emotions difficult.

In **Study 2** the same six emotions were examined from Study 1 but in this case, a single intensity level for each emotion was selected for group comparisons in two separate comparisons: (1) using stimuli from each of the six categories representing 100% intensity as commonly used in emotion recognition research and (2) using stimuli from each category at an intensity level selected to provide equivalent levels of accuracy in control participants as far as possible. When comparing recognition rates of positive and negative emotions using the full-blown emotions, the TBI participants were more impaired in recognising negative than positive emotions, re-confirming the valence effect. In contrast, when using expressions that were equated on task difficulty, individuals with TBI displayed a general impairment in emotion recognition, rather than a selective impairment in the recognition of some emotions compared to others. Thus, while both TBI and control groups found negative emotions more difficult than positive, the TBI group was not differentially more impaired in recognising negative emotions compared to controls. These findings contradict the claim that TBI results in a selective impairment in recognising negative, rather than positive emotions. They indicate that, once emotions are equated for difficulty, individuals with TBI perform worse than controls across all emotions although they follow the same patterns of responses, i.e., finding the same emotions difficult.

In addition, Study 2 suggested that emotion recognition is a complex skill that partly relies upon other, non-social abilities and is also independent of these. Specifically it was found that emotion perception using the ERT was negatively associated with measures of non-verbal reasoning and processing speed in people with TBI, replicating earlier findings (e.g., McDonald et al., 2006; Yim et al., 2013) but also that it was uniquely predicted by injury severity. The importance of injury severity is consistent with the recent findings (Spikman et al., 2012), and emphasises the notion of dose-response relationship in TBI (Temkin et al., 2009).

Study 3 outlined the development and pilot testing of the CAVEAT, which was designed to address the limitations of conventional emotion recognition measures by (1) including an equal number of positive and negative emotions, (2) designing items to have similar levels of task difficulty, (3) representing surprise as both positive and negative in valence (4)-(5) incorporating multi-modal cues, (6) representing genuine (not posed) displays of emotion, and (7) including a larger number of emotions, including more complex emotions that vary according to different conceptualisations of emotion (valence, social vs. non-social, basic vs. complex), mirroring the wider range of emotions as experienced in everyday life. This was a complex undertaking. Studies 3A-3C aimed to develop a version of the CAVEAT which is both sensitive to emotion perception difficulties following TBI and other brain impairments and predictive of real world functioning. Study 3D was an auxiliary validity study that compared performance of the TBI and control groups on a subgroup of emotions from the CAVEAT that represented the six basic emotions used in conventional emotion research. This was conducted in order to confirm that (a) the pattern of recognition rates of these six basic emotions was similar to those reported in the literature (e.g., Palermo & Coltheart, 2004) and that (b) floor and ceiling effects, especially for fear and happiness respectively, were ameliorated relative to conventional measures.

Study 4 aimed to establish the psychometric properties of the CAVEAT by examining performance of a healthy control group and a TBI group in order to provide estimates of its validity and reliability. The findings revealed that CAVEAT demonstrated high construct validity, correlating with other measures of emotion recognition and social cognition related measures such as empathy and alexithymia (convergent validity) and discriminating between groups that are expected to have differences in their ability to recognise emotions (discriminant validity). In addition, CAVEAT was shown to have strong internal consistency, demonstrating that all items consistently measure emotion recognition. These findings provided some evidence for the psychometric properties of CAVEAT, indicating that it can be used as a clinical test for assessing emotion recognition in people with moderate-severe TBI. It might also be suitable to use with other clinical populations, however, this is yet to be established.

Study 5 used CAVEAT to re-examine (1) the valence effect (2) the role of neuropsychological functioning and (3) the relationship between emotion perception and scores on selected measures of social outcome, in a group of people with moderate-severe TBI. The novelty of this study rested upon the many carefully designed innovations incorporated in developing the CAVEAT as a sophisticated measure of emotion perception. Importantly, the CAVEAT was designed to assess performance on a much broader range of emotions than the conventional six, encompassing exemplars arising from a variety of emotion conceptualisations, specifically valence (which overlapped with the concept of approach tendency), basic versus complex emotions, and social versus non-social emotions. The findings revealed that people with TBI were poorer in recognising emotion overall, rather than displaying selective deficits in recognising some emotions compared to others. In addition, the findings indicated that, as with Study 2, emotion recognition deficits following TBI were accounted for by reduced non-verbal reasoning (but not, in this case, speed of processing). In addition, as before, they were accounted for by a specific deficit related to injury severity rather than other cognitive abilities, at least as measured in this study.

Finally, the findings indicated that performance on CAVEAT translated into broader indices of social outcomes, such as self-reported symptoms of apathy, specifically, problems with inattention, psychomotor retardation, spontaneity, drive, persistence, loss of energy and interest, lack of concern for self-care and/or blunted facial expression. In addition, poorer performance on CAVEAT was associated with lower number of friends, suggesting that reduced emotion recognition might be one of the contributors to the decrease in number of friends experienced after severe TBI (Oddy et al., 1978). Thus, the findings provided some evidence for CAVEAT's ecological validity by demonstrating that CAVEAT performance is related to real life psychosocial outcomes.

Combined, the findings of these five studies, substantially increase understanding of the nature of emotion recognition deficits following TBI, and how this relates to neuropsychological functioning, and real life psychosocial functioning. The implications of these findings are discussed below.

Do people with TBI really have problems with specific emotional categories/dimensions?

The present findings are consistent with literature documenting emotion recognition difficulties in individuals with moderate-severe TBI (R. E. Green et al., 2004; Hopkins et al., 2002; McDonald, 2003; McDonald & Flanagan, 2004; Milders et al., 2003; Spell & Frank, 2000). Moreover, taken together, these findings indicate that moderate-severe TBI results in a general impairment in emotion recognition rather than a selective impairment in recognising some emotions (e.g., specific emotions) or specific dimensions (e.g., positive vs negative emotions), once task difficulty is taken into account. Moreover, the present studies suggest that the emotion recognition deficits following TBI, while to some extent influenced by cognitive deficits such as impairments in non-verbal processing and processing speed, are not solely a secondary consequence of reduced neuropsychological functioning, but a direct consequence of brain injury and injury severity.

These findings contradict claims that selective impairments in recognising negative compared to positive emotions, which are often reported in the literature (e.g., Croker & McDonald, 2005; R. E. Green, Turner, & Thompson, 2004; Hopkins et al, 2002; Jackson & Moffat, 1987; Kucharska-Pietura, Phillips, Gernand, & David, 2003; McDonald, Flanagan, Rollins, & Kinch, 2003) represent damage to specific dedicated neural systems underpinning recognition of different emotional states. In contrast, they suggest that such differential impairment is likely to be an artefact of the use of a limited set of six emotions and static, 100% full blown expressions. This is consistent with the findings by Rapcsak et al. (2000) who used an emotion labelling task in a large sample of patients with focal left, right or bilateral lesions, including ventromedial frontal and amygdala damage, and reported that while neurologic patients were impaired compared to controls in recognising facial expressions, when general difficulty was accounted for, not even patients with unilateral or bilateral amygdala pathology demonstrated a disproportionate impairment in recognising fear. The results of this comprehensive study suggested that emotion recognition can be disrupted by damage to a range of brain structures, but that specific emotions, especially fear, are not necessarily implicated above others even when dedicated neural networks are compromised (Rapcsak et al., 2000).

While the studies included in this thesis did not find evidence for selective impairment of negative compared to positive emotions, nor of any other impairment of different emotion categories or dimensions, the data supported the view that emotion perception is, at least partly, mediated by specialised cognitive systems independent of other cognitive processes. This ability was impaired in people with TBI, more so in those with more severe injuries and was not accounted for by impairments in other cognitive abilities, although these did make some contribution. Further, the fact that the TBI samples used in these studies sustained their injuries a long time ago (time post injury ranged from 2 to 40 years) is consistent with recent research suggesting a general lack of recovery at one year follow-up (Milders et al., 2008). They highlight the need for caution when drawing conclusions about selective impairment in the recognition of some emotions compared to others in TBI and other clinical populations (Rapcsak et al., 2000).

The difficulty with facial expressions of happiness and fear and the underlying floor and ceiling effects - The curious case of happiness and fear

A clear result from studies 1 and 2, which is consistent with previous literature (e.g., Biehl et al., 1997; Palermo & Coltheart, 2004), is that recognition of the six basic emotions, using a standard multiple choice format, is not equally difficult. Selecting the label for happiness from a choice of six, proved to be extremely easy, and fear quite difficult in Study 1. This was starkly apparent in Study 2, where it proved impossible to select exemplars from these two categories that were correctly recognised by the control group 50 percent of the time, and, thus, equally difficult. Indeed, control participants found very intense (100%) facial expressions of fear more difficult than very low intensity (20%) happiness.

There are a few possible reasons for this disparity in the recognition of fear and happiness in the ERT. One possibility is that these differences are an artefact of the

ERT's reliance on dynamic, rapidly changing stimuli. However, since as outlined in Study 2, the recognition rates of the six emotions included in the ERT are very similar to those obtained in the static measures, this does not seem likely. Alternatively, the discrepancy between fear and happiness might be due to (1) salience (i.e., distinctiveness) of emotions being expressed and/or (2) the number of distracters in the task. Both factors affect difficulty by influencing the ambiguity, as less salient emotions are more ambiguous and also, ambiguity is expected to increase along with the number of distractors for each emotion. As discussed, a limitation of the conventional static photographs is that the ambiguity of negative emotions is higher than for positive for both these reasons. The four negative emotions all rely upon subtle configurations of the eyebrows, nose and lips, compared to the distinctive features of the happy expressions, often identified by the "smile" (Bornhofen & McDonald, 2010). In addition, there are twice as many distractors available for the negative emotions than positive, which increases ambiguity even further.

These design limitations were addressed in the development of the CAVEAT. The CAVEAT used dynamic, naturalistic representations of emotions to better emulate emotion recognition in everyday life. The CAVEAT was also designed to better represent other theoretical conceptualisations of emotion to provide a wider range of emotions as they occur in everyday settings, i.e., to potentially increase its ecological validity. It included 22 distractors, a substantially greater number relative to conventional measures, and had an equal number for both negative and positive emotions (11 each). The design reduced the discrepant difficulty between happiness and fear by, firstly, increasing the difficulty of recognising happiness (by providing an increased number of possible response choices related to this emotion). Secondly, actors were instructed during CAVEAT development to increase the intensity of their portrayed fear to increase its salience. Moreover, by incorporating multimodal displays of emotion it was expected that the salience of fear would be increased by introducing additional cues such as tone of voice and body language, and the salience of happiness might be decreased as it would no longer be judged from a single feature-the smile.

The first step in determining how these manipulations affected recognition of the basic emotions, including happiness and fear, was to compare performance on the CAVEAT basic (incorporating only 6 emotions as described in Study 3D) to the ERT. Overall, the findings suggest that increasing the salience of the portrayal of fear increased its recognition rates in both control and TBI participants. This also decreased its ambiguity, as evident by the substantial decrease in labelling errors for this emotion in both groups. When happiness was presented alongside five other emotions in the CAVEAT basic, the recognition rates were high (at approx. 85% for both control and TBI participants) comparable but not quite as high as on the ERT (94% and 88% for control and TBI participants, respectively). The slight reduction of the ceiling effect in CAVEAT basic, compared to the ERT, suggests that the naturalistic, multimodal expression of happiness in the CAVEAT might be slightly (but not overly so) more difficult than recognition of a uni-modal and posed expressions of the ERT.

The second step in examining the differential between happiness and fear was to examine the effects of increasing the number of distractors. Interestingly, this revealed that the increase in recognition rates of fear was not dependent on availability of distractors in the negative category, as recognition rates were very similar on 6-item CAVEAT basic (Study 3D) and studies 3C and 5, which used the 22-item of CAVEAT. However, the recognition accuracy of happiness decreases drastically when more emotions are introduced in the positive category in 22-items CAVEAT (i.e., the number of positive emotions in increased from two to 11). Examining the labelling errors on the 22-item CAVEAT revealed that happiness was frequently confused with other emotions in the positive category, and, as expected, people with TBI demonstrated greater confusion than the control group. This suggested that, as expected, increasing the number of distractors in the positive category increased the ambiguity of happiness.

Overall, these comparisons suggested that both salience and number of distractors may explain differences in the recognition rates for fear and happiness in the ERT studies (and others in the literature). Fear recognition is mostly affected by low salience and happiness recognition by availability of distracters, both of which influence ambiguity. This illustrates the difficulty faced in emotion recognition research in selecting assessment measures which allow a valid assessment of emotion perception of clinical populations and healthy controls, and emphasise the need for caution when considering how the task characteristics might affect results.

Ecological validity

While it has become common practice to assess neuropsychological defects following TBI, and despite the importance of such assessments to ascertaining strengths and difficulties, such tests have limited ecological validity (e.g., Chaytor & Schmitter-Edgecombe, 2003; Spooner & Pachana, 2006; Van der Elst, Van Boxtel, Van Breukelen, & Jolles, 2008). A comprehensive review by Chaytor and Schmitter-Edgecombe (2003) suggested that many of the commonly used neuropsychological tests have a *moderate* level of ecological validity when predicting everyday cognitive functioning in clinical and non-clinical populations. For example, studies examining ecological validity of a few commonly used tests of executive functioning, such as the Trail Making Test (Reitan, 1992), Wisconsin Card Sorting Test (WCST; Heaton, Chelune, Talley, Kay, & Curtiss, 1993), Stroop (Golden, 1978), and Controlled Oral Word Association Test (COWAT; Benton, Hamsher, Varney, & Spreen, 1983), accounted for approximately 20% of the variance in everyday executive ability in a mixed sample of people with acquired brain injuries and epilepsy (Chaytor, Schmitter-Edgecombe, & Burr, 2006).

Another concern regarding the ecological validity of neuropsychological measures is that most neuropsychological tests involve stimuli and environments that are very different from real life situations. Subsequently, the focus of neuropsychology research and clinical practice has shown a shift towards a greater emphasis on understanding the relationship between assessment results and performance of everyday tasks (Spooner & Pachana, 2006). One example on a task developed especially to provide a functional assessment of executive functioning is the Hamburger turning task (HTT; Shugars, 2007), which was found to be related to real-life aspects of executive functioning.

Social cognition, the subject of this thesis, is rapidly being recognised as representing a set of skills that are pivotal to social performance. In light of the recognised importance of employing assessment tools which predict real life functioning, an additional aim of this thesis was to examine the ecological validity of the CAVEAT as a clinical assessment tool. As discussed above, the CAVEAT was shown to have some ecological validity by its association with a few real life psychosocial outcomes, such as apathy and number of friends, although it was not associated with self-reported disinhibition and interpersonal relationships. While the relation of CAVEAT to other aspects of everyday functioning is yet to be established, the present findings do provide some support of its ecological validity, at least at a number of domains. Since the accuracy of predicting real-life functioning on the basis of test scores increases in accordance with the similarity between the test requirements and everyday demands (Sbordone, 2001; Wilson, 1993), the dynamic, naturalistic, multimodal nature of CAVEAT stimuli are pivotal. Following the guidelines by Cohen and Cohen (1983), the effect sizes of the correlations between CAVEAT and a measure of apathy (r=-.32), and a number of friends (r=.43) represent a medium-large effect. The clinical importance of these effects is emphasised when considering that the recommended minimum effect size representing a ‘practically’ significant effect for social science data is r=.2 (Ferguson, 2009), approximately half of the size of CAVEAT effect sizes.

The findings regarding an association between emotion recognition, as measured by CAVEAT and real life domains are consistent with research reporting an association between other measures of emotion recognition and real life social functioning (e.g., Knox & Douglas, 2009; McDonald et al., 2004; Spikman et al., 2013; Struchen et al., 2008; Watts & Douglas, 2006). They extend this previous work by demonstrating the relationship between everyday function and a measure that assesses sensitivity to a wider range of naturalistic, dynamic, multi-modal emotions, including a wider range of positive and negative emotions, as well as complex and social emotions.

A potential limitation of the current investigation of the ecological validity of CAVEAT is that psychosocial functioning in this thesis was measured solely by self-report rather than by collecting proxy data from family members of the TBI participants, or real-life observations of social behaviour. While the decision to use self-report versus relative-report measures was justified by research that has found that head injured people are able to reliably complete self-report scales as indicated by the ‘close others’ similar reports (Kinsella, Moran, Ford, & Ponsford, 1988), providing confidence for the use of self-report scales in severe head injury, other research also suggests that severe TBI is often associated with poor insight into deficits. In particular, some studies suggested that approximately 45% of people with TBI display impaired insight or self-awareness, as evident in disparities between their self-appraised versus actual level of functioning (Flashman & McAllister, 2002), leading people to underestimate post-injury changes in their competency level (Prigatano, 1986; Prigatano, Altman, & O'Brien, 1990; Stuss, 1991).

If these rates were applied to the TBI sample in Study 5 (i.e., estimating that 45% of the participants may have impaired self-awareness and therefore underestimate post-injury changes in their competency level), few associations between CAVEAT performance and measures of social functioning might be expected. Despite this, the study did find such relationships with apathy and number of friends. It may be the case, however, that inclusions of some participants with impaired insight weakened all correlations to the extent that no association could be detected with other measures of social functioning such as interpersonal relationships and disinhibition. Obtaining proxy reports would certainly have been useful to corroborate the self-report and potentially reveal other associations. This was demonstrated by a recent study, which did not find a significant correlation between FEEST (Young, Perret, Calder, Sprengelmeyer, & Ekman, 2002) scores and self-ratings on a questionnaire that measures behavioural problems, but did find that impaired emotion recognition in the patients was correlated with behavioral problems as rated by proxies (Spikman et al., 2013). This strengthens the importance of obtaining a family rating in assessing behavioral functioning post TBI, and this would be explored with future research with CAVEAT.

Overall, the present findings suggest that CAVEAT demonstrates some ecological validity, however, the extent to which it predict varied domains of everyday functioning is to be explored in future research, preferably with assessment incorporating family ratings.

The role of neuropsychological functioning in emotion recognition in TBI

An additional aim of this thesis was to re-visit the role of neuropsychological functioning in emotion recognition in TBI. While it is well established that emotion recognition can be impaired on its own right, independent of other cognitive abilities (e.g., Spikman et al., 2012), it remains to be examined whether or not cognitive ability has a role in perception of more complex emotions when these are dynamic and multi-modal, changing over time and inclusive of a wider range of cues. In light of the dynamic nature of the stimuli used in this thesis (in both ERT and the CAVEAT), alongside the multi-modal nature of the cues, the inclusion of complex emotions and the availability of a large number of distractors when responding (in the CAVEAT), it was speculated that ERT and CAVEAT performance would be more dependent on neuropsychological abilities than performance on conventional measures.

The findings partially supported this hypothesis. While ERT performance was associated with processing speed and non-verbal processing, injury severity, as measured by PTA, was the only predictor of the ERT performance. The CAVEAT yielded a somewhat similar pattern with some differences. Specifically, processing speed, non-verbal processing and working memory were all associated with CAVEAT performance. Further, findings revealed that both non-verbal reasoning and injury severity were unique predictors of CAVEAT performance. This indicated that non-verbal reasoning was a unique predictor of CAVEAT performance, over and above

PTA. The increased role of non-verbal processing in predicting emotion recognition as measured by CAVEAT, but not ERT, is consistent with the claim that neuropsychological functioning might have a larger role in recognition of multimodal, naturalistic, and dynamic displays of emotion, such as the TASIT (McDonald et al., 2003a). For example, TASIT (McDonald et al., 2002), which the CAVEAT was modelled on, was shown to be associated with a number of cognitive functions, such as information processing speed, working memory, new learning and executive functioning (McDonald et al., 2006). Thus, the inclusion of a larger array of emotions than those included in conventional measures, and a larger number of emotions to choose from might have increased the role of non-verbal reasoning.

The importance of injury severity, as demonstrated by studies using ERT and CAVEAT, which both found that PTA is an important predictor of emotion recognition, is consistent with the findings by (Spikman et al., 2012), emphasising the notion of dose-response relationship in TBI (Temkin et al., 2009). While the present findings indicate that emotion recognition difficulties increase with increased injury severity, it is not clear what this dose-response relationship actually reflects in TBI. Specifically, it is not clear whether greater injury severity is indicative of a greater number of networks being damaged, or a greater damage to specific networks, or both. This demonstrates the challenge in considering brain-behaviour relationships in TBI, which is examined below.

What do these findings tell us regarding brain-behaviour relationships in emotion recognition?

The evidence from the present studies does not support the view that emotion perception represents a set of specialised cognitive systems for different emotions, or at least in the case in TBI. A general limitation with TBI research is that the neuropathology is variable in severity, location and extent across individuals, all factors that make it difficult to draw conclusions about brain-behaviour relationships. Research based on participants with focal lesions points to specific structures underpinning emotion perception including the ventromedial prefrontal regions and the amygdala. Given that these are the same regions that are vulnerable to brain injury (Bigler, 2007; Fujiwara, Schwartz, Gao, Black, & Levine, 2008), it can be inferred that such pathologies are prevalent in the TBI group.

However, the results of this thesis call into question the veracity of such research, when the stimuli used are not equated for difficulty. As clearly demonstrated by Studies 1, 2, 3 and 5, different emotions can appear differentially difficult due to floor and ceiling effects. This, as well as the other limitations (such as unequal number of positive and negative emotions, use of posed stimuli, etc.), substantially confound the conclusions which can be drawn regarding specific impairments in recognition of some emotions compared to others. Moreover, it greatly impairs conclusions on how performance on the recognition measures translates to potential damage of specific neural substrates. This difficulty is observed in both studies using individuals with brain pathology and neuroimaging studies of clinical populations and healthy controls.

For example, it seems that a general difficulty with studies that support the right hemisphere hypothesis in the perception and recognition of emotions (e.g., Adolphs et al., 2000; Adolphs, Damasio, Tranel, & Damasio, 1996; Borod et al., 1998), as well as studies that support the valence hypothesis (e.g., Borod, Koff, Lorch, & Nicholas, 1986; Mandal et al., 1999; Schmitt, Hartje, & Willmes, 1997) is that they commonly used static photographs of facial expression, such as the Pictures of Facial Affect (Ekman &

Friesen, 1976) to assess emotion recognition. Some studies used them in conjunction with other modes of assessment (e.g., Adolphs et al., 2000; Borod et al., 1986; Mandal et al., 1999) while others solely rely on these measures to ascertain individuals emotion recognition (eg., Adolphs et al., 1996). For example, Adolphs and colleagues (1996) used the photographs of facial affect (Ekman, 1976) to investigate the involvement of cortical systems in emotion recognition of 37 people with focal lesions. The authors concluded that all participants recognised the facial expression of happiness normally, but some people were more impaired in recognising negative emotions, especially fear and sadness. The findings were taken as evidence for a neural system important for processing facial expressions of some emotions involving discrete somatosensory and visual cortical sectors in the right hemisphere.

A similar issue is observed in neuroimaging research. A comprehensive meta-analysis of the functional neuroanatomy of emotions by Murphy and colleagues (Murphy, Nimmo-Smith, & Lawrence, 2003) examined 106 PET and fMRI studies of human emotion, and the findings revealed some evidence to suggest asymmetry for approach and avoidance emotions, and specifically for fear, anger, and disgust, which were significantly different from each other and from happiness and sadness. However, while the meta-analysis included studies using mixed measures of emotion, such as emotion induction, pain anticipation, viewing emotional pictures, the included studies which investigated *emotion recognition*, largely used the conventional emotion recognition measures (static photographs of facial expressions). This emphasises the need for increased awareness for the challenges faced in emotion recognition research due to differential task difficulty of the different emotions included in these measures.

The work of this thesis supports the conclusions of Rapcsak et al. (2000), who, in their systematic investigation of people with focal lesions, stressed that only with testing materials equated carefully on difficulty, would it be possible to adequately address emotion-specific recognition impairment. Without equating difficulty it is not possible to establish whether there are specialised neural systems that underpin the recognition of some emotional categories (such as fear or disgust) or dimensions (such as positive vs. negative or approach vs. avoidance). In addition, it emphasises the importance of converging evidence from studies using neuroimaging, EEG, and behavioural investigations, in both healthy individuals and clinical populations, and using stimuli which allow for an adequate assessment of emotion recognition.

It is possible that TBI is so multi-focal and diffuse that it damages numerous neural systems, which might explain why (when emotions are equated on difficulty), there is no evidence for specific impairments of particular emotions or particular dimensions. However, since task difficulty of the different emotions has not largely been controlled for in emotion research, at this point, it does not seem possible to confidently make any conclusion regarding specialised systems which underlie facial emotion recognition.

Clinical Implications

In addition to shedding more light on the nature of emotion recognition difficulties following TBI, these findings have important implications for psychoeducation and remediation. While more research is necessary to establish the ingredients of efficacious remediation techniques for emotion recognition in TBI, some research reporting positive outcome of such remediation programs in TBI and other clinical populations (eg., Bornhofen & McDonald, 2008a, 2008c; Dawn Radice-

Neumann, Zupan, Tomita, & Wilier, 2009) suggests that such treatment can be efficacious, with beneficial effects on psychosocial functioning. However, it is unclear to what extent the treatment gains are maintained long term or generalise to everyday life (McDonald et al., 2013). In addition, a confound of some rehabilitation programs is that they only focus on recognition of photographs of facial expression or prosody only, while in real life emotion includes all of the above, alongside body expression and gestures (Bornhofen & McDonald, 2010). The CAVEAT has potential here as it provides a more realistic range of stimuli to represent a wide range of emotions. It may, therefore, be useful not simply for assessment but also training to increase real life demands and subsequently have a larger effect on increasing function.

Moreover, the present findings demonstrate that people with moderate-severe TBI have difficulties in recognising emotions expressed by others. This was present both in posed, unimodal, and dynamic displays of the face only (ERT) and in dynamic, naturalistic and multimodal expressions of a wide range of emotions (CAVEAT). Moreover, consistent with the dose-response notion (Temkin et al., 2009), people who sustained more severe injuries were shown to have greater deficit in emotion recognition than people with less severe injuries.

Since people with TBI were found to be poorer than controls in their general ability to recognise emotions, treatment needs to focus on strategies to improve overall emotion perception, potentially by increasing awareness to the general characteristics of emotion expression, such as the eyes, tone of voice, and body language. In the development of the CAVEAT it was found that dividing the positive and negative emotions into separate lists based on valence reduced the cognitive demands of the task and made it easier to make a selection. This has interesting clinical implications. In treatment, patients might fruitfully be instructed to build awareness to the pleasantness/unpleasant dimension when identifying emotions in others, prior to considering what emotion they might be feeling. The relative accuracy that people with TBI demonstrated in sorting emotions into one or other of the pleasantness versus unpleasantness dimension is consistent with the notion that valence is important, coding as it does for the most salient quality of a stimulus, which is important for evolutionary survival. Thus, even if the person cannot understand how another person is feeling, comprehending the valence of the emotion might provide some preliminary information that will help to guide an appropriate response in the social situation.

In addition, findings suggest that carers might benefit from instruction to act as coaches in emotional situations by using reflective listening, verbal instruction and modelling, to help the person with TBI to make sense of the emotional situation rather than expecting them to simply be able to ‘understand’ why others are upset or angry. This might reduce anger and frustration and increase pro-social functioning and societal reintegration.

Limitations and Future Directions

While substantially increasing the understanding of the emotion recognition difficulties experienced by people with TBI, these studies are not without limitations. One limitation, which is generally found in the field of TBI, is that neuropathology is variable in severity, location and extent across individuals, which makes it difficult to draw conclusions about brain-behaviour relationships. The focal neurological literature points to specific structures underpinning emotion perception including the ventromedial prefrontal regions and the amygdala. Given these are the same regions that are vulnerable to brain injury (Adams et al., 1985; Bigler, 2007; Fujiwara et al., 2008;

Levin et al., 1987), it was inferred that there will be prevalence of such pathology in the TBI groups that took part in these studies. However, as discussed above, whether the impairments revealed in this study reflect such deficits or arise from more widespread and complex neuropathology that typically occurs is yet to be determined. A potential avenue for future research may involve using MRI to localize the lesions of people with TBI in order to link damage in particular structures to deficits in emotion recognition.

In addition, the present studies focused on emotion recognition in general, and did not examine separate modalities of emotion recognition such as face only, prosody only, or body only. While this is an important research question, in light of research reporting dissociate brain pathways processing dynamic versus static and face versus prosody (Adolphs et al., 2002), separating the different response modes is a direction for future research with the CAVEAT. In the present investigation all the cues were used together to mirror as closely as possible how emotion is expressed and perceived in real life, i.e., in a multimodal format.

Additionally, the present research used a circumscribed set of neuropsychological tests to determine whether other cognitive functions might explain poor emotion perception. Although all such tests did discriminate between people with TBI and the control group, and while all were selected as common, sensitive measures of the relevant construct, it remains possible that other non-social cognitive processes, not measured here, could account for the emotion deficits. Finally, since participant's age and gender are known to be related to emotion recognition ability in adults (e.g., Palermo & Coltheart, 2004), these variables could have influenced these results. To minimise this effects, the control and TBI groups were closely matched on these variables.

Further limitation concerns the length of the CAVEAT. The final version of the CAVEAT, which was the product of intensive pilot testing in studies 3A-3C, and subsequently used in Study 4 and 5 takes approx. 45 min to complete for a healthy controls and approx. 50-60 min for people with TBI. While this length was necessary for the present thesis in order to provide an adequate examination of the study hypotheses, a shorter version would be beneficial for use in clinical settings. This could be obtained by removing a few of the emotions included in the measure, or reducing the number of items per emotion from four to two. One means by which this could be achieved is using Rasch analysis which would enable the most reliable and consistent stimuli for the short version of the CAVEAT to be obtained. This awaits future research.

An additional direction for future research is to obtain larger norms for the CAVEAT, for healthy controls of different age groups, such as those recently obtained for the ERT (Kessels et al., 2013), and to apply the short version of the CAVEAT to additional clinical populations with emotion recognition difficulties such as Alzheimer's disease (Kohler et al., 2005), schizophrenia (Mandal et al., 1998), stroke (Braun et al., 2005), and frontotemporal dementia (Fernandez-Duque & Black, 2005). In addition, examining the relationship between CAVEAT and ERT might be another direction for future research. The data were combined for a subset of TBI (n=15) and control (n=8) participants from studies 1-5 who completed both CAVEAT and ERT, and analysis revealed a high positive correlation ($r=.68$, $p<.0001$) between the two measures. However, to fully assess the relationship between CAVEAT and ERT, studies on larger samples are necessary.

Another limitation, as discussed above, relates to the lack of proxy data in assessing real life psychosocial functioning. Given the question of variable insight often experienced by people with TBI participants, the use of self-report data is a potential limitation. As discussed above, while these findings are solely based on self-report data, which raises the possibility that some people might be under-reporting their difficulties (Prigatano, 1986; Prigatano et al., 1990; Stuss, 1991), other evidence suggests that people with head injury are able to reliably complete self-report scales as indicated by the 'close others' similar reports (Kinsella et al., 1988), supporting the ability of people with TBI to have some insight into their difficulties. Future research needs to include proxy ratings to fully ascertain the ecological validity of CAVEAT and other measures of social cognition (Spikman et al., 2013).

Concluding Remarks

The series of studies presented in this thesis, considerably expand on the existing literature pertaining to emotion recognition difficulties in people with moderate-severe TBI. Studies 1 and 2 replicated the valence effect, commonly reported in TBI, with ERT, a task which allows examining emotion recognition across intensity, and demonstrated that this effect dissipates once differential item difficulty is taken into account. This was further supported by the later studies using CAVEAT, which also demonstrated that people with moderate-severe TBI are impaired in their ability to recognise emotions, compared to matched controls, with no difference between specific emotion categories such as basic, complex, social, non-social, or positive versus negative. In fact, across all studies in which between-group performance was compared, people with TBI were finding the same emotions more difficult as did the controls. However, importantly, examining the CAVEAT confusability data (i.e., error matrices) revealed that people with TBI tended to select emotions more widely, almost guessing, rather than following a more limited response selection as the controls. Thus, taken together, the findings suggest that the differential impairment in the recognition of some emotions compared to others, such as negative versus positive emotions, which is often reported in the literature, might be an artefact of the use of a limited set of six emotions and static, 100% full blown expressions, rather than representing a real neurological phenomenon.

In addition, these studies demonstrated that, as expected, there was an association between neuropsychological measures and emotion recognition, and also that emotion recognition can be impaired independent of these abilities, which is all the more reason to make sure it is assessed as part of a neuropsychological examination.

These findings also demonstrated that CAVEAT directly maps into a few aspects of everyday and psychosocial functioning such as self-reported apathy and number of friends. Overall, the findings have important implications for understanding the link between brain injury, cognitive processes and behaviour. Crucially, they indicate that TBI does produce specific deficits in emotion recognition that affects all emotion types and that are not readily accounted for by impairments in other cognitive processes such a processing speed and working memory. This evidence adds to a now rapidly accruing literature that details emotion perception deficits as a common consequence of a range of neurological conditions and TBI in particular and urges for caution in interpreting specific impairments based on performance on emotion recognition measures without taking into account the potential confounds of these measures.

Finally, the present thesis outlined the development and pilot testing of the CAVEAT, a new measure of emotion recognition which was designed to address the limitations of conventional measures. It did this by incorporating an equal number of positive and negative emotions, using items with similar levels of task difficulty and representing surprise as both positive and negative in valence. It also incorporated multi-modal cues, represented genuine (not posed) displays of emotion, and included a larger number of emotions (including more complex emotions that vary across different dimensions), mirroring the wider range of emotions as experienced in everyday life. As demonstrated by Study 4, CAVEAT has some evidence for construct validity and reliability, and as revealed by Study 5, also has some ecological validity, which is especially important given the recognised need of social cognition measures to map into real life functioning.

The hope is that with future research, the CAVEAT might become a useful tool for an assessment and remediation of emotion recognition in TBI and other clinical populations, an important target for the scientific community, the individuals suffering from social cognition difficulties, and their families.

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Appendices

Appendix 1. Study 3A

Table A1.

Error matrix of the incorrect labels given to each emotion in study 3A

	Incorrect Label								
Emotion	1st	2nd	3rd	4th	5th	6th	7th	8th	other
Relieved	75% - Positively surprised	25% - Satisfaction							
Fearful/anxious	80% - Worried	20% - Negatively surprised							
Flirtatious	90% - Cheeky/playful	10% - Arrogant/cocky							
Disinterested	47% - Bored	20% - Neutral	13% - Sad	13% - Contempt	7% - Worried				
Angry	41% - Contempt	35% - Annoyed	12% - Arrogant/cocky	6% - Disgusted	6% - Contented				
Negatively surprised	69% - Baffled/unsure	13% - Annoyed	6% - Angry	6% - Neutral	6% - Embarrassment				
Amused	61% - Happy	11% - Cheeky/playful	11% - Positively surprised	6% - Caring	6% - Embarrassment	6% - Guilt			
Caring	27% - Positively surprised	18% - Flirtatious	14% - Hopeful	9% - Contented	9% - Touched	9% - Happy	9% - Interested	5% - Confident	
Neutral	71% - Disinterested	14% - Bored	7% - Caring	7% - Interested					
Baffled/unsure	25% - Embarrassment	20% - Worried	15% - Neutral	15% - Suspicious	10% - Fearful/anxious	5% - Shy	5% - Guilt	5% - Amused	
Suspicious	26% - Annoyed	21% - Negatively surprised	21% - Baffled/unsure	11% - Interested	11% - Disgusted	5% - Contempt	5% - Fearful/anxious		
Annoyed	50% - Contempt	36% - Angry	14% - Arrogant/cocky						
Bored	100% - Disinterested								
Positively surprised	57% - Excited	19% - Happy	14% - Touched	10% - Amused					

Table A.1 *(Continued)*

	Incorrect Label								
Emotion	1st	2nd	3rd	4th	5th	6th	7th	8th	other
Disgusted	26% - Annoyed	17% - Contempt	13% - Negatively surprised	13% - Fearful/anxious	9% - Worried	4% - Sad	4% - Neutral	4% - Baffled/unsure	8% other
Sad	32% - Worried	23% - Annoyed	14% - Shame	14% - Embarrassment	5% - Baffled/unsure	5% - Caring	5% - Fearful/anxious	5% - Guilt	
Shy	32% - Fearful/anxious	23% - Embarrassment	10% - Guilt	10% - Baffled/unsure	10% - Worried	6% - Hopeful	3% - Flirtatious	3% - Shame	3% - Cheeky/playful
Happy	24% - Proud	21% - Excited	17% - Amused	14% - Contented	7% - Satisfaction	7% - Interested	3% - Touched	3% - Positively surprised	3% - Enjoyment
Confident	32% - Neutral	14% - Arrogant/cocky	14% - Satisfaction	11% - Contented	11% - Hopeful	7% - Amused	4% - Excited	4% - Interested	4% - Annoyed
Contempt	56% - Annoyed	22% - Angry	11% - Disgusted	4% - Suspicious	4% - Arrogant/cocky	4% - Baffled/unsure			
Enjoyment	48% - Satisfaction	29% - Contented	10% - Touched	10% - Happy	3% - Proud				
Worried	34% - Sad	31% - Fearful/anxious	6% - Caring	6% - Guilt	6% - Baffled/unsure	6% - Shy	3% - Shame	3% - Hopeful	6% other
Excited	47% - Positively surprised	18% - Happy	12% - Hopeful	6% - Cheeky/playful	6% - Confident	6% - Interested	3% - Amused	3% - Proud	
Hopeful	24% - Interested	21% - Excited	15% - Positively surprised	12% - Happy	9% - Flirtatious	6% - Confident	6% - Fearful/anxious	3% - Baffled/unsure	6% other
Arrogant/cocky	31% - Annoyed	28% - Contempt	19% - Disinterested	6% - Confident	3% - Amused	3% - Contented	3% - Suspicious	3% - Neutral	3% - Satisfaction
Cheeky/playful	37% - Amused	34% - Arrogant/cocky	14% - Flirtatious	3% - Positively surprised	3% - Interested	3% - Satisfaction	3% - Excited	3% - Happy	
Proud	22% - Satisfaction	16% - Confident	16% - Arrogant/cocky	8% - Contented	8% - Relieved	8% - Hopeful	5% - Cheeky/playful	5% - Enjoyment	12% other
Satisfaction	28% - Happy	19% - Contented	19% - Confident	11% - Proud	6% - Cheeky/playful	6% - Relieved	3% - Neutral	3% - Arrogant/cocky	6% other
Interested	44% - Baffled/unsure	27% - Positively surprised	12% - Neutral	7% - Suspicious	5% - Negatively surprised	2% - Touched	2% - Amused		
Contented	20% - Satisfaction	20% - Proud	20% - Confident	14% - Hopeful	7% - Excited	7% - Happy	5% - Caring	5% - Positively surprised	2% - Touched
Guilt	33% - Worried	21% - Sad	16% - Shame	12% - Embarrassment	9% - Baffled/unsure	5% - Fearful/anxious	2% - Shy	2% - Annoyed	
Embarrassment	20% - Baffled/unsure	18% - Worried	9% - Negatively surprised	9% - Guilt	7% - Fearful/anxious	7% - Positively surprised	7% - Shame	4% - Excited	18% other

Table A.1 *(Continued)*

	Incorrect Label								
Emotion	1st	2nd	3rd	4th	5th	6th	7th	8th	other
Touched	45% - Caring	10% - Hopeful	7% - Relieved	7% - Proud	5% - Happy	5% - Interested	5% - Satisfaction	2% - Neutral	12% other
Shame	22% - Worried	18% - Sad	16% - Embarrassment	12% - Shy	10% - Guilt	6% - Fearful/anxious	4% - Disgusted	4% - Baffled/unsure	6% other

Appendix 2. Study 3C

Table A.2

Error matrix of the incorrect labels given to each emotion in study 3C, control group (top panel) and TBI group (bottom panel)

	CONTROL GROUP								
	Incorrect Label								
Emotion	1st	2nd	3rd	4th	5th	6th	7th	8th	other
Fearful/anxious	100% - Baffled/unsure								
Flirtatious	50% - Confident	50% - Interested							
Relieved	50% - Positively surprised	25% - Interested	25% - Proud						
Disinterested/Bored	43% - Contempt	29% - Suspicious	14% - Baffled/unsure	14% - Negatively surprised					
Caring	38% - Positively surprised	38% - Confident	13% - Happy	13% - Flirtatious					
Amused	33% - Positively surprised	33% - Happy	22% - Confident	11% - Enjoyment					
Angry	44% - Annoyed	33% - Contempt	11% - Disgusted	11% - Negatively surprised					
Suspicious	30% - Baffled/unsure	30% - Disgusted	20% - Annoyed	10% - Contempt	10% - Negatively surprised				
Annoyed	36% - Angry	36% - Contempt	18% - Disgusted	9% - Baffled/unsure					
Enjoyment	58% - Happy	33% - Relieved	8% - Positively surprised						
Disgusted	50% - Baffled/unsure	25% - Negatively surprised	25% - Annoyed						
Interested	83% - Positively surprised	8% - Happy	8% - Relieved						
Proud	25% - Positively surprised	25% - Confident	17% - Relieved	17% - Interested	17% - Happy				
Positively surprised	62% - Excited	15% - Interested	15% - Happy	8% - Relieved					
Sad	38% - Annoyed	31% - Baffled/unsure	23% - Negatively surprised	8% - Fearful/anxious					
Shy	31% - Suspicious	23% - Negatively surprised	23% - Fearful/anxious	15% - Baffled/unsure	8% - Annoyed				
Excited	23% - Positively surprised	23% - Confident	23% - Happy	15% - Enjoyment	8% - Proud	8% - Interested			
Negatively surprised	36% - Baffled/unsure	21% - Suspicious	14% - Annoyed	7% - Disgusted	7% - Contempt	7% - Fearful/anxious	7% - Sad		

Table A.2 *(Continued)*

	CONTROL GROUP								
	Incorrect Label								
Emotion	1st	2nd	3rd	4th	5th	6th	7th	8th	other
Confident	21% - Interested	21% - Positively surprised	14% - Proud	14% - Relieved	7% - Flirtatious	7% - Happy	7% - Excited	7% - Annoyed	
Baffled/unsure	33% - Fearful/anxious	20% - Shy	13% - Negatively surprised	13% - Disinterested/Bored	7% - Contempt	7% - Disgusted	7% - Annoyed		
Happy	31% - Proud	25% - Relieved	19% - Excited	13% - Confident	6% - Interested	6% - Amused			
Contempt	56% - Annoyed	19% - Disgusted	13% - Angry	6% - Suspicious	6% - Negatively surprised				
Fearful/anxious	100% - Baffled/unsure								
Flirtatious	50% - Confident	50% - Interested							
Relieved	50% - Positively surprised	25% - Interested	25% - Proud						
Disinterested/Bored	43% - Contempt	29% - Suspicious	14% - Baffled/unsure	14% - Negatively surprised					
Caring	38% - Positively surprised	38% - Confident	13% - Happy	13% - Flirtatious					
Amused	33% - Positively surprised	33% - Happy	22% - Confident	11% - Enjoyment					
Angry	44% - Annoyed	33% - Contempt	11% - Disgusted	11% - Negatively surprised					
Suspicious	30% - Baffled/unsure	30% - Disgusted	20% - Annoyed	10% - Contempt	10% - Negatively surprised				
Annoyed	36% - Angry	36% - Contempt	18% - Disgusted	9% - Baffled/unsure					
Enjoyment	58% - Happy	33% - Relieved	8% - Positively surprised						
Disgusted	50% - Baffled/unsure	25% - Negatively surprised	25% - Annoyed						
Interested	83% - Positively surprised	8% - Happy	8% - Relieved						

Table A.2 *(Continued)*

				TBI GROUP					
				Incorrect Label					
Emotion	1st	2nd	3rd	4th	5th	6th	7th	8th	other
Fearful/anxious	25% - Baffled/unsure	25% - Sad	25% - Negatively surprised	13% - Suspicious	13% - Disgusted				
Flirtatious	38% - Interested	25% - Excited	13% - Confident	13% - Amused	13% - Happy				
Relieved	80% - Positively surprised	20% - Interested							
Disinterested/Bored	43% - Annoyed	29% - Negatively surprised	14% - Baffled/unsure	14% - Suspicious					
Caring	20% - Flirtatious	20% - Confident	15% - Positively surprised	15% - Interested	10% - Happy	10% - Relieved	5% - Excited	5% - Enjoyment	
Amused	69% - Happy	8% - Flirtatious	8% - Excited	8% - Positively surprised	8% - Enjoyment				
Angry	60% - Annoyed	13% - Disgusted	7% - Suspicious	7% - Fearful/anxious	7% - Contempt	7% - Baffled/unsure			
Suspicious	33% - Baffled/unsure	20% - Annoyed	20% - Fearful/anxious	13% - Negatively surprised	7% - Confident	7% - Disgusted			
Annoyed	63% - Negatively surprised	25% - Angry	13% - Disgusted						
Enjoyment	33% - Relieved	13% - Excited	13% - Confident	13% - Happy	13% - Amused	7% - Positively surprised	7% - Proud		
Disgusted	27% - Baffled/unsure	27% - Negatively surprised	18% - Annoyed	9% - Sad	9% - Contempt	9% - Fearful/anxious			
Interested	53% - Positively surprised	13% - Amused	13% - Relieved	13% - Happy	7% - Caring				
Proud	31% - Confident	13% - Excited	13% - Positively surprised	13% - Amused	13% - Interested	6% - Happy	6% - Relieved	6% - Enjoyment	
Positively surprised	53% - Excited	13% - Happy	13% - Relieved	7% - Proud	7% - Enjoyment	7% - Interested			
Sad	29% - Annoyed	18% - Disinterested/Bored	18% - Fearful/anxious	12% - Baffled/unsure	12% - Shy	6% - Suspicious	6% - Contempt		
Shy	52% - Baffled/unsure	24% - Fearful/anxious	10% - Suspicious	10% - Negatively surprised	5% - Annoyed				
Excited	56% - Positively surprised	19% - Relieved	13% - Happy	6% - Interested	6% - Confident				
Negatively surprised	36% - Baffled/unsure	36% - Suspicious	18% - Annoyed	9% - Fearful/anxious					
Confident	35% - Interested	24% - Positively surprised	12% - Relieved	12% - Caring	6% - Happy	6% - Amused	6% - Proud		
Baffled/unsure	21% - Suspicious	21% - Disinterested/Bored	21% - Negatively surprised	7% - Interested	7% - Annoyed	7% - Relieved	7% - Fearful/anxious	7% - Shy	
Happy	21% - Interested	21% - Excited	21% - Positively surprised	11% - Confident	11% - Enjoyment	5% - Relieved	5% - Amused	5% - Proud	

Table A.2 *(Continued)*

	TBI GROUP								
	Incorrect Label								
Emotion	1st	2nd	3rd	4th	5th	6th	7th	8th	other
Contempt	45% - Annoyed	18% - Disgusted	14% - Disinterested/Bored	9% - Angry	9% - Negatively surprised	5% - Fearful/anxious			
Fearful/anxious	25% - Baffled/unsure	25% - Sad	25% - Negatively surprised	13% - Suspicious	13% - Disgusted				
Flirtatious	38% - Interested	25% - Excited	13% - Confident	13% - Amused	13% - Happy				
Relieved	80% - Positively surprised	20% - Interested							
Disinterested/Bored	43% - Annoyed	29% - Negatively surprised	14% - Baffled/unsure	14% - Suspicious					
Caring	20% - Flirtatious	20% - Confident	15% - Positively surprised	15% - Interested	10% - Happy	10% - Relieved	5% - Excited	5% - Enjoyment	
Amused	69% - Happy	8% - Flirtatious	8% - Excited	8% - Positively surprised	8% - Enjoyment				
Angry	60% - Annoyed	13% - Disgusted	7% - Suspicious	7% - Fearful/anxious	7% - Contempt	7% - Baffled/unsure			
Suspicious	33% - Baffled/unsure	20% - Annoyed	20% - Fearful/anxious	13% - Negatively surprised	7% - Confident	7% - Disgusted			
Annoyed	63% - Negatively surprised	25% - Angry	13% - Disgusted						
Enjoyment	33% - Relieved	13% - Excited	13% - Confident	13% - Happy	13% - Amused	7% - Positively surprised	7% - Proud		
Disgusted	27% - Baffled/unsure	27% - Negatively surprised	18% - Annoyed	9% - Sad	9% - Contempt	9% - Fearful/anxious			
Interested	53% - Positively surprised	13% - Amused	13% - Relieved	13% - Happy	7% - Caring				