SOCIAL INFORMATION PROCESSING AFTER MILD TRAUMATIC BRAIN INJURY

BY

JIA YAN ZHANG

A THESIS SUBMITTED IN CONFORMITY WITH THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE

INSTITUTE OF MEDICAL SCIENCE
UNIVERSITY OF TORONTO

© COPYRIGHT BY JIA YAN ZHANG 2017
Social Information Processing after Mild Traumatic Brain Injury

Jia Yan Zhang

Master of Science, 2017

Institute of Medical Science, University of Toronto

ABSTRACT

Deficits in social information processing, including emotion perception, theory of mind, and social behavioral control, have been shown in individuals with moderate to severe Traumatic Brain Injury (TBI). However, little is known about social information processing after mild TBI. The current study aims to address this knowledge gap. 47 mild TBI subjects and 30 healthy controls (HC) were tested in three social information processing domains: social perception, social cognition, and social regulation. Non-social cognition was also assessed. Mild TBI subjects performed significantly worse than HC in executive function ($p = 0.039$), but not in any of the social information processing domains. However, those with mild global non-social cognitive impairment also performed poorer in social cognition domain ($p = 0.028$). The current results contrast with findings from moderate to severe TBI patients, and suggest that deficits in social information processing in mild TBI may arise secondary to non-social cognitive impairment.
ACKNOWLEDGEMENTS

This project would not have been successful without the help and support of many individuals.
First and foremost, my sincerest gratitude goes to Dr. Anthony Feinstein, for his tremendous
supervision, guidance, and support throughout the project. His immense knowledge in
neuropsychology, expertise in research, and excellence in writing have taught me valuable
research, analytical, and writing skills that will forever benefit me in my future endeavours. As a
mentor, he modeled remarkable leadership qualities and wisdom that continuously enlightened
me. His superb sense of humour was a delight on many occasions and has made this journey a
very pleasant one. I am extremely grateful for the many hours you dedicated to carefully
reviewing and editing my writing and analysis.

I would like to extend my gratitude to Dr. Brian Levine for his assistance and guidance
throughout this project. As an expert in the TBI field, your vast knowledge and expertise have
contributed enormously to the overall improvement and success of the project. I would also
like to thank Dr. Neil Rector for his insightful suggestions and help with statistical analysis
method. As an accomplished researcher, your inputs were imperative to the completion of this
project. My gratitude also goes to Dr. Angelica Staniloiu, who helped proposing the many ideas
that first generated this project. Your extensive knowledge in the social neuroscience field and
rigorous research conduct had helped shaping this project to be well-built. It was my honour
and pleasure to have Dr. Levine, Dr. Rector, and Dr. Staniloiu as secondary supervisors. Your
thought-provoking questions on many occasions further drove me to be a better critical thinker
and a better researcher.
I wish to thank the many researchers who kindly provided me the tests used in this project. Dr. Jim Grigsby, thank you for the Behavioral Dyscontrol Scale and for mailing the video demonstration of test administration. I thank Dr. Shamay-Tsoory and Dr. Maren Bodden for kindly sharing the Yoni Task. I also thank Dr. Matthias Brand for kindly sharing the Game of Dice Task. Finally, I thank Dr. Michael Koenigs for providing the Ultimatum Game and for explaining the test administration. I truly appreciate all of your kindness in sharing the research tools that not only benefited my project, but also the overall scientific advancement.

My sincere thanks goes to Elke McLellan for her assistance in screening and recruiting subjects. Thank you for patiently organizing daily patient lists and identifying potential subjects suitable for recruitment for me. I am also grateful for Colleen Barry, for her continuous support with office administrative tasks and her encouragement throughout this project.

I would like to thank my fellow research team members for their encouragement and support. Many thanks to Viral Patel, Bennis Pavisian, Cecilia Meza, and Jonas Osmann for their help and positive energy starting from my very first day, and for making the work environment an enjoyable one. I greatly cherished your presence, sense of humour, and team spirit.

The completion of this project would not have been possible without all of the participants. I am grateful to all of them for generously volunteering their time and contributing their efforts to help advancing TBI research.

I would like to thank my family and friends for their unwavering support and encouragement. I owe my deepest gratitude to my parents, who unceasingly supported me in my endeavours. I would not be who I am without your love, patience, and guidance. I would also like to thank my
HWC family, both near and far, for their support, advice, and encouragement in my life journey.

A big thank-you to all of my friends as well for their constant encouragement and help.

Finally, *Soli Deo Gloria.*
CONTRIBUTIONS

Anthony Feinstein – Principle investigator and supervisor on the project; assisted in designing and conducting the study, statistical analysis, and editing of the thesis

Angelica Staniloiu – Co-investigator on the project; assisted in study design and subject recruitment

Brian Levine – Program Advisory Committee member; guided the project to completion, assisted in statistical analysis and editing of the thesis

Neil Rector – Program Advisory Committee member; guided the project to completion, assisted in statistical analysis and editing of the thesis
TABLE OF CONTENTS

LIST OF TABLES..................................................................................................................X
LIST OF ABBREVIATIONS......................................................................................................XI

CHAPTER 1. INTRODUCTION.................................................................................................1
1.1 TRAUMATIC BRAIN INJURY ......................................................................................... 1
  1.1.1 SEVERITY .................................................................................................................. 2
  1.1.2 EPIDEMIOLOGY ......................................................................................................... 3
  1.1.3 OUTCOME .................................................................................................................. 3
1.2 SOCIAL INFORMATION PROCESSING AND THE SOCIAL BRAIN ..................................... 5
  1.2.1 SOCIAL INFORMATION PROCESSING ..................................................................... 5
  1.2.2 THE SOCIAL BRAIN .................................................................................................. 6
1.3 SOCIAL PERCEPTION IN TBI ......................................................................................... 7
  1.3.1 FACIAL AFFECT ........................................................................................................ 7
  1.3.2 VOCAL PROSODY ..................................................................................................... 9
  1.3.3 SOCIAL PERCEPTION IN CHILDREN AND ADOLESCENTS WITH TBI ..................... 10
  1.3.4 FACTORS AFFECTING SOCIAL PERCEPTION.......................................................... 11
  1.3.5 BRAIN IMAGING CORRELATES OF SOCIAL PERCEPTION DEFICITS FOLLOWING TBI .... 13
1.4 SOCIAL COGNITION IN TBI .......................................................................................... 15
  1.4.1 THEORY OF MIND ..................................................................................................... 15
  1.4.2 PRAGMATICS .......................................................................................................... 19
  1.4.3 EMPATHY ............................................................................................................... 20
1.5 SOCIAL REGULATION IN TBI ....................................................................................... 23
  1.5.1 SOCIAL DISINHIBITION ........................................................................................... 23
  1.5.2 APATHY .................................................................................................................. 27
1.5.3 Social Decision Making .......................................................... 27
1.6 Challenges of the Current Literature ........................................ 30
1.7 Current Study ............................................................................ 33

Chapter 2: Methods ....................................................................... 37

2.1 Sample Selection ...................................................................... 37
  2.1.1 Mild TBI Subjects ................................................................. 37
  2.1.2 Healthy Controls ................................................................. 37
2.2 Subject Recruitment ................................................................. 37
2.3 Ethics ......................................................................................... 38
2.4 Data Collection Measures .......................................................... 38
  2.4.1 Demographic Data ................................................................. 38
  2.4.2 Injury Related Data ............................................................... 39
  2.4.3 Pre-Injury History ................................................................. 39
  2.4.4 Cognitive Assessment .......................................................... 39
  2.4.5 Effort Testing ......................................................................... 55
  2.4.6 Depression and Anxiety ....................................................... 55
2.5 Testing Procedures .................................................................... 56
2.6 Statistical Analysis ................................................................... 57

Chapter 3: Results ....................................................................... 59

3.1 Sample Demographics and Injury Related Data ............................ 59
3.2 Comparison of Non-Social Cognitive and Social Information Processing Data between Mild TBI and HC Subjects ................................. 61
  3.2.1 Non-Social Cognitive Data .................................................... 61
  3.2.2 Social Information Processing Data ...................................... 64
3.2.3 Influence of anxiety and depression on task performances .................. 69

3.3 Comparison of social information processing measures between cognitively impaired and intact mild TBI subjects .............................................................. 74

3.4 Return to work, social information processing, and non-social cognition ........ 79

Chapter 4. Discussion ..............................................................................85

References .............................................................................................98
LIST OF TABLES

TABLE 1: DEMOGRAPHIC AND PSYCHIATRIC DATA BETWEEN MILD TBI AND HC SUBJECTS ..........60
TABLE 2: CORRELATIONS BETWEEN NON-SOCIAL COGNITIVE MEASURES WITHIN THE SAME DOMAIN ..................................................................................................................62
TABLE 3: COMPARISON OF NON-SOCIAL COGNITION BETWEEN MILD TBI AND HC SUBJECTS ........63
TABLE 4: CORRELATIONS BETWEEN SOCIAL INFORMATION PROCESSING MEASURES WITHIN THE SAME DOMAIN ..................................................................................................................65
TABLE 5: COMPARISON OF SOCIAL INFORMATION PROCESSING DATA BETWEEN MILD TBI AND HC SUBJECTS ..................................................................................................................67
TABLE 6: COMPARISON OF NON-SOCIAL COGNITION BETWEEN MILD TBI AND HC SUBJECTS AFTER CONTROLLING FOR ANXIETY AND DEPRESSION CASENESS ..............................................................................71
TABLE 7: COMPARISON OF SOCIAL INFORMATION PROCESSING DATA BETWEEN MILD TBI AND HC SUBJECTS AFTER CONTROLLING FOR ANXIETY AND DEPRESSION CASENESS ..............................................................................72
TABLE 8: DEMOGRAPHIC, INJURY CHARACTERISTICS, NEUROLOGIC, AND PSYCHIATRIC DATA BETWEEN COGNITIVELY IMPAIRED AND INTACT MILD TBI SUBJECTS ..............................................................................76
TABLE 9: COMPARISON OF SOCIAL INFORMATION PROCESSING DATA BETWEEN COGNITIVELY IMPAIRED AND INTACT MILD TBI SUBJECTS AFTER CONTROLLING FOR AGE ..............................................................................77
TABLE 10: DEMOGRAPHIC, INJURY CHARACTERISTICS, NEUROLOGIC, AND PSYCHIATRIC DATA BETWEEN MILD TBI SUBJECTS WHO HAD RETURNED TO WORK AND THOSE WHO HAD NOT ..............81
TABLE 11: COMPARISON OF NON-SOCIAL COGNITION BETWEEN MILD TBI SUBJECTS WHO HAD RETURNED TO WORK AND THOSE WHO HAD NOT ....................................................................................82
TABLE 12: COMPARISON OF SOCIAL INFORMATION PROCESSING DATA BETWEEN MILD TBI SUBJECTS WHO HAD RETURNED TO WORK AND THOSE WHO HAD NOT ....................................................................................83
LIST OF ABBREVIATIONS

ABI: ACQUIRED BRAIN INJURY
ACRM: AMERICAN CONGRESS OF REHABILITATION MEDICINE
AD: AFFECT DISCRIMINATION
AES: APATHY EVALUATION SCALE
BDS: BEHAVIORAL DYSCONTROL SCALE
BEES: BALANCED EMOTIONAL EMPATHY SCALE
BIS: BARRATT IMPULSIVENESS SCALE
BNT: BOSTON NAMING TEST
CAVEAT: COMPLEX AUDIO-VISUAL EMOTION ASSESSMENT TASK
CLTR: CONSISTENT LONG TERM RETRIEVAL
CP: CONCENTRATION PERFORMANCE
CT: COMPUTED TOMOGRAPHY
DAI: DIFFUSE AXONAL INJURY
DANVA2: DIAGNOSTIC ASSESSMENT OF NONVERBAL ACCURACY 2
DS: DIGIT SPAN
DTI: DIFFUSION TENSOR IMAGING
EC: EMPATHIC CONCERN
EET: EMOTION EVALUATION TASK
ERT: EMOTION RECOGNITION TASK
FAB: FLORIDA AFFECT BATTERY
FEIT: FACIAL EMOTION IDENTIFICATION TEST
fMRI: FUNCTIONAL MAGNETIC RESONANCE IMAGING
FrSBEd: Frontal System Behavior Scale
FS: Fantasy Scale
GCS: Glasgow Coma Scale
GDT: Game of Dice Task
HADS: Hospital Anxiety and Depression Scale
HC: Healthy Control
IFOF: Inferior Fronto-Occipital Fasciculus
IGT: Iowa Gambling Task
ILF: Inferior Longitudinal Fasciculus
IRI: Interpersonal Reactivity Index
JLO: Judgment of Line Orientation Test
KDEF: Karolinska Directed Emotional Faces Test
LOC: Loss of Consciousness
LTS: Long Term Storage
MA: Match Affect
MRI: Magnetic Resonance Imaging
NA: Name Affect
PA: Pick Affect
PD: Personal Distress
PLACS: Pathological Laughter and Crying Scale
PLC: Pathological Laughter and Crying
PT: Perspective Taking
PTA: Post-Traumatic Amnesia
RMET: Reading the Mind in the Eyes Test
SDMT: Social Decision Making Task
SIE: Social Inference – Enriched
SIM: Social Inference – Minimal
TAS: Toronto Alexithymia Scale
TASIT: The Awareness of Social Inference Test
TBI: Traumatic Brain Injury
TMT: Trail Making Test
ToM: Theory of Mind
UPPS: Urgency-Premeditation-Perseverance-Sensation seeking Impulsive Scale
VSRT: Verbal Selective Reminding Test
CHAPTER 1. INTRODUCTION

Traumatic Brain Injury (TBI) is one of the most frequent causes of brain damage, with an estimated incidence rate of 150 – 300 people per 100,000 individuals across the globe (World Health Organization, 2006). Survivors of TBI can experience significant physical, emotional, and psychosocial deficits, interfering with employment, leisure activities, and relationships (Dijkers, 2004; Franulic, Carbonell, Pinto, & Sepulveda, 2004; Ponsford, Draper, & Schönberger, 2008; Ponsford & Spitz, 2014). Although TBI research has largely focused on cognitive (intellectual) and mood related impairments, the area of social information processing has been increasingly investigated given its potential contribution to social outcomes. In this introduction of the thesis, the focus falls on social information processing in individuals with TBI. Specifically, the literature review aims to discuss the type of social processing deficits observed post-TBI, the measures used for assessment, their associations with non-social cognition, and the underlying structural changes.

1.1 Traumatic Brain Injury

By definition, TBI is a traumatically induced disruption of the brain function and/or underlying neural structures (Orman, Kraus, Zaloshnja, & Miller, 2011). It is caused by an external physical force (including acceleration/deceleration and blast-related force), which results in the new onset of disturbances in cognitive and neurological functions (Orman et al., 2011). While skull fracture is a possible indicator of TBI, skull fracture in itself is insufficient to establish a diagnosis (Orman et al., 2011).
1.1.1 Severity

TBI typically can be divided into three severity levels: mild, moderate, and severe. Although the criteria for severity differs between different organizations, the most commonly used criteria for mild TBI are those defined by the American Congress of Rehabilitation Medicine (ACRM) (American Congress of Rehabilitation, 1993). Accordingly, the diagnosis of mild TBI is made when a person sustains a mechanically induced physiological disruption of brain function accompanied by any of the following: a loss of consciousness (LOC) of less than 30 minutes; an inability to remember events immediately preceding or following the injury (Post-Traumatic Amnesia or PTA) of less than 24 hours; and the Glasgow Coma Scale (GCS) score of 13 or above (American Congress of Rehabilitation, 1993). The Department of Veterans Affairs and Department of Defense further outlined the criteria for defining moderate and severe TBIs in their guideline (Department of Veteran Affairs, 2009). A moderate TBI is diagnosed when any of the following happens: a LOC of at least 30 minutes but less than 24 hours; a PTA of any duration between 24 hours to a week; and a GCS score of 9 to 12 (Department of Veteran Affairs, 2009). Finally, a diagnosis of severe TBI is made when the patient has a LOC of greater than 24 hours, or a PTA of at least one week, or a GCS score of less than 9 (Department of Veteran Affairs, 2009). In most cases, ACRM-defined mild TBI do not yield evidence of injury-induced structural changes on conventional imaging modalities, such as computed tomography (CT) or conventional magnetic resonance imaging (MRI) (Borczuk, 1995; Haydel et al., 2000). The presence of trauma induced intracerebral pathology as seen on CT or MRI scanning shifts the diagnosis of ACRM-defined mild TBI to what is termed “complicated” mild, where the prognosis is similar to a moderate TBI (Iverson, 2006; Kashluba, Hanks, Casey, & Millis, 2008).
1.1.2 Epidemiology

The incidence and prevalence rates of TBI vary in different geographic locations. The incidence rate of TBI in Europe is reported to be 235 per 100,000 people per year (World Health Organization, 2006). In the United States, it is estimated that approximately 1.7 million U.S. civilians sustain a TBI annually (Coronado et al., 2011). Data across the globe typically show peak incidence rates in children, young adults, and elderly adults (World Health Organization, 2006). On average, males are 2 to 3 times more likely to be injured than females (World Health Organization, 2006). Although the etiology for TBI varies, globally the three main causes are motor vehicle accidents, falls, and violence (World Health Organization, 2006). Finally, mild TBIs are estimated to constitute more than 80% of all TBIs, with some studies estimating that moderate to severe TBIs represent less than 10% of the TBI population (World Health Organization, 2006).

1.1.3 Outcome

TBI can impact cognition negatively even at the mild end of the severity spectrum. Impairments in attention, memory, information processing speed, and executive function are common cognitive consequences post-injury (McCullagh & Feinstein, 2011). TBI can further cause changes in behaviour and personality (the latter limited to more severe injury), leading to poor psychosocial outcomes (Morton & Wehman, 1995). Difficulties in personal relationships (Ponsford et al., 2014), reduced ability to partake in leisure activities (Wise et al., 2010), and loss of employment have all been reported (Temkin, Corrigan, Dikmen, & Machamer, 2009), in some instances even ten years after the injury (Ponsford et al., 2014).
One important functional outcome post-TBI is the resumption of work. Returning to work can be challenging following TBI, given the combined physical, cognitive, and emotional problems (Shames, Treger, Ring, & Giaquinto, 2007). In a review, Temkin et al. (2009) found that TBI adversely affects the probability of employment after injury, increases the time it takes to return to work, and decreases the probability of returning to the same employment pre-injury. It is difficult to accurately ascertain the numbers of people with a TBI who return to work post-injury due to a number of factors, such as differences in study methodologies and samples of varying injury severities. This has resulted in a wide range of reported return to work rate, namely 12.5% to 71% (Shames et al., 2007). Findings from studies of individuals with moderate to severe TBI generally report a rate of less than 50% (Doctor et al., 2005; Shames et al., 2007; Sherer et al., 2002). A higher figure is found in those who experienced mild TBI, although a few studies reported 25% to 50% of these individuals failed to return to work 3- to 12-month post-injury (Doctor et al., 2005; Friedland & Dawson, 2001; Kristman et al., 2010). Various factors have been reported to be significant predictors of work status post-injury. These include severity of the injury, age at the time of injury, pre-injury professional and educational background, and severity of cognitive impairment (Benedictus, Spikman, & van der Naalt, 2010; Drake, Gray, Yoder, Pramuka, & Llewellyn, 2000; Shames et al., 2007; Stulemeijer, van der Werf, Borm, & Vos, 2008). Although there is some evidence implicating social information processing deficits in challenges integrating back to work (Knox & Douglas, 2009; Yeates et al., 2016), there remains a lack of data. Given the potential for adverse psychosocial changes post-TBI and a
growing social neuroscience field, the extent to which social information processing may contribute to impaired functional outcome such as return to work is worthy of exploring.

**Social Information Processing and the Social Brain**

Humans are social creatures by nature. The proper processing of social information, or the information related to other humans, is critical for survival and everyday interactions throughout the lifespan (Harmon-Jones & Winkielman, 2007). It allows individuals to form dependable interpersonal relationships with each other, to promote effective communication and cooperation, and to share experiences and understand one another. Indeed, the unique nature of social information processing suggests it is partially distinct from non-social cognitive intellects, with evidence from studies in individuals with lesion or other psychiatric disorders (such as autism spectrum disorders and William’s syndrome) further supporting this notion (Adolphs, 2009; Kennedy & Adolphs, 2012).

1.1.1 **Social Information Processing**

Conceptually social information processing is thought to have three broad stages: perception, cognition, and regulation (Adolphs, 2010). At the basic level, social information processing starts with the perception of social cues, during which information processing is primarily driven by encoding sensory inputs. Perhaps in the case of humans, the most important function of this stage is to perceive, identify, and interpret the emotions of others through nonverbal communication such as facial expressions, vocal prosody, and body language. Once the perception of social information reaches beyond simple sensory inputs, it is further processed thereby allowing the person to comprehend the mental states and perspectives of others (what
is known as theory of mind), to mimic others’ actions through simulation, and to understand or empathise with the feelings of others. These processes, considered uniquely human and different from non-social cognition, add a richer dimension to the perceived sensory stimuli. This stage of processing allows people to infer and predict the intentions of others, to understand others’ perspectives and thoughts, to comprehend nonliteral language use such as irony and sarcasm, to identify friends and foes, and to share emotional experiences. Finally, the information reaches higher metacognitive abilities where it can regulate and control social behaviours, modify emotions, and inhibit impulsive behaviours.

1.1.2 The Social Brain

A number of neural structures have been implicated in subserving social information processing from findings of neuroimaging studies in healthy individuals and those with brain diseases. Starting at the social perception level, regions in the temporal lobe including the fusiform gyrus are critical for processing the perception of faces and facial affect. The limbic system, including the amygdala, the prefrontal cortex, parahippocampal gyrus, and other subcortical regions further contribute to facial affect recognition (Fusar-Poli et al., 2009; Harmon-Jones & Winkielman, 2007; Kennedy & Adolphs, 2012; Schutt, Keshavan, & Seidman, 2015). The medial prefrontal cortex, temporoparietal junction, superior temporal sulci, ventromedial prefrontal cortex, and the orbitofrontal cortex are then involved in mentalizing abilities to help individuals infer the mental states and intentions of others (theory of mind) (Adolphs, 2009; Cacioppo, Visser, & Pickett, 2006; Gallagher & Frith, 2003; Harmon-Jones & Winkielman, 2007; Saxe & Kanwisher, 2003; Schutt et al., 2015). Finally, the orbitofrontal cortex and regions underpinning
executive functions including the dorsolateral prefrontal cortex are critical for regulating social behaviours and emotions (Adolphs, 2009; Cacioppo et al., 2006; Harmon-Jones & Winkielman, 2007; Schutt et al., 2015).

1.2 Social Perception in TBI

1.2.1 Facial Affect

One of the most fundamental aspects of emotion perception is the recognition of facial affect. In a meta-analysis comparing affect recognition in adults with moderate to severe TBI and their matched healthy controls, 13% to 39% of those with TBI had marked deficits in identifying facial expressions from static visual cues (Babbage et al., 2011). Evidence from numerous studies using a number of affect naming, matching, and discrimination tasks have confirmed impairments in facial affect recognition after TBI. For example, using Ekman and Friesen’s facial affect photos representing the six basic emotions (happiness, sadness, fear, anger, surprise, and disgust), Mancuso et al. (2015) found that individuals with severe TBI were significantly more impaired in recognizing all of the basic emotions except anger when compared to their healthy counterparts. The authors also found that those with severe TBI performed significantly poorer in matching emotions than healthy controls, irrespective of whether the emotions were the same or different. Using the same photo stimuli, a number of other studies have shown similar deficits in the recognition of all basic emotions in individuals with TBI across severities, with some studies demonstrating impaired performance in emotion recognition both in the acute phase of recovery and at 12-month follow-up (Braun, Baribeau, Ethier, Daigneault, & Proulx, 1989; Croker & McDonald, 2005; Henry, Phillips, Crawford, Ietswaart, & Summers, 2006;
A standardized task commonly used for the assessment of static facial affect recognition, the Diagnostic Assessment of Nonverbal Accuracy-2 Adult Faces (DANVA2 – Faces) task has been utilized in the TBI population as well. The DANVA2 – Faces task presents coloured photos portraying happy, sad, angry, and fearful emotions with both high and low intensities to participants for identification (Nowicki, 2000). Individuals with TBI are significantly impaired on this task, with some studies reporting a third of moderate to severe TBI patients performing 1.5 or more standard deviations below age-matched normative groups (Spell & Frank, 2000; Zupan, Babbage, Neumann, & Willer, 2014). Another commonly used test is the Florida Affect Battery (FAB), which consists of ten subtests measuring face identity discrimination, facial affect discrimination, affect naming, affect matching and vocal emotion discrimination (Bowers, Blonder, & Heilman, 1998). Using this battery, two studies were able to demonstrate impairments in facial affect labelling and matching post-TBI, despite intact face perception abilities (Biszak & Babbage, 2014; Green, Turner, & Thompson, 2004). Several other tasks have been used to examine facial affect identification from static cues in TBI. For example, using the Facial Emotion Identification Test (FEIT), Genova et al. (2016) found that people with severe TBI were impaired when it came to recognizing fear.

While tasks presenting facial emotions in photographs with full intensity have been useful, some have argued that the perception of social cues in real-world setting is more dynamic and nuanced than posed static stimuli. Accordingly, methods presenting emotions at different intensities using other modalities, such as video vignettes, have been adapted to test facial
affect perception. One of the common dynamic affect recognition tasks used is the Emotion Recognition Task (ERT) (Montagne, Kessels, De Haan, & Perrett, 2007). The ERT is a computer-based program using a series of video clips showing neutral and the six basic facial emotions expressed at different intensities. The video clips are created by morphing images between a face with no emotion (0%) and a face with full-blown emotion (100%), with 10% increments of increasing intensity between each stimulus. Using this task, various studies were able to demonstrate that individuals with moderate-to-severe TBI performed poorly in overall emotion recognition (Rigon, Turkstra, Mutlu, & Duff, 2016; Rosenberg et al., 2015; Rosenberg, McDonald, Dethier, Kessels, & Westbrook, 2014). McDonald et al. (2003) also developed a clinical assessment tool named The Awareness of Social Inference Test (TASIT) for assessing emotional expression using videotaped vignettes. The first part of the TASIT, the Emotion Evaluation Task (EET), assesses individual’s ability to identify the six basic emotions by using short video scenarios of professional actors naturalistically displaying emotions in spontaneous reactions. The EET has been shown to be sensitive to emotion recognition impairment post-TBI (McDonald et al., 2006, 2003; McDonald & Flanagan, 2004).

1.2.2 Vocal Prosody

Impairment in recognizing vocal prosody, or the emotional inflexion in speech, is another facet of social perception deficits that can occur post-TBI. For example, Milders et al. (2003) reported poorer performance on both facial and vocal emotion recognition tasks in a group of people with severe TBI when compared to their matched healthy controls. Other studies have found conflicting results regarding the severity of emotion recognition deficits across modalities. For
instance, Spell and Frank (2000) found that individuals with TBI were more accurate in identifying facial expressions than vocal emotions when stimuli of children and young adults were used, a finding that reversed using older adults stimuli. On the other hand, McDonald and Saunders (2005) showed that a group of adults with severe TBI did not perform more poorly than healthy subjects on facial affect recognition tasks (static and dynamic), but were more impaired on vocal emotion recognition tasks. Ietswaart et al. (2008) also explored emotion recognition across media in a group of mild to severe TBI patients, and found that these individuals performed better on recognizing vocal emotion than facial expressions, although a general deficit in emotion perception was still noted. Finally, in a more recent study by Zupan et al. (2014), the authors examined vocal and facial emotion perception in a large sample of adults with moderate to severe TBI (n = 203), and found that they were more impaired on recognition of facial affects than vocal emotions when compared to age-matched norms. Given the diversity of presentation (static to dynamic to audiovisual) in emotion perception tasks, and the heterogeneity in injury severity and injury duration of the sample populations across studies, more effort is needed to unravel the complexities within emotion perception deficits caused by TBI.

1.2.3 Social Perception in Children and Adolescents with TBI

Although studies looking at adults after TBI have shown relatively consistent impairments in affect recognition, evidence from adolescent and pediatric studies is less clear. In a recent study by Tousignant et al. (2016), no significant differences were found between a group of adolescents who sustained moderate to severe TBI and their case matched healthy controls on
affect recognition tasks. Similarly, McDonald et al. (2013) found no differences in emotion perception abilities between a group of adolescents with moderate to severe TBI and their uninjured peers. However, evidence to the contrary revealing impaired emotion recognition abilities in children and adolescents with TBI has also been reported (McLellan & McKinlay, 2013; Tlustos et al., 2011; Tonks, Williams, Frampton, Yates, & Slater, 2007; Tukstra, Lyn S. McDonald Skye, 2001). Reasons for these discrepant findings may relate to a failure to control for factors such as age at the time of injury, family environment, and socioeconomic status (Schmidt, Hanten, Li, Orsten, & Levin, 2010; Schmidt, Orsten, Hanten, Li, & Levin, 2010). Overall, research in emotion recognition abilities in children and adolescents with TBI is scant compared to the adult population.

1.2.4 Factors Affecting Social Perception

Effect of Valence

One potential contributor to the accuracy of affect identification is the valence of the emotions. For example, Zupan and Neumann (2013) found that individuals with moderate-to-severe TBI were not impaired in recognizing positive affect on the DANVA2-Faces task, but they performed significantly poorer than their matched healthy counterparts in identifying negative emotions. A number of other studies have suggested that the ability to recognize negative emotions, such as fear, anger, disgust, and sadness, is more impaired than the ability to recognize positive emotions, such as happiness and surprise (Braun et al., 1989; Callahan, Ueda, Sakata, Plamondon, & Murai, 2011; Croker & McDonald, 2005; Green et al., 2004; Hopkins, Dywan, & Segalowitz, 2002; Spikman et al., 2013; C. Williams & Wood, 2010b). On the other hand, some
researchers have argued that the valence effect could be confounded by the unequal representation of positive and negative emotions in most tasks, with happiness being the single definitive positive emotion, while there are four negative emotions (fear, anger, disgust, and sadness) (Rosenberg et al., 2015). Indeed, in a study by Rosenberg et al. (2016), the authors used a novel approaching called the Complex Audio-Visual Emotion Assessment Task (CAVEAT) to comprehensively examine the effect of valence of emotions. The CAVEAT presents 11 different positive emotional expressions and 11 different negative emotional expressions using 88 audiovisual vignettes of everyday scenarios. These emotional expressions include the six basic emotions while including a range of other more complex emotions. Using this method, the authors were unable to find any significant impairment specific to negative emotions in people with a moderate-to-severe TBI, although there was an overall emotion recognition deficit in the TBI group. Similarly, other studies found that although people with a TBI were more impaired in recognizing negative than positive emotions, a selective impairment in recognizing negative emotions was not evident when expressions of emotions were matched in task difficulty (Ietswaart et al., 2008; Rosenberg et al., 2015, 2014).

Effect of Sex

Another potential predictor of performance in affect recognition tasks post-TBI is the sex of the participant. Given extensive normative evidence that females are better at recognizing emotions it has been hypothesized that being female is relatively protective of affect recognition after TBI. In a study by Rigon et al. (2016), the authors compared the abilities of females and males with moderate-to-severe TBI patients in recognizing the six basic emotions using two tasks that contained static (the Karolinska Directed Emotional Faces test or KDEF) and
dynamic (the ERT) stimuli. It was found that although facial affect recognition abilities did not significantly differ between the sexes in the control group, males performed significantly worse than females in the TBI group on the ERT. Indeed, it was found that females with TBI scored similarly to both sexes in the control group, while males with TBI underperformed significantly when compared to females in both groups and matched healthy males. These sex difference in task performance could not be explained by factors such as injury severity or other neuropsychological measures.

Effect of Non-Social Cognitive Function

The relationship between non-social cognitive functions and social perception abilities in individuals with TBI remains inconclusive. Given that the perception of social cues requires attention to dynamic and rapidly changing stimuli, it is plausible that non-social cognitive abilities could account for some of the variance in social perception impairment. Data supporting this comes from studies showing that impairments in social perception were associated with deficits in speed of information processing (McDonald et al., 2003), and working memory (McDonald et al., 2003; Yim, Babbage, Zupan, Neumann, & Willer, 2013). However, other studies have found that social perception abilities can only be predicted by injury severity and task difficulty, and not by impairments in specific cognitive abilities (Rosenberg et al., 2015, 2014, 2016).

1.2.5 Brain Imaging Correlates of Social Perception Deficits Following TBI

There are only a handful of imaging studies that have specifically examined neural correlates of emotion perception deficits following TBI. In a recent functional magnetic resonance imaging
(fMRI) study, Neumann et al. (2015) utilized the neuroimaging face emotion identification task to examine the functional brain changes in people with moderate to severe TBI who were impaired in emotion perception (TBI-impaired) compared to those with TBI who were unimpaired (TBI-normal) and healthy controls. The neuroimaging face emotion identification task utilizes 3-dimensional facial expressions of different emotions as stimuli for functional imaging of emotion perception (R. C. Gur et al., 2002; R. E. Gur et al., 2002). Using this task, Neumann et al. (2015) noted activation of an extensively distributed network of structures across all three groups. These included the limbic and subcortical areas (amygdala, fusiform gyrus, and regions of temporal and parietal lobes), and the prefrontal cortex (ventromedial prefrontal cortex and orbitofrontal cortex). The TBI-impaired group had significantly less activation in the right fusiform gyrus compared to healthy subjects, with the TBI-normal group demonstrating an intermediate level of activation within this area. Genova et al. (2015) used diffusion tensor imaging (DTI) to examine microstructural changes in white matter tracts after moderate to severe TBI in relation to performance on the FEIT. The authors found that reduced white matter integrity in the inferior longitudinal fasciculus (ILF) and the inferior fronto-occipital fasciculus (IFOF) were associated with poorer performance on the FEIT task. In the pediatric and adolescent population, Schmidt and colleagues (2013) found that the compromised integrity of the cingulum bundle was associated with impaired emotional prosody using DTI, while Ryan et al. (2014) found that accuracy on emotion perception tasks was associated with the volume of the posterior corpus callosum.
1.3 Social Cognition in TBI

1.3.1 Theory of Mind

When considering social cognition, the individual’s first and foremost function is to use the information received from the social perception stage to infer the mental state of others and to understand and predict the behaviours of others. This is known as Theory of Mind (ToM). ToM abilities start developing as early as infancy and progress over several years until adulthood. For example, the ability to understand first-order false belief (what others believe about the world) is thought to develop between the ages of 3 and 4 years (Wimmer & Perner, 1983), and the ability to understand second-order false belief (what others believe about others’ beliefs) is thought to develop between the ages 6 and 7 years (Perner & Wimmer, 1985). The ability to recognize a social faux pas, a more advanced ToM function, is thought to develop between the ages of 9 and 11 years (Baron-Cohen, O’Riordan, Stone, Jones, & Plaisted, 1999). Finally, it is only in adulthood that the ability to infer the feelings and mental states of other individuals by only looking at the eyes becomes fully developed (Baron-Cohen, Jolliffe, Mortimore, & Robertson, 1997).

ToM abilities have been shown to be impaired following TBI. A recent meta-analysis revealed that individuals with an acquired brain injury (ABI), of whom approximately 50% had sustained a TBI, were moderately to severely impaired in ToM tasks (effect sizes: 0.5 – 0.7) (Martín-Rodríguez & León-Carrión, 2010). A substantial number of studies have shown that impairments in ToM are found in individuals with TBI across multiple tasks. For instance, Muller et al. (2010) explored ToM abilities in a group of adults with severe TBI using four verbal and
nonverbal ToM tasks: the Faux Pas Test (Stone, Baron-Cohen, & Knight, 1998), first-order and second-order false belief tasks, character intention task, and the Reading the Mind in the Eyes Test (RMET) (Baron-Cohen, Wheelwright, Jacqueline, Raste, & Plumb, 2001). The authors reported that those with a severe TBI performed more poorly than matched healthy subjects on all tasks with the exception of the first-order false belief task. Similar results have been replicated in other adult studies. Therefore, TBI is thought to negatively impact the abilities of individuals to judge whether a person has committed a faux pas (Geraci, Surian, Ferraro, & Cantagallo, 2010; Milders et al., 2003; Milders, Ietswaart, Crawford, & Currie, 2006; Milders et al., 2008; Spikman, Timmerman, Milders, Veenstra, & van der Naalt, 2012), to identify the false beliefs another individual has about the world or other people’s belief (Bibby & McDonald, 2005), to infer a character’s intention through comic strips (Havet-Thomassin, Allain, Etcharry-Bouyx, & Le Gall, 2006), and to judge the mental states of others by examining only the eye regions of the face (Geraci et al., 2010; Havet-Thomasss et al., 2006; Henry, Phillips, Crawford, Ietswaart, et al., 2006; Honan, McDonald, Gowlan, Fisher, & Randall, 2015; Turkstra, 2008).

Impairments in ToM in individuals with TBI have also been revealed using the Cartoon Test (Bibby & McDonald, 2005; Milders et al., 2008; Spikman et al., 2012), a test that measures the ability to understand humorous situations based on the false belief of a character (Happé, Brownell, & Winner, 1999).

Similar to social perception tasks, more complex tasks using video vignettes with professional actors depicting different social scenarios have been used to measure nuanced ToM abilities. For example, The Awareness of Social Inference Test (TASIT) not only has an emotion evaluation component, but also a Social Inference – Minimal (SIM), and a Social Inference –
Enriched component (SIE) (McDonald et al., 2006, 2003). In the SIM part, video vignettes depicting sincere and sarcastic conversational exchange between professional actors are shown, and the participants are asked questions regarding the characters’ feelings, beliefs, intentions, and meaning. In the SIE component, more videos of social conversations depicting diplomatic lies or sarcastic exchanges are shown with additional contexts provided before or after the dialogue of interest. Participants are again asked a set of four questions after viewing each video to determine their abilities to interpret the video correctly. Using these two components of the TASIT, two studies have demonstrated the significant impairments in recognizing the emotional and mental states of others post-TBI (McDonald & Flanagan, 2004; Turkstra, Dixon, & Baker, 2004).

*Children and ToM*

A number of studies have explored the impact of TBI on ToM in children and adolescents. For instance, in a recent study by Bellerose et al. (2015), the authors found that first-order ToM was moderately impaired even in preschool children with mild TBI compared with case-matched healthy children, with deficits not explained by pre-existing differences prior to the injury. In other studies, children and adolescents with varying TBI severities have seemed to have difficulties in understanding thoughts and intentions of others (Chertkoff Walz, Owen Yeates, Gerry Taylor, Stancin, & Wade, 2010; Dennis et al., 2012; Dennis, Simic, Bigler, et al., 2013), and interpreting thoughts and feelings from just the eye regions of individuals (Snodgrass & Knott, 2006).
ToM abilities may be associated with non-social cognitive functioning, although mixed results have been reported. For instance, using the RMET and the verbal fluency test (FAS), Henry et al. (2006) found significant correlation between ToM and executive function that was specific to individuals with TBI, but not healthy controls. Bibby and McDonald (2005) found working memory to be a significant predictor of performance on a second-order false belief task. Similarly, studies have found an association between ToM impairments and executive function performance in children and adolescents and adults with TBI using different tasks (Dennis, Agostino, Roncadin, & Levin, 2009; Milders et al., 2006). On the contrary, other studies reported no relationship between non-social cognitive functions and ToM abilities. Spikman et al. (2012) found that performance on ToM tasks were not significantly correlated with measures of speed of information processing, attention, memory, and executive function. Muller et al. (2010) did not find a significant correlation between executive function (Trail Making Test (TMT) A and B, Stroop Test, and the verbal fluency test) and ToM (RMET). Havet-Thomassin et al. (2006) and Struchen et al. (2008) found no association between non-social cognitive deficits and impairments in ToM in TBI individuals. The relationship between non-social cognitive functions and ToM abilities therefore remains inconclusive. This may reflect methodological variations, namely the varying difficulty levels in the chosen ToM tasks and the multi-domain nature of non-social cognitive abilities.
Cognitive and Affective Theory of Mind

Within ToM abilities, further distinction can be made between “cognitive” ToM and “affective” ToM, where the former refers to the knowledge of others’ thoughts and beliefs, and the latter to the understanding of others’ emotional states and feelings (Shamay-Tsoory & Aharon-Peretz, 2007b). For example, the false belief tasks are thought to be measures of cognitive ToM, the faux pas task is thought to reflect affective ToM abilities, while the RMET is regarded as an index of both subtypes of ToM. The use of these tasks in a series of neuroimaging studies has provided evidence that there might be different neuroanatomical networks underlying cognitive and affective ToM. Evidence suggests that the orbitofrontal cortex, the ventromedial prefrontal cortex, and the inferior lateral frontal cortex are involved in processing affective ToM, whereas the dorsal medial prefrontal cortex and the dorsolateral prefrontal cortex are involved in processing cognitive ToM (Abu-Akel & Shamay-Tsoory, 2011; Shamay-Tsoory & Aharon-Peretz, 2007b; Shamay-Tsoory, Tibi-Elhanany, & Aharon-Peretz, 2006; Shamay-Tsoory, Tomer, Berger, Goldsher, & Aharon-Peretz, 2005).

1.3.2 Pragmatics

A related aspect of social cognition that relies on ToM abilities is pragmatics, or the comprehension of language use in social contexts. To interpret pragmatics appropriately, it is critical to have an intact understanding of the intentions of others, and the context in which the language is being used. For example, depending on the context and the intention of the speaker, an utterance of “You did great on the test!” could be interpreted as a sincere compliment or a sarcastic remark. As such, pragmatic inferences play a critical role in social communication. It
ensures both the speaker and the listener can understand the non-literal conversational meaning, and thereby facilitate appropriate social behaviours. Although other cognitive abilities such as language and working memory may influence pragmatics, several studies have demonstrated deficits in pragmatics after TBI despite a generally low incidence of aphasia in this population. For example, adults with severe TBI are reported to have poorer discrimination between sincere and insincere remarks (McDonald, Fisher, Flanagan, & Honan, 2015), a reduced ability to interpret the meaning of sarcastic remarks (Channon, Pellijeff, & Rule, 2005; McDonald & Flanagan, 2004), and impaired comprehension of ironic jokes (Martin & McDonald, 2005). Similar deficits in pragmatics have been replicated in children and adolescent TBI studies (Dennis, Simic, Agostino, et al., 2013; Dennis, Purvis, Barnes, Wilkinson, & Winner, 2001; McDonald et al., 2013).

1.3.3 Empathy

Another facet of social cognition that overlaps with ToM is empathy. Empathy refers to the ability to understand and resonate with how someone else feels while differentiating this from one’s own feelings (i.e. I feel what you feel). Similar to ToM, empathy is thought to have an affective (the ability to recognize others’ emotional states and experience affective reactions) and a cognitive (the ability to understand how someone else feels) component (Shamay-Tsoory, Aharon-Peretz, & Perry, 2009). Conceptually, cognitive empathy is very similar to affective ToM. Therefore empathy plays a critical role in forming successful interpersonal relationships. A few studies have attempted to examine affective and cognitive empathy in individuals with TBI. For instance, using the Balanced Emotional Empathy Scale (BEES) (Mehrabian, 1996), a validated
self-report measure of affective empathy, Wood and Williams (2008) reported significantly higher frequency of low affective empathy in a sample of mild to severe TBI patients (60.7%) than matched control samples (31%). A subsequent study by the same authors using the same scale replicated the results, showing that 64.1% of individuals with TBI reported low affective empathy, in contrast to 34.4% matched controls (C. Williams & Wood, 2010a). de Sousa et al. (2010, 2012) reported similar rates of low levels of affective empathy using the BEES in two groups of severe TBI patients. In one of their studies, they also utilized the Interpersonal Reactivity Index (IRI), another validated self-report questionnaire, to examine both cognitive and affective empathy in individuals with severe TBI (de Sousa et al., 2010). The IRI consists of four subscales, namely Perspective Taking (PT), Fantasy Scale (FS), Empathic Concern (EC), and Personal Distress (PD) (Davis, 1983). The authors found that the TBI group scored significantly lower on the Empathic Concern and Perspective Taking subscales than matched controls, demonstrating a marked reduction in their abilities to empathize cognitively and emotionally (de Sousa et al., 2010). However, it should be noted that a few studies have failed to find lower empathy in people with TBI using the IRI. For example, Muller et al. (2010) did not find significant differences in empathy as measured by the IRI between individuals with severe TBI and healthy controls. McLellan and McKinlay (2013) also did not find any differences in the total score on the IRI between adults who sustained mild to severe TBI as children and their matched controls.

**Empathy and Alexithymia**

A factor that could contribute to the loss of ability to empathize with others in individuals with TBI is alexithymia. Alexithymia refers to difficulties in identifying and describing one's own
emotions, and a tendency to exhibit externally oriented thinking (Neumann, Zupan, Malec, & Hammond, 2014; C. Williams & Wood, 2010a). A frequently used measure of alexithymia is the Toronto Alexithymia Scale (TAS), a self-report questionnaire consisting of three subscales measuring difficulty with identifying feelings, difficulty describing feelings, and externally-oriented thinking (Bagby, Parker, & Taylor, 1994). Using this measure, the prevalence of alexithymia has been shown to be significantly higher in TBI patients (ranging from 30% to 60%) than in healthy controls (ranging from 5% to 15%) (Henry, Phillips, Crawford, Theodorou, & Summers, 2006; Koponen et al., 2005; Mcdonald, Rosenfeld, Henry, Togher, & Tate, 2001; C. Williams & Wood, 2010a; K. R. Williams et al., 2001; R. L. Wood, Williams, & Kalyani, 2009). Theoretically, impairment in identifying one’s own emotions could interfere with one’s ability to understand and experience others’ emotional states. A significant association between alexithymia and empathy has been observed in other neurological disorders as well as healthy populations (Gleichgerrcht, Tomashitis, & Sinay, 2015; Grynberg, Luminet, Corneille, Grèzes, & Berthoz, 2010). In the TBI population, Williams and Wood (2010a) found significant, albeit moderate, negative correlations between alexithymia (as measured by the TAS) and affective empathy (as measured by BEES) in both control and TBI groups. Furthermore, they found that alexithymia accounted for 21.1% and 9% of the variance in BEES scores in the healthy control and TBI groups respectively. However, in a separate TBI study by Neumann et al., (2014) no significant association between alexithymia and affective empathy was found. This could be due a difference in the scale used by Neumann et al. (the Empathic Concern subscale of the IRI was chosen rather than the BEES used by Williams and Wood), which may result in different
aspects of affective empathy being measured. Future research is needed to clarify this relationship between empathy and alexithymia.

1.4 Social Regulation in TBI

Finally, social information processing reaches the regulation stage where the information is used to facilitate emotion regulation, social decision making, and inhibition of inappropriate social behaviours. Amongst the problems that manifest post-TBI, dysregulation of social behaviours is one of the most significant causes of poor psychosocial outcome and distress in relationships. There are broadly two types of impairments in social regulation that are commonly observed in individuals with TBI.

1.4.1 Social Disinhibition

The first type of impairment in social regulation associated with TBI is social disinhibition, which can include a number disturbances in emotional and behavioural controls including irritability, emotion dysregulation, and impulsivity (Arciniegas & Wortzel, 2014; Osborne-Crowley & McDonald, 2016). Although social disinhibition frequently occurs after TBI, it is difficult to estimate the prevalence rate due to the lack of consensus regarding its definition and measurement (Osborne-Crowley & McDonald, 2016). In one review, Arciniegas and Wortzel (2014) defined disinhibition as “socially or contextually inappropriate nonaggressive verbal, physical, and sexual acts that reflect a lessening or loss of inhibitions and/or inability to appreciate social or cultural behavioral norms”. Osborne-Crowley and McDonald (2016) subsequently adapted and proposed this definition to be the working definition of social
disinhibition when reviewing the TBI literature. This wide definition encompasses a broad array of phenomena that reflect the social disturbances after TBI.

Pathological Laughter and Crying

A severe manifestation of emotional dysregulation that can occur after TBI is pathological laughter and crying (PLC), also known as pseudobulbar affect. PLC is defined as the occurrence of brief, uncontrollable episodic outbursts of laughing or crying that are triggered by inappropriate stimuli, which typically do not cause such intense emotional responses under normal circumstances (Roy, McCann, Han, & Rao, 2015). PLC can be examined using a number of measures. When patients have preserved self-awareness, administration of the Pathological laughter and Crying Scale (PLACS) coupled with a clinical interview of the person with TBI (Robinson, Parikh, Lipsey, Starkstein, & Price, 1993). The prevalence rate of PLC has been shown to be 5.3% and 10.9% in two groups of consecutively admitted TBI patients with varying severities (Tateno, Jorge, & Robinson, 2004; Zeilig, Drubach, Katz-Zeilig, & Karatinos, 1996). While Zeilig et al. (1996) reported all TBI patients with PLC sustained severe or very severe TBI, Tateno et al. (2004) reported those with PLC to be of all TBI severities. Clear incidence and prevalence of PLC could not established due to the paucity of research. In a recent study by Roy et al. (2015), the authors found a prevalence of PLC of 21.4%, 17.5%, and 15.5% at 3-, 6-, and 12-month in a group of mild to severe TBI patients respectively. The rates of PLC in different severities of TBI were 66.3%, 14.6%, and 19.1% for mild, moderate, and severe TBI respectively. Finally, individuals with TBI who had PLC also had higher rates of psychiatric diagnoses and increased rates of mood and anxiety symptoms compared to people without PLC (Roy et al., 2015).
**Impulsivity**

Impulsivity is a multidimensional construct that may refer to a number of behaviours that are considered to be inappropriate or immature and which can result in detrimental effects (Kocka & Gagnon, 2014). There is a lack of consensus regarding the dimensions encompassed by impulsivity in the literature, with some studies using the term interchangeably with social behaviour disinhibition in general, while others making a clear distinction between the two (Arciniegas & Wortzel, 2014; Kocka & Gagnon, 2014). In people with intact self-awareness, the Barratt Impulsiveness Scale (BIS), a self-report questionnaire can be used to assess impulsivity (Barratt, Patton, & Stanford, 1975). The BIS captures motor (acting without thinking), cognitive (making decisions briskly), and non-planning impulsivity (Barratt et al., 1975). Using this scale, various studies have demonstrated higher impulsivity in groups of TBI patients than matched healthy counterparts (McHugh & Wood, 2008; Travis Seidl, Pastorek, Troyanskaya, & Scheibel, 2015). In individuals with limited self-awareness, an assessment based on information from knowledgeable informants can be used. One commonly used questionnaire is the informant version of Urgency-Premeditation-Perseverance-Sensation seeking (UPPS) Impulsive Behaviour Scale (Whiteside, Lynam, Miller, & Reynolds, 2005). This scale measures impulsivity in terms of four components: urgency or the tendency to act impulsively in reaction to positive and particularly negative affect; (lack of) premeditation or deficiency in thinking about the consequences of an action before engaging; (lack of) perseverance or the inability to stay focused on tasks that might boring or difficult; and sensation seeking or the tendency and willingness to enjoy exciting and new activities (Whiteside et al., 2005). Using this scale, individuals with moderate to severe TBI were found to have increased urgency, lack of
premeditation, and lack of perseverance, while sensation seeking decreased (My et al., 2015; Rochat et al., 2010; Rochat, Beni, Annoni, Vuadens, & Van der Linden, 2013; Rochat, Beni, Billieux, Annoni, & Van Der Linden, 2011).

**Irritability**

Irritability is a dimension of emotion disturbances that can occur after TBI. Irritability refers to both an internal subjective feeling of becoming annoyed easily, and the external display of impatience and anger (Yang, Hua, Lin, Tsai, & Huang, 2012). Although irritability is observed in the general population, a few studies have demonstrated its increased frequency after TBI. For example, in one of the earliest studies examining outcome after brain injuries, McKinlay et al. (1981) found irritability occurring in 63%, 69%, and 71% in a sample of severe TBI subjects at 3, 6, and 12 months post-injury respectively. Deb et al. (1998) reported 30% of a sample of mild to complicated mild TBI patients showed irritability one year post-injury. In another sample of 196 individuals with TBI of varying severities, Deb et al. (1999) reported irritability in 35% of the patients one year post-injury, with 21.3% of those with mild to moderate TBI complaining of irritability one year post-injury. Yang et al. (2012) also found that 14.8% of a group of mild to severe TBI patients and 29.4% of their families reported the patients being irritable post-injury.

Irritability can be assessed using a number of validated psychometric measurements. For individuals with TBI who have intact self-awareness, self-report measures such as the Neurobehavioral Symptom Inventory (Alt, 2012), the Irritability Questionnaire (Craig, Hietanen, Markova, & Berrios, 2008), and the National Taiwan University Irritability Scale can be effective in assessing irritability after TBI (Yang, Huang, Lin, Tsai, & Hua, 2011). However, self-awareness
can be impaired after TBI, especially in those with moderate to severe injury (Bach & David, 2006; Bivona et al., 2014; Robertson & Schmitter-Edgecombe, 2015). Hence an interesting finding emerged in a study by Yang et al. (2013), who found that patients with mild TBI self-reported significantly higher levels of irritability relative to matched healthy controls, while those with moderate to severe TBI did not. Of note in this study was the reverse finding in caregivers’ ratings, where caregivers of those with moderate to severe TBI reported significantly higher levels irritability in these patients relative to healthy controls, a finding not reported by caregivers of mild TBI patients. From this, the authors concluded that the seemingly lower self-reported frequency of irritability in moderate to severe patients was the result of an impairment in self-awareness (Yang et al., 2013).

1.4.2 Apathy

On the flip side of disinhibition is the second type of impairment in social regulation associated with TBI, namely apathy. Apathy may refer to a general reduction in motivation and drive, typically manifested by diminished goal-directed cognition (decreased interests, lack of planning, and lack of concern about one’s own health or functional status), and diminished goal-directed behaviour (lack of effort, initiative, and productivity) (Arnould, Rochat, Azouvi, & Van Der Linden, 2013; Starkstein & Pahissa, 2014). Apathy may also encompass emotional concomitants of goal-directed behaviour including flattened affect, indifference towards emotionally salient stimuli, and restricted responses to important life events (Arnould et al., 2013; Starkstein & Pahissa, 2014).
Research investigating apathy specifically within the TBI population is limited, although different studies have shown that apathy is a common neuropsychiatric symptom post-injury. For example, Kant et al. (1998) reported apathy in 71.1% of a sample of mild to severe TBI patients using the Apathy Evaluation Scale (AES) self-report version. The Apathy Evaluation Scale (AES) is an 18-item scale measuring behavioural, emotional, and cognitive aspects of apathy (Marin, Biedrzycki, & Firinciogullari, 1991). The AES can be administered to individuals in a self-report version (AES-S), to their caregivers and knowledgeable informants (AES-I), or to their clinicians after a semi-structured interview with the patients (AES-C) (Marin et al., 1991). Using the same scale, three other studies reported rates of apathy to be 62.3% and 66.7% in two groups of severe TBI patients, and 46.4% in another group of TBI patients with unspecified severity (Andersson & Bergedalen, 2002; Andersson, Gundersen, & Finset, 1999; Andersson, Krogstad, & Finset, 1999). Al-Adawi et al. (2004) also reported the rate of apathy to be 20% in an Omani brain injury population using the AES. A few other instruments can be used to assess apathy. For example, Lane-Brown et al. (2009) used the apathy subscale of the Frontal System Behavior Scale (FrSBe) in a group of TBI patients, and found the prevalence of apathy to be 72%. Finally, Ciurli et al. (2011) utilized the Neuropsychiatric Inventory (NPI) to comprehensively characterize neuropsychiatric symptoms, including apathy, in a group of individuals with severe TBI. The authors found that apathy was the most common neuropsychiatric symptom presented, with a prevalence rate of 42%.

There is a large variation in the prevalence rates of apathy across studies. This likely reflects a few factors, including the heterogeneity in different TBI sample populations, the diverse assessments and cut-off scores utilized, and the varying definitions of apathy (Starkstein &
Pahissa, 2014). Common cognitive deficits observed post-TBI can contribute to the prevalence of apathy, as apathy is associated with memory, speed of information processing, and executive function deficits (Andersson & Bergedalen, 2002).

1.4.3 Social Decision Making

Finally, certain tasks have been developed to measure overall social decision making abilities in individuals with TBI. The Iowa Gambling Task (IGT) is one of them (Bechara, 2007), with poor performance linked to lesions in the ventromedial (Fellows & Farah, 2005), dorsomedial and the dorsolateral prefrontal regions (Fellows & Farah, 2005; Manes et al., 2002), and the amygdala (Bechara, Damasio, Damasio, & Lee, 1999). A handful of studies have examined IGT performance in individuals with TBI. For instance, Levine et al. (2005) compared the performance on the IGT in a group of people with mild to severe TBI and a group of demographically matched healthy counterparts. Although impairments were found in the TBI group, performance was not correlated with injury severity. Fujiwara et al. (2008) also found impaired performance in people with TBI, noting that although the TBI sample began the task more cautiously, they were slower in improving their strategies than compared to healthy controls. It should be noted that Fujiwara et al. (2008) and Levine (2005) incorporated the same patients. Impaired performances on the IGT have been reported in other studies, with TBI patients making less advantageous card selections and strategy than compared to healthy controls (Bonatti et al., 2008; Sigurdardottir, Jerstad, Andelic, Roe, & Schanke, 2010).

Although the IGT is thought to be a good measure of decision making abilities, the deficits reflected on this task may not explain impairments in social regulation. Rather, other non-social
cognitive functions, including working memory, information processing speed, executive functioning, and cognitive flexibility have been associated with IGT performance in individuals with TBI (Bonatti et al., 2008; Levine et al., 2005). Furthermore, the degree to which performance on IGT is predictive of real-world social decision making is questionable. For example, Namiki et al. (2008) described a person with lesions in the orbitofrontal cortex who had severe behavioural disturbances and poor real-life decision making abilities, but who performed within the normal range on the IGT.

As an alternative to the IGT, the Social Decision Making Task (SDMT) has been recently developed (Kelly, McDonald, & Kellett, 2014). The SDMT is a pseudo-online computerized task in which participants are instructed to play a game of “catch-and-throw” with four other players on the internet. The goal is to get the ball passed back to them as much as possible. In reality, the four other players are programmed so that they return the ball back to the participant at different probabilities. The SDMT has 100 trials, similar to that of the IGT. Using this task, Kelly et al. (2014) showed that the SDMT is sensitive to decision making impairments following severe TBI. Furthermore, it was shown that performance on the SDMT was not associated with scores on other non-social and social cognitive measures. The SDMT may therefore offer a novel method for assessing decision making in a social context, although more studies are needed to further explore the utility of this task (Kelly et al., 2014).

1.5 Challenges of the Current Literature

While current research supports the presence of impairments in social information processing following TBI, substantial challenges exist in characterizing these deficits and their outcomes.
First and foremost, TBI in itself is heterogeneous. Factors such as injury severity, the developmental stage during which the injury occurred, the injury location, and the time since the injury can all alter the deficits observed. As most of the studies consist of relatively small sample sizes with a miscellany of injury characteristics, the generalizability of the findings is called into question. To date the majority of research in social information processing has focused on the impact of moderate to severe TBI, with few studies specifically examining the effects of mild TBI. Paradoxically, mild TBI is the largest injury severity group within this clinic population, making up more than 80% of all TBI cases. Given the size of the mild TBI population, future research efforts are needed to investigate potential social information processing deficits and their recovery trajectory post-injury in this group.

Further compounding the complexity of the questions asked is the multi-faceted nature of social information processing. Although it can be broadly divided into three stages, each stage contains several inter-related aspects. For example, social perception is reliant not only on emotion perception from facial affect and vocal prosody, but also biologically driven gestures that constitute nonverbal communication. Within the catch-all of social cognition, there are not only subcategories like cognitive and affective theory of mind and empathy, but also phenomena that have been less thoroughly researched, such as moral reasoning and social judgment. Finally, social regulation can encompass error correction, self-reflection, and deception, all of which require future investigation.

There also remains a lack of consensus regarding the definitions of different constructs within social information processing. For example, while some studies include emotion recognition as a part of “social cognition”, other studies make a clear differentiation between social
perception and social cognition. The term “social disinhibition” is used interchangeably with impulsivity, irritability, and aggression by some authors, whereas others separate these concepts. Furthermore, there is a lack of consensus as to the specific conceptual ideas that should be included in each stage of social information processing. These inadequacies are understandable and reflect a gradually evolving social neuroscience field. However, without clear definitions, it is difficult to pool results across studies and reach a clear, informed conclusion.

Another challenge is to untie the complex interplay between different parts of social information processing and non-social cognitive functions. This can be attributed partially to the large number of tasks that are used in different studies to assess social information processing deficits. Since different studies use diverse tasks, it is difficult to match task difficulty and task modality across the literature. As a result, disparate conclusions may be reached when examining the relationship between social functioning on the one hand and non-social cognitive abilities on the other. The challenge, therefore, is to develop a standardized battery with established reliability and validity, to assess social information processing across studies and disease types.

Lastly, the contribution of sociocultural factors to social information processing outcomes post-TBI needs to be considered. Because social information processing is a social concept, factors such as ethnicity and gender may influence performances on the different tasks. For example, there has been evidence of advantage for emotion perception of own-ethnicity faces reported in the literature (Elfenbein & Ambady, 2002). As the existing (if not all) measurements of social information processing present stimuli of Caucasian individuals, this may not accurately reflect
the performance of participants with other ethnicities. Sociocultural factors may also contribute to variability in social decision making and self-reported perception of social competency. These factors have yet to be explored and suggest that novel, innovative designs are now needed to control for this multiple influences.

All in all, social information processing represents a critical area that may be impaired following TBI. Although increasing effort has been devoted to researching social processes post-TBI, there remains a need for a better understanding of the dysfunction. As TBI is the most common cause of brain damage, it is crucial to advance conceptual models, refine neuropsychological assessments, and adjust the clinical practice of detecting, managing, assessing, and treating social information processing deficits in this population.

1.6 Current Study

The primary purpose of the present study is to address the knowledge gap in the current literature, namely changes in social information processing abilities that might follow mild TBI. As mentioned earlier, mild TBI constitutes the majority of TBI population, yet research exploring social information processing in people with mild TBI is sparse. Only a handful of studies have been completed and the results are mixed (Bellerose et al., 2015; D’Hondt et al., 2016; James, Strom, & Leskela, 2014; Jang & Kwon, 2016; Travis Seidl et al., 2015; Zakzanis & Grimes, 2016). Preschool children with mild TBI have been shown to have poorer performances on first-order ToM tasks (Bellerose et al., 2015) and altered electrophysiological response when viewing emotional faces (D’Hondt et al., 2016). However, findings from adult veterans with and without a mild TBI did not find an association between brain trauma and impulsivity and risk-taking
behaviours (James et al., 2014; Travis Seidl et al., 2015). Finally, Zakzanis and Grimes (2016), showed that rates of apathy were elevated in people with mild TBI, but this did not predict real-world disability.

As aforementioned, several neuroanatomical structures constitute the so-called social brain, and these structures are especially vulnerable to traumatic brain injuries. Although the causes and the pathophysiology of TBI are diverse, injuries typically result in the scraping, collision, and compression of soft brain tissues against the bony structures of the skull (Bigler, 2007; Bigler & Maxwell, 2011). As a result, disruptions of brain regions and their connections can be specifically concentrated around areas close to the anterior and middle fossa, and the medial cerebral falx (Bigler, 2007; Bigler & Maxwell, 2011). Hence the ventromedial and orbitofrontal parts of the frontal lobe, and ventromedial area of the temporal lobe can all be affected (Bigler, 2007; Bigler & Maxwell, 2011). Diffuse axonal injury (DAI) of the white matter of the brainstem and subcortical regions can cause further disruption of the social brain networks, adding to the potential social information processing problems that may arise (Meythaler, Peduzzi, Eleftheriou, & Novack, 2001). DAI have also been associated with social information processing abilities in individuals with moderate to severe TBI as previously mentioned (Genova et al., 2015; Schmidt et al., 2013). Importantly, using DTI, research has demonstrated that mild TBI can be associated with DAI in multiple frontal white matter tracts as well, including the anterior corona radiata, uncinate fasciculus, corpus callosum, and the cingulum (Niogi & Mukherjee, 2010; Voelbel, Genova, Chiaravalotti, & Hoptman, 2012).

The limited number of studies looking at social information processing in mild TBI population means that it is difficult to draw any definitive conclusions as to brain-behaviour correlates. It is
also difficult to determine if any potential changes in social information processing contribute to negative functional outcomes in this population. These unanswered questions are clearly worthy of exploration given the large numbers of people who acquire a mild TBI.

The objectives of the current study are threefold:

1) To comprehensively assess social information processing in individuals with mild TBI by using a battery of tasks measuring facial affect perception abilities, theory of mind abilities, global empathy, risk-taking behaviours, and socioeconomic decision making abilities.

2) To examine the association between non-social cognition and social information processing abilities in mild TBI by also administering a battery of tests assessing attention and information processing speed, memory, language, executive function, and visuospatial orientation.

3) To determine if performances on social information processing tasks would be associated with functional outcome, namely the ability to return to work following mild TBI.

The hypotheses are as follows:

1) Individuals with mild TBI will show deficits in social information processing when compared to healthy control subjects

2) Non-social cognitive deficits will be associated with social information processing impairments.
3) Performances on social information processing tasks will be associated with vocational functioning post-injury
CHAPTER 2: METHODS

2.1 Sample Selection

2.1.1 Mild TBI Subjects

Individuals with a confirmed diagnosis of mild TBI based on the ACRM criteria were recruited from an outpatient TBI clinic in a large general hospital. Subjects between the ages 18 to 65 were enrolled. Exclusion criteria included a history of other neurological disorders affecting the central nervous system, major psychiatric illnesses (psychosis or dementia), learning disability, colour blindness, and a corrected visual acuity of less than 20/70, the latter in accordance with standard neuropsychological testing protocol. Subjects with a history of pathological gambling, substance abuse, and/or alcohol abuse were also excluded.

2.1.2 Healthy Controls

Healthy controls (HC) between the ages of 18 to 65 were also enrolled. The exclusion criteria for HC subjects were the same as those for mild TBI subjects, with the addition of no history of traumatic brain injuries.

2.2 Subject Recruitment

The study took place at the Sunnybrook Health Sciences Centre in Toronto. Mild TBI subjects were recruited by a research assistant from the outpatient TBI clinic. HC subjects were recruited via study flyers and online advertisements posted throughout the hospital bulletin boards and websites. Interested participants contacted the research assistant via email or telephone.
All subjects were reimbursed for parking and transportation costs after their study visits. The results of the cognitive testing were also made available upon request.

2.3 Ethics

This study was approved by the Research Ethics Board at Sunnybrook Health Sciences Centre, affiliated with the University of Toronto. Informed consent was obtained from all subjects.

2.4 Data Collection Measures

2.4.1 Demographic Data

Demographic variables collected included age, sex, years of education, marital status, living situation, and employment status. The demographic questionnaire was administered to all subjects prior to cognitive testing.

Laterality

The lateral preference of all subjects was also measured as a part of the demographic data collection to match subjects for laterality. Here the Lateral Preference Inventory was used (Coren, 1993). It is a brief, 16-item questionnaire with 4 subscales (4 items per subscale), measuring hand, foot, eye, and ear laterality. Each item asks the subjects to imagine if they were performing a certain activity, and subsequently answer whether they would prefer to use the right side, left side, or either sides of the body. A score of 1, -1, or 0 are assigned to right preference, left preference, and ambilaterality respectively. Scores can therefore range from -4 to 4 for each subscale, with -4 indicating consistent left preference, 4 indicating consistent right
preference, and 0 meaning ambilaterality. For the present study, the handedness subscale is used as the measure for laterality.

2.4.2 Injury Related Data

Injury related data were collected from the trauma notes in the Emergency Room, patients’ medical files, and from interviews conducted by the attending physician and occupational therapist attached to the TBI clinic. Information collected included Glasgow Coma Scale (GCS) scores (if available), duration of Loss of Consciousness (LOC), duration of Post-Traumatic Amnesia (PTA), and duration between the cognitive assessment and the time of the injury.

2.4.3 Pre-injury History

Pre-injury medical history, history of psychiatric illness (including depression, anxiety, bipolar disorder, or schizophrenia), and use of medications was also collected from patients’ medical files and interviews conducted by attending physician and occupational therapist of the TBI clinic.

2.4.4 Cognitive Assessment

Prior to completing the cognitive assessment all subjects were tested for visual acuity with the Snellen near vision eye chart. Colour blindness was also ruled out.
a. Assessment for Social Information Processing

i. Social Perception

*Florida Affect Battery (FAB) Visual Subtests 1 to 5*

The FAB is a measure of emotion perception (Bowers et al., 1998). In the current study, the facial affect subtests 1 to 5 were used to assess facial expression perception.

Subtest 1 of the FAB (Person Discrimination) is a facial identity discrimination task that serves as a perceptual control for subsequent facial affect tasks. In this task, subjects are shown black and white photographs of twenty pairs of unfamiliar female faces. The faces are presented in neutral facial expressions, with surgical caps covering the hair to reduce non-facial identification cues. The subjects are asked to determine whether the faces are of the same or different persons. Half of the trials consist of faces of the same person, while the other half consist of faces of different women.

Subtest 2 of the FAB (Affect Discrimination) is a facial affect discrimination task. Subjects are shown pictures of twenty pairs of different actresses. In half of the trials, the actresses are depicting similar emotional expressions (for example, happiness), while in the other half of the trials the actresses depict different emotional expressions (for example, anger and sadness). The subjects are then asked to identify whether the actresses were displaying similar or different emotions on their faces.

Subtest 3 (Name Affect) is a facial affect naming task. In this task, subjects are presented with individual female faces depicting one of five emotions: happiness, sadness, anger, fear, and neutral. The subjects are asked to verbally label the emotion each woman was showing.
Subtest 4 (Pick Affect) is a facial affect selection task. For each trial in this task, subjects are presented with faces of five different women, each displaying a different emotion. The subjects are then asked to identify the picture of the face corresponding to the emotion named by the test administrator (e.g. point to the angry face).

Lastly, subtest 5 (Match Affect) is a facial affect matching task. For each trial in this task, subjects are presented with a target emotional face on the left side, and five pictures of women each displaying a different emotional expression on the right side. The subjects are asked to select one of the five pictures on the right side that match the emotional expression on the target face on the left side.

There are 20 trials for each subtest, and the number of correctly answered trials constitutes the raw score for each subtest.

ii. **Social Cognition**

*Reading the Mind in the Eyes Test (RMET) Revised Version*

The RMET is a measure of theory of mind (ToM) (Baron-Cohen et al., 2001). It assesses individuals’ abilities to understand other people’s mental states by looking at their eyes. In this task, subjects are presented with 36 black and white photographs of the eye regions of different actors. A choice of four words is simultaneously presented along with each photograph. The subjects are asked to select, out of the four words, the one that best describe what the person in the picture was thinking or feeling. The subjects are encouraged to read all four words before making the most suitable word choice. The subjects are also instructed to consult an accompanying glossary of all the mental state
terms if they were unsure of any word’s definition. A practice trial is presented before the 36 test trials. This test probes how well subjects can place themselves into the minds of others. The raw score is the number of correctly answered trials.

**Yoni Task**

The Yoni task assesses both cognitive and affective ToM. It was designed by Shamay-Tsoory and Aharon-Peretz, and has previously been shown to be sensitive to cognitive and affective theory of mind deficits in people with brain lesions and Parkinson’s disease (Bodden et al., 2010; Shamay-Tsoory & Aharon-Peretz, 2007a). It measures individuals’ abilities to judge others’ mental states based on eye gaze and verbal cues. Here, the 60-trial version used by Bodden et al. (2010) was adapted for the current study.

In each trial, a cartoon face named “Yoni” is presented in the centre of a computer screen, and four coloured pictures of faces or objects belonging to a semantic category (e.g. animals, fruits) are presented, one in each corner of the computer screen. The subjects are asked to point to the correct corner image that could best answer a question presented simultaneously at the top of the computer screen based on the available cues (E.g. Yoni’s eye gaze and facial expression). The trials can be subdivided into three categories that correspond to cognitive ToM, affective ToM, and control conditions. While the control conditions require only the physical attributes of the character for a choice to be made, the ToM trials require mentalizing abilities based on verbal cues contained in the question, eye gaze, and/or facial expression. In cognitive ToM trials both Yoni’s facial expression and the question presented at the top are emotionally neutral, while in affective ToM trials both
cues carry affective information. Each category is further divided into two types: first-order or second-order inferences. In first-order trials, the subjects are asked to infer Yoni’s mental state or physical character (e.g. “Yoni is thinking of...” in cognitive ToM trials, “Yoni likes...” in affective ToM trials, and “Yoni is close to...” in control conditions). In second-order items, the four stimuli consist of face images, and the subjects are asked to infer Yoni’s beliefs and emotions regarding others’ mental states or physical character (e.g. “Yoni is thinking about the car that ... wants” in cognitive ToM trials, “Yoni loves the flower that ... loves” in affective ToM trials, and “Yoni has the animal that ... has” in control conditions). Therefore, there are six conditions in total, each consisting of 10 trials: first-order physical, first-order cognitive ToM, first-order affective ToM, second-order physical, second-order cognitive ToM, and second-order affective ToM. The outcomes for this task are the numbers of correctly answered trials for each condition.

*Interpersonal Reactivity Index (IRI)*

The IRI is a 28-item self-report questionnaire that measures global empathy using a multidimensional approach (Davis, 1983). This IRI consists of four 7-item scales, with two scales measuring cognitive empathy and two subscales measuring affective empathy. The cognitive subscales are: the perspective-taking subscale (PT), assessing the reported tendency to spontaneously adopt the psychological point of view of others (e.g. I sometimes try to understand my friends better by imagining how things look from their perspective); and the fantasy scale (FS), which measures the reported tendency to imaginatively transpose oneself into fictitious characters and situations (e.g. When I am reading an interesting story or novel, I imagine how I would feel if the events in the story
were happening to me). The two affective scales are: the empathic concern scale (EC), which taps into respondents’ feelings of sympathy and concern for others (e.g. I often have tender, concerned feelings for people less fortunate than me); and the personal distress scale (PD), assessing self-oriented feelings of anxiety and discomfort in tense interpersonal settings (e.g. I sometimes feel helpless when I am in the middle of a very emotional situation). For each item subjects are asked to rate themselves on a scale from A to E, where “A” indicates the item does not describe the subject well, and “E” meaning the item describes the subject very well. A score of 0 to 4 is then given to each rating.

The primary outcomes include the four total scores for each subscale, each out of a maximum of 28. The higher the scores on each subscale, the more perspective taking ability, empathic concern, fantasy ideas, and personal distress the subject has.

iii. Social Regulation

Iowa Gambling Task (IGT)

The IGT is a computerized test providing a measure of behavioural decision-making. The detailed instruction for standard test administration can be found elsewhere (Bechara, 2007). In brief, the subjects are presented with four decks of cards faced-down on the screen, labeled A, B, C, and D. Before beginning the task, the subjects are instructed to win the most amount of virtual money by choosing cards from any of the four decks using the computer mouse. After each selection, the computer informs the participants of the amount they have won, followed by the amount they lost, if any. Winnings are accompanied by a happy face and an increasing pitch tone, while losses are accompanied
with a frowning face and a decreasing pitch tone. Two bars appear at the top of the screen to indicate wins and losses: the green bar shows cumulative winnings, and the red bar shows the amount in debt (“borrowed” from the examiner). The subjects start with a fixed $2000 credit “borrowed” from the examiner. Lastly, the subjects are informed that some decks are less advantageous than others, and they can win as long as they stay away from these decks. These decks are not, however, identified in advance, as it is the purpose of the test for the subjects to determine which they are. Subjects are free to switch between the decks of cards at any time, and as often as they wish.

In the current study the decks were stacked according to a previously published schedule (Bechara, 2007). Decks A and B produce high winnings but also higher losses, whereas decks C and D produce modest winnings but smaller losses. Over time, selections from decks C and D yield the highest overall gains, while selections from A and B accrue an overall loss. The subjects are unaware that the test would continue until 100 cards had been drawn. Thus, the IGT is meant to resemble real-life decision making, where outcomes and contingency are uncertain. The number of cards drawn from deck C and D minus the number of cards drawn from decks A and B constitutes the net score and the main outcome measure for this task.

Game of Dice Task (GDT)

The GDT is a relatively newly constructed computerized test based on the concepts of the Iowa Gambling Task (Brand, Fujiwara, et al., 2005). It is used to assess risk-taking behaviour in a gambling situation. In this task, a virtual single dice and a shaker are used. The subjects
are instructed to gain as much fictitious money as possible by guessing the correct number that turns up on a throw of the dice. The subjects are informed that they start from a balance of $1000 and have a total of 18 throws of the dice. Before each throw, subjects may choose to wager on a single number or a combination of numbers (two, three, or four numbers). Each choice is associated with a specific amount of gain and loss depending on the probability of occurrence of the choice (i.e. a single number: $1000 gain/loss; combination of two numbers: $500 gain/loss; combination of three numbers: $200 gain/loss; combination of four numbers: $100 gain/loss). Therefore, if the thrown number is congruent with the selected number(s), the subjects gains the associated amount, while incongruence between the thrown number and the selected number(s) results in the loss of the associated amount. The rules and the extent of gains and losses are explicitly outlined and displayed on the computer screen. The winning probability for each choice can be easily inferred by the ratio of occurrence, and the amount of risk associated with each choice is obvious (e.g. by choosing a single number, there is a 1/6 chance to win $1000 but a 5/6 chance to lose $1000, while by choosing a combination of four numbers, there is a 4/6 chance to win $100 but only a 2/6 chance to lose $100). The results of the throws are pseudo-randomized, with each of the six possible numbers occurring three times in a balanced order within the duration of the task. Finally, the number of remaining throws and the altered capital are also presented simultaneously on the computer screen.

To assess risky decision-makings, the choices of one or two numbers (i.e. probability of winning is less than 50% with high gains but also high losses) are considered risky decisions, whereas the choices of three or four numbers (i.e. probability of winning is 50% or higher
with low gains but also low losses) are classified as safe decisions. A net score (i.e. the number of safe decisions subtracting the number of risky decisions) is generated and used as a raw score for this task.

_Ultimatum Game_

The Ultimatum Game is a widely used laboratory measure of economic decision making. In this study the computerized task designed by Koenigs and Tranel (2007) was adapted. In this task, subjects are told that they will receive a series of offers made by different proposers. A total of 22 offers are made. In each offer, the subject first sees a picture of a proposer making the Ultimatum offer with the proposer’s name (e.g. “John has made you an offer”). Next, the subject sees the offer (some take-it-or-leave-it split of $10, e.g. “John has offered that: He gets $8, you get $2”). Then, the subject sees the prompt “Accept or Reject?” on the screen. The subject has unlimited time to consider the offer before selecting either “Accept” or “Reject” options using the computer mouse. After selection, the subject is informed of the outcome based on his/her response (e.g. “You both get $0” if the offer was rejected or “You get $2” if the offer was accepted). Before beginning the task, the subject is also informed that the offers are real and made before the task administration. The subject is also told that his or her response for each offer will not affect subsequent offers, and that both the subject and the proposer will be paid according to the participant’s decision. There is a 3-second interval between trials, and the 22 pictured “proposers” are ethnically diverse to match the demographic diversity of the region.
All subjects receive the same 22 offers in fixed random order, and the offers are predetermined according to a previously published schedule (Koenigs & Tranel, 2007). Out of the 22 offers, there are two offers of $5 (the proposer keeps $5) and two offers of $4 (the proposer keeps $6). These four offers are considered to be fair based on previous empirical data (Güth, Schmittberger, & Schwarze, 1982; Koenigs & Tranel, 2007). The remaining 18 offers are considered to be unfair: six offers of $3 (the proposer keeps $7), six offers of $2 (the proposer keeps $8), and six offer of $1 (the proposer keeps $9).

The number of offers each subject accepts for each type of offers constitutes the raw scores. Therefore, five raw scores are generated for this test: the number of accepted offers for $5/$5 split, for $4/$6 split, for $3/$7 split, for $2/$8 split, and for $1/$9 split.

b. Assessment for Non-Social Cognitive Functioning

i. Attention and Working Memory

*D2 Test*

The standard version of the D2 test is a useful measure of attention and concentration processes. In this test, subjects are presented with 14 rows (trials) of letters on a single page (Brickenkamp & Zillmer, 1998). Each row contains 47 interspersed letter “p”s and letter “d”s. Each letter may have one to four dashes configured individually or in pairs above and/or below the character. The subjects are instructed to cross out, with a pencil, any letter “d”s with two dashes (hence “d2”), regardless of whether the dashes appear both above the “d”, both below the “d”, or one above and one below the “d”. Subjects are also instructed not to cross out any letter “p”s and any letter “d”s with more or less than two dashes (which are
distracters). Finally, the subjects are instructed to cancel out as many correct d2s as possible, moving from left to right, within a duration of 20s per trial. No pauses are allowed between trials.

Several pre-established performance scores can be calculated for this test. For the purpose of the current study, the concentration performance score (CP) was calculated and adapted as the primary outcome measure. The CP score has been shown to be a superior measure of overall performance on this test, appropriately reflecting both the speed and the accuracy of task performance (Bates & Lemay, 2004). For each trial, the CP score is calculated by subtracting the total number of incorrectly cancelled letters from the number of correctly cancelled letters. A total CP score is then calculated by adding the scores of the 14 trials together, and this constitutes the raw score of this test.

*Digit Span Forward and Backward (DS Forward and Backward)*

The DS is a test measuring attention and working memory. The DS in the standardized version of the Wechsler Adult Intelligence Scale-Third Edition was used in the current study (Wechsler, 1997). The DS consists of a forward and a backward part independent of each other. For both parts, subjects are read a series of number sequences at one digit per second and are then asked to repeat them. In the DS forward component, subjects are asked to repeat the span in the same order as presented, whereas in the DS backward part, subjects are asked to repeat the sequence in the reverse order. The DS forward begins with 3 digits and ends with a maximum length of 9 digits, whereas the DS backward begins with 2 digits and ends with a maximum length of 8 digits. Two trials are presented at each digit
length. A score of one is given to each correctly answered trial. The test is discontinued when subjects fail both trials at the same digit length. The numbers of correctly answered trials for each part constitute the raw scores for this test.

**ii. Memory**

*Doors Test*

The Doors test is a measure of visual memory and recognition taken from the Doors and People Battery (Baddeley, Emslie, & Nimmo-Smith, 1994). The test has two parts. In each part, subjects are shown 12 consecutive target doors, each individually presented for 3 seconds. This is followed by the presentation of 12 two by two arrays, each containing three distractor doors along with a target item. The distractors and target fit the same general label (e.g. house door). The subjects are instructed to choose one door out of the four doors that they have seen before. The second part of the test is harder than the first in that the distractors and the targets are more similar than in the first part. Each correct answer receives a score of 1, with 24 being the maximum score possible. The raw score for this test is the number of correct answers.

*Verbal Selective Reminding Test (VSRT)*

The VSRT is a measure of short-term and long-term memory (Buschke & Fuld, 1974). The 6 learning trials from the Brief Repeatable Battery were used in the current study. In this test, subjects are first read a list of 12 unrelated words (beg, darling, sink, toothache, float, middle, echo, hook, pure, dish, strip, and fact) at a rate of one word per 2 second. The subjects are subsequently asked to recall as many words as they remembered in any order.
Thereafter, the examiner repeats only those words that were not given by the subjects in the immediately preceding trial, until the completion of six trials. Subjects are instructed to recall as many words as they can after each learning trial, including the ones they might have said already.

Scoring followed the instructions of Buschke and Fuld (1974). A word spontaneously recalled for two consecutive trials is considered to have entered long term storage (LTS), and is scored as such for all subsequent trials regardless of whether the word is called. The primary outcome measure is the total sum of the words in LTS for all six trials (VSRT – LTS). If a word in LTS is consistently recalled on all subsequent trials (not just the last trial), it is considered to have entered consistent long term retrieval (CLTR). The secondary primary outcome measure is the total sum of words in CLTR from all six trials (VSRT – CLTR). Lastly, a third measure records the total number of words recalled after a delayed period of 15 minutes (delayed recall or VSRT – Delay).

**iii. Language**

*Semantic Fluency Test*

The semantic fluency test is a measure of language (Randolph, Tierney, Mohr, & Chase, 1998). Subjects are instructed to name as many animals as possible in one minute, irrespective of what letters of the alphabet they started with. The outcome for this test is the total number of animals named by subjects in one minute.
**Boston Naming Test (BNT)**

The BNT is a test used to assess naming ability (Kaplan, Goodglass, & Weintraub, 1983). In this test, subjects are asked to name 60 line-drawing pictures of common objects presented in decreasing order of frequency ranging from “bed” to “abacus”. If an object is misperceived by the subject (e.g. subject says “snake” instead of pretzel), a stimulus cue is given to provide conceptual information (e.g. “it is something to eat”). If the subject is unable to answer after the stimulus cue, or gives an incorrect answer, a phonemic cue is then given using the sound produced by the initial letter of the object (e.g. “it is a pre…”). The number of items correctly identified (spontaneously recalled, after stimulus cue, and after phonemic cue) constitutes the raw score for this test.

**iv. Executive Function**

**Trail-Making Test A and B (TMT A and B)**

The TMT is a test assessing cognitive flexibility, speed of information processing, and attention (Reitan, 1992). It consists of two parts. In part A, subjects are instructed to connect a series of 25 encircled numbers in ascending order using a pencil as quickly as possible. In part B, subjects are asked to connect 25 encircled numbers and letters in ascending numerical and alphabetical order, alternating between the numbers and the letters (i.e. 1-A-2-B-3-C etc.). Practice trials consisting of eight circles containing only numbers or numbers and letters are conducted before each part. Any errors are corrected by the test administrator and sequence is re-established immediately. The amount of time spent on part B constitutes the primary outcome for this test. The differences between the
amount of time spent on part B and part A (B minus A) constitutes the secondary outcome for this measure.

**Stroop Test**

The Stroop Test is a measure of executive function (Stroop, 1935). It measures the reaction time used to complete an interference task when subjects are asked to selectively identify a certain aspect of a stimulus (the colour in which the word is written) while ignoring another prominent feature (the semantic meaning of the word). A computerized version was used in the present study. In the first condition, subjects are presented with a list of names of colours (red, purple, green etc.) and asked to read them aloud. In the second condition, subjects are presented with a screen with different coloured squares and asked to identify the colour of each square. Lastly, subjects are presented with a list of names of colours written in different colours and asked to identify the colours the words are written in rather than the names of the words. Subjects are asked to complete all three conditions as quickly as they can. The administrator starts and finishes each condition by striking the space bar, and the computer automatically generates the time used to complete each task. The time used to complete the final condition, recorded in seconds, constitutes the raw score for this test.

**Phonemic Fluency Test**

Phonemic fluency is a measure of verbal fluency and executive function (Rosen, 1980; Spreen & Benton, 1977). Subjects are instructed to generate as many words as possible in one minute for a given letter of the alphabet. Subjects are also instructed to refrain from
using proper nouns such as names of people or places (e.g. “Nancy” or “Nigeria”), counting numbers (e.g. ninety-one, ninety-two, ninety-three, etc...), and using similar words with different endings (e.g. “nap”, “naps”, “napping”, “napped” would only count as one word).

Three trials are presented using the letters F, A, and S. The total number of words generated in the three trials constitutes the primary outcome for this test.

Behavioral Dyscontrol Scale (BDS)

The BDS is a brief measure assessing individuals’ capacities for executive, behavioural control (Grigsby, Kaye, & Robbins, 1992). The BDS has nine items with each item scored from 0 to 2 giving a possible total score of 27 points. Seven of the items assess control of motor functioning (e.g. participant squeezes the examiner’s hand when the examiner says “red”, and does nothing when examiner says “green”). One item assesses working memory and mental flexibility (i.e. alternate counting numbers with alphabets: “1a2b3c...”), and the final item is the examiner’s rating of the participant’s quality of awareness into his or her own performance. The primary measure for this test is the total score out of 27.

v. Visuospatial Orientation

Judgment of Line Orientation (JLO)

The JLO is a test measuring visuospatial skills (Benton, Hamsher, Varney, & Spreen, 1983). Subjects are presented with a key of eleven lines arranged from 0 to 180 degrees (18 degrees apart) numbered 1 to 11. For each trial, two stimuli lines are simultaneously presented above the key, each in a different orientation corresponding to one of the lines in the key. The subjects are instructed to verbally match the two stimuli lines with their
associated numbers using the key. A practice of 5 trials is conducted before starting 30 test trials. The raw score is the total number of correct responses out of 30.

2.4.5 Effort Testing

The Rey 15 Item Test was used in the current study as a measure of effort put forth during psychometric testing (Rey, 1964). In this quick test, subjects are presented with a card showing five rows of three characters each (A B C, 1 2 3, a b c, □ ○ Δ, I II III). Subjects are given the card for 10 seconds and instructed to memorize the items. They are then asked to reproduce the card on a blank piece of paper. Subjects are told the test is difficult, whereas in reality, it is not given the redundancy and ordering of the items. People with cognitive impairment are capable of performing the task with a correct response rate that exceeds chance. Individuals who wish to exaggerate or feign their symptoms on the other hand, may score below chance.

The number of correctly remembered items constitutes the raw score for this test. A score of 8 or less is deemed a fail according to previously established cut-off score in the literature (Lezak, 2004). Subjects who failed the test were excluded from the analyses.

2.4.6 Depression and Anxiety

Depression and anxiety of all mild TBI and HC subjects were assessed using the 14-item Hospital Anxiety and Depression Scale (HADS; Zigmond & Snaith, 1983). The HADS is a self-report questionnaire measuring mood within one week prior to cognitive assessment that has been previously used in the TBI population (Schönberger & Ponsford, 2010). The scale consists of 7 items measuring depression and 7 items measuring anxiety. Each item is scored from 0 to 3.
Therefore, the total score for each subscale ranges from 0 to 21, with a score of 8 or above used to indicate clinically significant anxiety or depression.

2.5 Testing Procedures

All of the subjects were administered a battery of tests in the same order. The testing processing was completed in a single 3-hour session. The order of test administration was as follows:

1) Informed consent
2) Interview to obtain demographic data
3) Visual acuity test with Snellen eye chart
4) D2 test of attention
5) TMT A and B
6) DS forward and backward
7) VSRT – Immediate recall trials
8) Stroop test
9) Rey 15 Item test
10) Doors test
11) GDT
12) VSRT – Delayed recall trial
13) RMET
14) Yoni task
15) Ultimatum game
16) IGT
17) Phonemic fluency test (FAS)
18) Semantic fluency test (Animals)
19) JLO
20) BNT
21) FAB (Subtests 1 to 5)
22) HADS
23) BDS
24) IRI

2.6 Statistical Analysis

Statistical analyses were conducted using IBM SPSS (Version 22). Normality of demographics, psychiatric, and cognitive data distribution was assessed using the Kolmogorov-Smirnov test. For between-group demographic comparisons, a two-sided t-tests was used for normally distributed data. When normality was violated, logarithmic transformation was applied. Ordinal data were compared using chi-squared analyses.

Tests were grouped into different domains as outlined above. For Non-social cognition, the domains were: attention/working memory, memory, language, executive function, and visuospatial orientation. For social information processing, the domains were: social perception, social cognition, and social regulation.

Between-group comparisons of performances on non-social cognitive and social information processing domains were conducted using multivariate analyses of variances (MANOVA) to reduce the number of statistical comparisons. Univariate analyses of variances (ANOVA) were used for single-test domains. The between-group factors were: mild TBI versus healthy control; cognitively impaired versus intact mild TBI subjects; and mild TBI subjects who had returned to work versus those who had not.
**Mild Global Non-social Cognitive Impairment**

Mild impairment on a cognitive test was defined as a score of 1.5 SD below the mean score obtained from healthy control subjects matched for age, gender, and years of education (Knopman et al., 2015). Failure in a cognitive domain was defined as impairment in any one test in that domain. For example, subjects were deemed to have failed in attention/working memory domain if they have scored 1.5 SD below the healthy control mean score in any of the following indices: D2 concentration performance, DS forward, or DS backward. Likewise, subjects were deemed to have failed the memory domain if they have scored 1.5 SD below the healthy control mean score in the Doors test, VSRT – LTS, VSRT – CLTR, or VSRT – Delay. For the language domain, a failure was deemed when subjects scored 1.5 SD lower than health control means in the BNT or the semantic fluency test. Finally, failure in the executive function domain was deemed when subjects have scored 1.5 SD lower than healthy control means in the phonemic fluency test, TMT B, TMT B-A, Stroop test, or BDS. Mild global non-social cognitive impairment was then defined as failure in two or more cognitive domains (see results for rationale).
CHAPTER 3: RESULTS

3.1 Sample Demographics and Injury Related Data

A total of 51 mild TBI and 30 HC subjects were recruited. Four mild subjects were excluded from analyses due to either a previous medical history of stroke or brain tumour (n=2), or a failure on the Rey-15-Item Test. Therefore, the final sample for analyses included 47 mild TBI and 30 HC subjects. Demographic and psychiatric comparisons between mild TBI and HC subjects are shown in Table 1. There were no differences with respect to age, gender, and years of education between mild TBI and HC subjects. There were also no differences in laterality between the two groups. However, the mild TBI group reported higher anxiety and depression scores than the HC group. A cut-off score of 8 or more on the two subscales of the Hospital Anxiety and Depression Scale (HADS) was used to determine clinically significant anxiety and depression. Based on this cut-off, 27 (57.4%) of mild TBI subjects and 5 (16.7%) HC subjects were considered to have clinically significant anxiety, and 21 (44.7%) mild TBI subjects and 3 (10.0%) HC subjects were considered to be depressed ($\chi^2=12.538$, $p < 0.001$ and $\chi^2=10.266$, $p = 0.001$ for anxiety and depression, respectively).

The mean GCS was 14.59 (SD = 0.57, range: 13 – 15) and the time between injury and cognitive testing was 194.70 days (SD = 123.01, range: 75 – 495, in days). Where GCS information was not available (n = 18), mild TBI severity was defined by either a loss of consciousness (LOC) of less than 30 minutes, or a post-traumatic amnesia (PTA) of less than 24 hours.
Table 1: Demographic and psychiatric data between mild TBI and HC subjects

<table>
<thead>
<tr>
<th></th>
<th>Mild TBI subjects – mean (SD) / frequency (%)</th>
<th>HC subjects – mean (SD) / frequency (%)</th>
<th>t-test/x²</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (Years)</td>
<td>41.32 (11.47)</td>
<td>41.83 (13.49)</td>
<td>t = -0.173</td>
<td>p = 0.864</td>
</tr>
<tr>
<td>Sex (% female)</td>
<td>18 (38.3%)</td>
<td>12 (40.0%)</td>
<td>x² = 0.022</td>
<td>p = 0.881</td>
</tr>
<tr>
<td>Years of Education</td>
<td>16.98 (2.47)</td>
<td>16.40 (2.31)</td>
<td>t = 1.026</td>
<td>p = 0.308</td>
</tr>
<tr>
<td>Laterality – Hand</td>
<td>3.06 (1.76)</td>
<td>2.87 (2.01)</td>
<td>t = 0.453</td>
<td>p = 0.652</td>
</tr>
<tr>
<td>HADS – Anxiety</td>
<td>8.81 (4.53)</td>
<td>3.70 (3.33)</td>
<td>t = 5.322</td>
<td>p &lt; 0.001</td>
</tr>
<tr>
<td>HADS – Depression</td>
<td>7.32 (4.27)</td>
<td>2.43 (2.90)</td>
<td>t = 5.980</td>
<td>p &lt; 0.001</td>
</tr>
</tbody>
</table>

Abbreviation: HADS – Hospital Anxiety and Depression Scale
3.2 Comparison of Non-Social Cognitive and Social Information Processing Data between Mild TBI and HC Subjects

3.2.1 Non-Social Cognitive Data

Four one-way MANOVA analyses were carried out to compare the non-social cognitive domains with multiple measures (attention/working memory, memory, language, and executive function) between mild TBI and healthy control groups. The correlations between different measures within the same cognitive domain are shown in Table 2. ANOVA was used to compare performances between mild TBI and healthy control groups in the visuospatial orientation domain, since a single measure, namely the Judgment of Line Orientation Test, was used.

The above analyses revealed significant differences between mild TBI and HC subjects for executive function only ($F = 2.787, p = 0.024$). Within the executive function domain, mild TBI subjects were significantly slower than healthy control subjects on the TMT B ($p = 0.002$, effect size (partial $\eta^2$): 0.129), the TMT B-A ($p = 0.010$, partial $\eta^2$: 0.089), and the Stroop test ($p = 0.004$, partial $\eta^2$: 0.109). Comparisons between the mild TBI subjects and the healthy controls on the non-social cognitive test are shown in Table 3.
Table 2: Spearman correlations between non-social cognitive measures within the same domain

<table>
<thead>
<tr>
<th></th>
<th>Attention / Working Memory</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DS Forward</td>
<td>DS Backward</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D2 CP</td>
<td>-0.007</td>
<td>0.108</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DS Forward</td>
<td>-</td>
<td></td>
<td>0.502**</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Memory</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>VSRT LTS</td>
<td>VSRT CLTR</td>
<td>VSRT Delay</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Doors Test</td>
<td>0.312**</td>
<td>0.323**</td>
<td>0.275*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VSRT LTS</td>
<td>-</td>
<td></td>
<td>0.904**</td>
<td>0.820**</td>
<td></td>
</tr>
<tr>
<td>VSRT CLTR</td>
<td>-</td>
<td></td>
<td></td>
<td>0.815**</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Language</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BNT</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Semantic Fluency – Animal</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.364**</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

|                              | Executive Function          |                         |               |                         |               |
|                              | TMT B                       | TMT B-A                 | Stroop        | BDS                     |               |
| Phonemic Fluency – FAS       | -0.284*                     | -0.261*                 | -0.383**      | 0.261*                  |               |
| TMT B                        | -                           |                         | 0.875**       | 0.581**                 | -0.391**      |
| TMT B-A                      | -                           | -                       | 0.433**       | -0.311**                |               |
| Stroop                       | -                           |                         | -0.366**      |                         |               |

Abbreviations: TMT – Trail Making Test; CP – Concentration Performance; DS – Digit Span; VSRT – Verbal Selective Reminding Test; LTS – Long Term Storage; CLTR – Consistent Long Term Retrieval; JLO – Judgment of Line Orientation Test; BNT – Boston Naming Test

* p < 0.05, ** p < 0.01
Table 3: Comparison of non-social cognition between mild TBI and HC subjects

<table>
<thead>
<tr>
<th></th>
<th>mild TBI (n=47) Mean (SD)</th>
<th>Healthy Controls (n=30) Mean (SD)</th>
<th>MANOVAs and ANOVA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>df</td>
<td>F</td>
</tr>
<tr>
<td>Attention / Working memory</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>[Wilks’ λ=0.931, F(3, 72)=1.791, p = 0.157, partial η²=0.069]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D2 CP</td>
<td>162.54 (49.69)</td>
<td>1</td>
<td>2.915</td>
</tr>
<tr>
<td>DS Forward</td>
<td>9.85  (2.27)</td>
<td>1</td>
<td>2.182</td>
</tr>
<tr>
<td>DS Backward</td>
<td>6.60  (1.84)</td>
<td>1</td>
<td>0.429</td>
</tr>
<tr>
<td>Memory [Wilks’ λ = 0.963, F(4,68)=0.653, p=0.627, partial η²=0.037]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Doors Test</td>
<td>16.89   (4.25)</td>
<td>1</td>
<td>0.696</td>
</tr>
<tr>
<td>VSRT – LTS</td>
<td>32.11 (14.73)</td>
<td>1</td>
<td>1.256</td>
</tr>
<tr>
<td>VSRT – CLTR</td>
<td>24.87 (14.87)</td>
<td>1</td>
<td>0.937</td>
</tr>
<tr>
<td>VSRT – Delay</td>
<td>6.63  (3.04)</td>
<td>1</td>
<td>0.095</td>
</tr>
<tr>
<td>Language [Wilks’ λ = 0.968, F(2,73)=1.188, p=0.311, partial η²=0.032]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BNT</td>
<td>53.65   (6.66)</td>
<td>1</td>
<td>0.256</td>
</tr>
<tr>
<td>Semantic Fluency – Animal</td>
<td>21.53  (4.61)</td>
<td>1</td>
<td>2.406</td>
</tr>
<tr>
<td>Executive Function [Wilks’ λ = 0.828, F(5,67)=2.787, p=0.024, partial η²=0.172]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phonemic Fluency – FAS</td>
<td>39.64 (12.89)</td>
<td>1</td>
<td>3.700</td>
</tr>
<tr>
<td>TMT B</td>
<td>78.40 (30.50)</td>
<td>1</td>
<td>10.543</td>
</tr>
<tr>
<td>TMT B-A</td>
<td>43.36 (24.81)</td>
<td>1</td>
<td>6.969</td>
</tr>
<tr>
<td>Stroop Test</td>
<td>31.22 (11.42)</td>
<td>1</td>
<td>8.647</td>
</tr>
<tr>
<td>BDS</td>
<td>22.29  (2.59)</td>
<td>1</td>
<td>1.032</td>
</tr>
<tr>
<td>Visuospatial Orientation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>JLO</td>
<td>21.32  (4.37)</td>
<td>1</td>
<td>3.635</td>
</tr>
</tbody>
</table>

Abbreviations: CP – Concentration Performance; DS – Digit Span; VSRT – Verbal Selective Reminding Test; LTS – Long Term Storage; CLTR – Consistent Long Term Retrieval; BNT – Boston Naming Test; TMT – Trail Making Test; BDS – Behavioral Dyscontrol Scale; JLO – Judgment of Line Orientation.
3.2.2 Social Information Processing Data

Three ANOVA analyses were carried out to compare performances between mild TBI subjects and the healthy control subjects on the control tests, and revealed no differences between-group. The control tests were the FAB Person Discrimination subtest (mild TBI: Mean = 19.68 [SD = 0.81] vs. HC: Mean = 19.67 [SD = 0.61], F=0.001, p=0.975), the first-order physical trials of the Yoni Task (mild TBI: Mean = 9.78 [SD = 0.60] vs. HC: Mean = 9.45 [SD = 1.15], F=2.636, p=0.109), and the second-order physical trials of the Yoni Task (mild TBI: Mean = 8.20 [SD = 2.03] vs. HC: Mean = 8.00 [SD = 1.91], F=0.235, p=0.629).

Three one-way MANOVA analyses were carried out to compare social information processing domains between the mild TBI group and the healthy control group. The correlations between different measures within the same social information processing domain are shown in Table 4. The comparisons between-group revealed no significant differences between mild TBI and HC subjects on the social information processing domains. However, mild TBI subjects scored significantly lower on the IGT compared to healthy control subjects (F=5.183, p=0.026, partial η²: 0.065). Comparison of performances on social information processing measures between mild TBI and healthy control subjects are shown in Table 5.
Table 4: Correlations between social information processing measures within the same domain

<table>
<thead>
<tr>
<th></th>
<th>Social Perception</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FAB – NA</td>
<td>FAB – PA</td>
<td>FAB – MA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FAB – AD</td>
<td>0.264*</td>
<td>0.213</td>
<td>0.235*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FAB – NA</td>
<td>-</td>
<td>0.277*</td>
<td>0.275**</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FAB – PA</td>
<td>-</td>
<td>-</td>
<td>0.387**</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Social Cognition</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Yoni Task 1st Cog</td>
<td>0.181</td>
<td>0.099</td>
<td>0.460**</td>
<td>0.406**</td>
<td>0.116</td>
<td>0.164</td>
<td>0.106</td>
<td>-0.135</td>
</tr>
<tr>
<td>Yoni Task 1st Aff</td>
<td>-</td>
<td>0.716**</td>
<td>0.429**</td>
<td>0.229</td>
<td>0.120</td>
<td>0.020</td>
<td>-0.105</td>
<td>-0.125</td>
</tr>
<tr>
<td>Yoni Task 2nd Cog</td>
<td>-</td>
<td>-</td>
<td>0.448**</td>
<td>0.334**</td>
<td>0.070</td>
<td>0.101</td>
<td>0.054</td>
<td>0.037</td>
</tr>
<tr>
<td>Yoni Task 2nd Aff</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.597**</td>
<td>0.161</td>
<td>0.114</td>
<td>0.072</td>
<td>0.040</td>
</tr>
<tr>
<td>IRI – FS</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.162</td>
<td>0.107</td>
<td>0.114</td>
<td>-0.022</td>
</tr>
<tr>
<td>IRI – PT</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.105</td>
<td>0.174</td>
<td>-0.014</td>
</tr>
<tr>
<td>IRI – EC</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.495**</td>
<td>-0.386**</td>
</tr>
<tr>
<td>IRI – PD</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-0.044</td>
</tr>
</tbody>
</table>

Abbreviations: FAB – Florida Affect Battery; AD – Affect Discrimination; NA – Name Affect; PA – Pick Affect; MA – Match Affect; RMET – Reading the Mind in the Eyes Test. IRI – Interpersonal Reactivity Index; FS – Fantasy Scale; PT – Perspective Taking; EC – Empathic Concern; PD – Personal Distress

*p < 0.05, **p < 0.01
Table 4: Correlation matrix between social information processing measures within the same domain, continued

<table>
<thead>
<tr>
<th></th>
<th>Social Regulation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ultimatum 4/6</td>
</tr>
<tr>
<td>Ultimatum 5/5</td>
<td>0.401**</td>
</tr>
<tr>
<td>Ultimatum 4/6</td>
<td>-</td>
</tr>
<tr>
<td>Ultimatum 3/7</td>
<td>-</td>
</tr>
<tr>
<td>Ultimatum 2/8</td>
<td>-</td>
</tr>
<tr>
<td>Ultimatum 1/9</td>
<td>-</td>
</tr>
<tr>
<td>GDT</td>
<td>-</td>
</tr>
</tbody>
</table>

Abbreviations: GDT – Game of Dice Task; IGT – Iowa Gambling Task; BDS – Behavioral Dyscontrol Scale.
* $p < 0.05$, ** $p < 0.01$
### Table 5: Comparison of social information processing data between mild TBI and HC subjects

<table>
<thead>
<tr>
<th></th>
<th>mild TBI (n=47) Mean (SD)</th>
<th>Healthy controls (n=30) Mean (SD)</th>
<th>df</th>
<th>F</th>
<th>p</th>
<th>Partial η²</th>
<th>Observed Power</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Social Perception</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wilks’ λ = 0.960, F(4,72)=0.754, p=0.559, partial η²=0.040</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FAB AD</td>
<td>16.79 (1.96)</td>
<td>17.03 (1.50)</td>
<td>1</td>
<td>0.466</td>
<td>0.497</td>
<td>0.006</td>
<td>0.103</td>
</tr>
<tr>
<td>FAB NA</td>
<td>17.87 (1.58)</td>
<td>17.83 (1.21)</td>
<td>1</td>
<td>0.000</td>
<td>0.989</td>
<td>0.000</td>
<td>0.050</td>
</tr>
<tr>
<td>FAB PA</td>
<td>19.00 (1.04)</td>
<td>19.00 (1.20)</td>
<td>1</td>
<td>0.001</td>
<td>0.971</td>
<td>0.000</td>
<td>0.050</td>
</tr>
<tr>
<td>FAB MA</td>
<td>17.30 (1.89)</td>
<td>17.97 (2.04)</td>
<td>1</td>
<td>1.706</td>
<td>0.195</td>
<td>0.022</td>
<td>0.252</td>
</tr>
<tr>
<td><strong>Social Cognition</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wilks’ λ = 0.848, F(9,63)=1.253, p=0.280, partial η²=0.152</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RMET</td>
<td>25.15 (4.02)</td>
<td>26.00 (4.96)</td>
<td>1</td>
<td>1.581</td>
<td>0.213</td>
<td>0.022</td>
<td>0.237</td>
</tr>
<tr>
<td>Yoni Task 1st Cog</td>
<td>9.11 (1.84)</td>
<td>8.76 (2.69)</td>
<td>1</td>
<td>1.035</td>
<td>0.312</td>
<td>0.014</td>
<td>0.171</td>
</tr>
<tr>
<td>Yoni Task 1st Aff</td>
<td>9.02 (1.90)</td>
<td>8.69 (2.14)</td>
<td>1</td>
<td>0.329</td>
<td>0.568</td>
<td>0.005</td>
<td>0.087</td>
</tr>
<tr>
<td>Yoni Task 2nd Cog</td>
<td>8.20 (2.03)</td>
<td>8.00 (1.91)</td>
<td>1</td>
<td>0.771</td>
<td>0.383</td>
<td>0.011</td>
<td>0.139</td>
</tr>
<tr>
<td>Yoni Task 2nd Aff</td>
<td>7.93 (2.02)</td>
<td>8.10 (1.76)</td>
<td>1</td>
<td>0.000</td>
<td>0.992</td>
<td>0.000</td>
<td>0.050</td>
</tr>
<tr>
<td>IRI – FS</td>
<td>14.04 (5.72)</td>
<td>16.23 (6.11)</td>
<td>1</td>
<td>2.797</td>
<td>0.099</td>
<td>0.038</td>
<td>0.378</td>
</tr>
<tr>
<td>IRI – PT</td>
<td>18.81 (5.20)</td>
<td>19.37 (4.18)</td>
<td>1</td>
<td>0.492</td>
<td>0.485</td>
<td>0.007</td>
<td>0.106</td>
</tr>
<tr>
<td>IRI – EC</td>
<td>21.11 (4.50)</td>
<td>21.03 (4.65)</td>
<td>1</td>
<td>0.000</td>
<td>0.994</td>
<td>0.000</td>
<td>0.050</td>
</tr>
<tr>
<td>IRI – PD</td>
<td>11.15 (6.10)</td>
<td>8.60 (5.39)</td>
<td>1</td>
<td>3.472</td>
<td>0.067</td>
<td>0.047</td>
<td>0.452</td>
</tr>
</tbody>
</table>

Abbreviations: FAB – Florida Affect Battery; AD – Affect Discrimination; NA – Name Affect; PA – Pick Affect; MA – Match Affect; RMET – Reading the Mind in the Eyes Test. IRI – Interpersonal Reactivity Index; FS – Fantasy Scale; PT – Perspective Taking; EC – Empathic Concern; PD – Personal Distress
<table>
<thead>
<tr>
<th></th>
<th>mild TBI (n=47) Mean (SD)</th>
<th>Healthy controls (n=30) Mean (SD)</th>
<th>df</th>
<th>F</th>
<th>p</th>
<th>Partial η²</th>
<th>Observed Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Social Regulation [Wilks’ λ = 0.870, F(7,68)=1.453, p=0.199, partial η²=0.130]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ultimatum 5/5</td>
<td>1.77 (0.52)</td>
<td>1.93 (0.25)</td>
<td>1</td>
<td>2.247</td>
<td>0.138</td>
<td>0.029</td>
<td>0.316</td>
</tr>
<tr>
<td>Ultimatum 4/6</td>
<td>1.55 (0.72)</td>
<td>1.53 (0.82)</td>
<td>1</td>
<td>0.064</td>
<td>0.801</td>
<td>0.001</td>
<td>0.057</td>
</tr>
<tr>
<td>Ultimatum 3/7</td>
<td>2.98 (2.71)</td>
<td>3.50 (2.60)</td>
<td>1</td>
<td>0.910</td>
<td>0.343</td>
<td>0.012</td>
<td>0.156</td>
</tr>
<tr>
<td>Ultimatum 2/8</td>
<td>2.23 (2.46)</td>
<td>2.67 (2.72)</td>
<td>1</td>
<td>0.542</td>
<td>0.464</td>
<td>0.007</td>
<td>0.112</td>
</tr>
<tr>
<td>Ultimatum 1/9</td>
<td>1.46 (2.13)</td>
<td>2.10 (2.73)</td>
<td>1</td>
<td>0.563</td>
<td>0.456</td>
<td>0.008</td>
<td>0.115</td>
</tr>
<tr>
<td>GDT</td>
<td>5.70 (11.54)</td>
<td>8.80 (10.62)</td>
<td>1</td>
<td>1.087</td>
<td>0.301</td>
<td>0.014</td>
<td>0.177</td>
</tr>
<tr>
<td>IGT</td>
<td>7.96 (25.85)</td>
<td>21.27 (28.78)</td>
<td>1</td>
<td>5.183</td>
<td>0.026</td>
<td>0.065</td>
<td>0.613</td>
</tr>
</tbody>
</table>

Abbreviations: GDT – Game of Dice Task; IGT – Iowa Gambling Task
3.2.3 Influence of anxiety and depression on task performances

To control for the effects of anxiety and depression on test performances, MANCOVA analyses were carried out to compare the non-social cognitive domains with multiple measures between the mild TBI and the healthy control group. HADS anxiety and depression caseness were entered as covariates. ANCOVA was used to compare visuospatial orientation domain between mild TBI and HC subjects while controlling for HADS casesness. These also revealed significant differences between the two groups for executive function ($F = 2.508, p = 0.039$), although the strength of significance changed. Within the executive function domain, mild TBI subjects were significantly slower than healthy control subjects on the TMT B ($p = 0.003$, partial $\eta^2$: 0.124), TMT B-A ($p = 0.003$, partial $\eta^2$: 0.122), and the Stroop test ($p = 0.022$, partial $\eta^2$: 0.074).

Comparisons between mild TBI subjects and healthy controls on the non-social cognitive measures while controlling anxiety and depression are shown in Table 6.

ANCOVA analyses did not reveal significant differences in performances between the mild TBI and the healthy control group on the control tests, namely the FAB Person Discrimination ($F = 0.088, p = 0.768$), the Yoni Task first-order physical trials ($F = 3.623, p = 0.061$), and the Yoni Task second-order physical trials ($F = 0.538, p = 0.466$). MANCOVA analyses comparing social information processing domains while controlling for HADS anxiety and depression caseness did not reveal significant differences between-group. While the mild TBI subjects scored significantly lower on the IGT than the healthy control subjects before analyses of covariance, such significance was not observed after controlling for anxiety and depression. The MANCOVA
comparisons between the mild TBI and the healthy control groups on the social information processing domains are shown in Table 7.
Table 6: Comparison of non-social cognition between mild TBI and HC subjects after controlling for anxiety and depression caseness

<table>
<thead>
<tr>
<th></th>
<th>Mild TBI (n=47) Mean (SD)</th>
<th>Healthy Controls (n=30) Mean (SD)</th>
<th>df</th>
<th>F</th>
<th>p</th>
<th>Partial $\eta^2$</th>
<th>Observed Power</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Attention / Working memory</strong> [Wilks' $\lambda=0.904$, $F(3, 70)=2.481$, $p = 0.068$, partial $\eta^2=0.096$]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D2 CP</td>
<td>162.54 (49.69)</td>
<td>184.57 (62.27)</td>
<td>1</td>
<td>2.390</td>
<td>0.127</td>
<td>0.032</td>
<td>0.332</td>
</tr>
<tr>
<td>DS Forward</td>
<td>9.85 (2.27)</td>
<td>10.53 (2.15)</td>
<td>1</td>
<td>3.385</td>
<td>0.070</td>
<td>0.045</td>
<td>0.443</td>
</tr>
<tr>
<td>DS Backward</td>
<td>6.60 (1.84)</td>
<td>7.17 (2.48)</td>
<td>1</td>
<td>0.067</td>
<td>0.797</td>
<td>0.001</td>
<td>0.058</td>
</tr>
<tr>
<td><strong>Memory</strong> [Wilks' $\lambda = 0.948$, $F(4,66)=0.913$, $p=0.462$, partial $\eta^2=0.052$]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Doors Test</td>
<td>16.89 (4.25)</td>
<td>16.20 (3.03)</td>
<td>1</td>
<td>0.313</td>
<td>0.578</td>
<td>0.005</td>
<td>0.086</td>
</tr>
<tr>
<td>VSRT – LTS</td>
<td>32.11 (14.73)</td>
<td>33.40 (12.17)</td>
<td>1</td>
<td>1.663</td>
<td>0.202</td>
<td>0.024</td>
<td>0.246</td>
</tr>
<tr>
<td>VSRT – CLTR</td>
<td>24.87 (14.87)</td>
<td>24.37 (12.25)</td>
<td>1</td>
<td>1.359</td>
<td>0.248</td>
<td>0.019</td>
<td>0.210</td>
</tr>
<tr>
<td>VSRT – Delay</td>
<td>6.63 (3.04)</td>
<td>6.57 (2.93)</td>
<td>1</td>
<td>0.029</td>
<td>0.865</td>
<td>0.000</td>
<td>0.053</td>
</tr>
<tr>
<td><strong>Language</strong> [Wilks’ $\lambda = 0.940$, $F(2,71)=2.254$, $p=0.112$, partial $\eta^2=0.060$]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BNT</td>
<td>53.65 (6.66)</td>
<td>54.60 (7.00)</td>
<td>1</td>
<td>0.241</td>
<td>0.625</td>
<td>0.003</td>
<td>0.077</td>
</tr>
<tr>
<td>Semantic Fluency – Animal</td>
<td>21.53 (4.61)</td>
<td>23.40 (5.34)</td>
<td>1</td>
<td>3.262</td>
<td>0.075</td>
<td>0.043</td>
<td>0.429</td>
</tr>
<tr>
<td><strong>Executive Function</strong> [Wilks’ $\lambda = 0.838$, $F(5,65)=2.508$, $p=0.039$, partial $\eta^2=0.162$]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phonetic Fluency – FAS</td>
<td>39.64 (12.89)</td>
<td>46.00 (10.66)</td>
<td>1</td>
<td>3.507</td>
<td>0.065</td>
<td>0.048</td>
<td>0.455</td>
</tr>
<tr>
<td>TMT B</td>
<td>78.40 (30.50)</td>
<td>57.08 (16.31)</td>
<td>1</td>
<td>9.798</td>
<td>0.003</td>
<td>0.124</td>
<td>0.870</td>
</tr>
<tr>
<td>TMT B-A</td>
<td>43.36 (24.81)</td>
<td>29.97 (11.03)</td>
<td>1</td>
<td>9.585</td>
<td>0.003</td>
<td>0.122</td>
<td>0.863</td>
</tr>
<tr>
<td>Stroop Test</td>
<td>31.22 (11.42)</td>
<td>23.82 (5.58)</td>
<td>1</td>
<td>5.522</td>
<td>0.022</td>
<td>0.074</td>
<td>0.640</td>
</tr>
<tr>
<td>BDS</td>
<td>22.29 (2.59)</td>
<td>23.00 (2.36)</td>
<td>1</td>
<td>0.326</td>
<td>0.570</td>
<td>0.005</td>
<td>0.087</td>
</tr>
<tr>
<td><strong>Visuospatial Orientation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>JLO</td>
<td>21.32 (4.37)</td>
<td>23.33 (4.75)</td>
<td>1</td>
<td>1.399</td>
<td>0.241</td>
<td>0.019</td>
<td>0.215</td>
</tr>
</tbody>
</table>

Abbreviations: CP – Concentration Performance; DS – Digit Span; VSRT – Verbal Selective Reminding Test; LTS – Long Term Storage; CLTR – Consistent Long Term Retrieval; BNT – Boston Naming Test; TMT – Trail Making Test; BDS – Behavioral Dyscontrol Scale; JLO – Judgment of Line Orientation.
Table 7: Comparison of social information processing data between mild TBI and HC subjects after controlling for anxiety and depression caseness

<table>
<thead>
<tr>
<th></th>
<th>mild TBI (n=47) Mean (SD)</th>
<th>Healthy controls (n=30) Mean (SD)</th>
<th>MANCOVAs</th>
<th>df</th>
<th>F</th>
<th>p</th>
<th>Partial η²</th>
<th>Observed Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Social Perception</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>[Wilks’ λ = 0.949, F(4,70)=0.946, p=0.443, partial η²=0.051]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FAB AD</td>
<td>16.79 (1.96)</td>
<td>16.53 (3.44)</td>
<td>1</td>
<td>0.922</td>
<td>0.340</td>
<td>0.012</td>
<td>0.158</td>
<td></td>
</tr>
<tr>
<td>FAB NA</td>
<td>17.87 (1.58)</td>
<td>17.83 (1.21)</td>
<td>1</td>
<td>0.077</td>
<td>0.782</td>
<td>0.001</td>
<td>0.059</td>
<td></td>
</tr>
<tr>
<td>FAB PA</td>
<td>19.00 (1.04)</td>
<td>19.00 (1.20)</td>
<td>1</td>
<td>0.708</td>
<td>0.403</td>
<td>0.010</td>
<td>0.132</td>
<td></td>
</tr>
<tr>
<td>FAB MA</td>
<td>17.30 (1.89)</td>
<td>17.97 (2.04)</td>
<td>1</td>
<td>0.898</td>
<td>0.347</td>
<td>0.012</td>
<td>0.155</td>
<td></td>
</tr>
<tr>
<td>Social Cognition</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>[Wilks’ λ = 0.917, F(9, 61)=0.610, p=0.784, partial η²=0.083]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RMET</td>
<td>25.15 (4.02)</td>
<td>26.00 (4.96)</td>
<td>1</td>
<td>1.541</td>
<td>0.219</td>
<td>0.022</td>
<td>0.232</td>
<td></td>
</tr>
<tr>
<td>Yoni Task 1st Cog</td>
<td>9.11 (1.84)</td>
<td>8.76 (2.69)</td>
<td>1</td>
<td>0.702</td>
<td>0.405</td>
<td>0.010</td>
<td>0.131</td>
<td></td>
</tr>
<tr>
<td>Yoni Task 1st Aff</td>
<td>9.02 (1.90)</td>
<td>8.69 (2.14)</td>
<td>1</td>
<td>0.064</td>
<td>0.802</td>
<td>0.001</td>
<td>0.057</td>
<td></td>
</tr>
<tr>
<td>Yoni Task 2nd Cog</td>
<td>8.20 (2.03)</td>
<td>8.00 (1.91)</td>
<td>1</td>
<td>0.002</td>
<td>0.966</td>
<td>0.000</td>
<td>0.050</td>
<td></td>
</tr>
<tr>
<td>Yoni Task 2nd Aff</td>
<td>7.93 (2.02)</td>
<td>8.10 (1.76)</td>
<td>1</td>
<td>0.012</td>
<td>0.913</td>
<td>0.000</td>
<td>0.051</td>
<td></td>
</tr>
<tr>
<td>IRI – FS</td>
<td>14.04 (5.72)</td>
<td>16.23 (6.11)</td>
<td>1</td>
<td>1.009</td>
<td>0.319</td>
<td>0.014</td>
<td>0.168</td>
<td></td>
</tr>
<tr>
<td>IRI – PT</td>
<td>18.81 (5.20)</td>
<td>19.37 (4.18)</td>
<td>1</td>
<td>0.262</td>
<td>0.611</td>
<td>0.004</td>
<td>0.080</td>
<td></td>
</tr>
<tr>
<td>IRI – EC</td>
<td>21.11 (4.50)</td>
<td>21.03 (4.65)</td>
<td>1</td>
<td>0.187</td>
<td>0.667</td>
<td>0.003</td>
<td>0.071</td>
<td></td>
</tr>
<tr>
<td>IRI – PD</td>
<td>11.15 (6.10)</td>
<td>8.60 (5.39)</td>
<td>1</td>
<td>0.073</td>
<td>0.787</td>
<td>0.001</td>
<td>0.058</td>
<td></td>
</tr>
</tbody>
</table>

Abbreviations: FAB – Florida Affect Battery; AD – Affect Discrimination; NA – Name Affect; PA – Pick Affect; MA – Match Affect; RMET – Reading the Mind in the Eyes Test. IRI – Interpersonal Reactivity Index; FS – Fantasy Scale; PT – Perspective Taking; EC – Empathic Concern; PD – Personal Distress
Table 7: Comparison of social information processing data between mild TBI and HC subjects after controlling for anxiety and depression caseness, continued

<table>
<thead>
<tr>
<th></th>
<th>mild TBI (n=47) Mean (SD)</th>
<th>Healthy controls (n=30) Mean (SD)</th>
<th>MANCOVAs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>df</td>
<td>F</td>
</tr>
<tr>
<td>Social Regulation [Wilks' λ = 0.902, F(7,66)=1.030, p=0.419, partial η²=0.098]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ultimatum 5/5</td>
<td>1.77 (0.52)</td>
<td>1.93 (0.25)</td>
<td>1</td>
</tr>
<tr>
<td>Ultimatum 4/6</td>
<td>1.55 (0.72)</td>
<td>1.53 (0.82)</td>
<td>1</td>
</tr>
<tr>
<td>Ultimatum 3/7</td>
<td>2.98 (2.71)</td>
<td>3.50 (2.60)</td>
<td>1</td>
</tr>
<tr>
<td>Ultimatum 2/8</td>
<td>2.23 (2.46)</td>
<td>2.67 (2.72)</td>
<td>1</td>
</tr>
<tr>
<td>Ultimatum 1/9</td>
<td>1.46 (2.13)</td>
<td>2.10 (2.73)</td>
<td>1</td>
</tr>
<tr>
<td>GDT</td>
<td>5.70 (11.54)</td>
<td>8.80 (10.62)</td>
<td>1</td>
</tr>
<tr>
<td>IGT</td>
<td>7.96 (25.85)</td>
<td>21.27 (28.78)</td>
<td>1</td>
</tr>
</tbody>
</table>

Abbreviations: GDT – Game of Dice Task; IGT – Iowa Gambling Task; BDS – Behavioral Dyscontrol Scale.
3.3 Comparison of Social Information Processing Measures between Cognitively Impaired and Intact Mild TBI subjects

To explore the association between non-social cognition and social information processing, mild TBI subjects were deemed to have mild global non-social cognitive impairment if they had impairments in two or more cognitive domains. The decision to use a minimum of two cognitive domains was made to avoid defining global impairment unidimensionally. With this criterion, 20 (42.6%) mild TBI subjects were found to have global non-social cognitive impairment. There were no differences in years of education, time since injury, and other injury related variables between cognitively impaired versus intact mild TBI subjects. However, cognitively impaired mild TBI subjects had a significantly greater age than those with intact cognition (Mean = 46.00 [SD = 10.31] vs. Mean = 37.85 [SD = 11.21] in years, \( t = 2.548, p = 0.014 \), respectively).

Comparisons of demographic, neurologic, and psychiatric variables between cognitively impaired and intact mild TBI subjects are shown in Table 8.

Three one-way ANCOVA analyses with age as covariate revealed no differences between cognitively impaired and cognitively intact mild TBI subjects on the control tests of FAB Personal Discrimination test (Impaired: Mean = 19.45 [SD = 1.00] vs. Intact: Mean = 19.85 [SD = 0.60], \( F = 1.621, p = 0.210 \)), the first-order physical trials of the Yoni Task (Impaired: Mean = 9.61 [SD = 0.85] vs. Intact: Mean = 9.89 [SD = 0.32], \( F = 2.840, p = 0.099 \)), and the second-order physical trials of the Yoni Task (Impaired: Mean = 9.35 [SD = 1.23] vs. Intact: Mean = 9.81 [SD = 0.49], \( F = 1.372, p = 0.248 \)).
Three one-way MANCOVA analyses were carried out to compare social information processing domains between the cognitively impaired and intact mild TBI subjects, with age as covariate. These revealed that there were significant differences in social cognition domains between cognitively impaired and intact mild TBI subjects ($F = 2.465, p = 0.028$). Specifically, individuals with mild TBI who had global cognitive impairment performed significantly poorer on the second order cognitive ToM trials ($p = 0.019$, partial $\eta^2$: 0.128). There were no significant differences of performances in the overall social perception and social regulation domains between cognitively impaired and cognitively intact mild TBI subjects. However, mild TBI subjects with global non-social cognitive impairment performed significantly poorer on the FAB Matching Affect Test than those without ($p = 0.003$, partial $\eta^2$: 0.181). Comparisons between mild TBI subjects with and without global impairment on the social information processing tests are shown in Table 9.
Table 8: Demographic, injury characteristics, neurologic, and psychiatric data between cognitively impaired and intact mild TBI subjects

<table>
<thead>
<tr>
<th></th>
<th>Cognitively impaired mild TBI subjects – mean (SD) /frequency (%); n = 20</th>
<th>Cognitively intact mild TBI subjects – mean (SD) /frequency (%); n = 27</th>
<th>t-test/x²</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (Years)</td>
<td>46.00 (10.31)</td>
<td>37.85 (11.21)</td>
<td>t = 2.548</td>
<td>p = 0.014*</td>
</tr>
<tr>
<td>Sex (% female)</td>
<td>11 (55.0%)</td>
<td>18 (66.7%)</td>
<td>χ² = 0.662</td>
<td>p = 0.416</td>
</tr>
<tr>
<td>Years of Education</td>
<td>16.60 (2.39)</td>
<td>17.26 (2.54)</td>
<td>t = -0.902</td>
<td>p = 0.372</td>
</tr>
<tr>
<td>Time since the injury (days)</td>
<td>189.30 (126.63) (range: 75 – 495)</td>
<td>198.70 (122.54) (range: 83 – 489)</td>
<td>t = -0.256</td>
<td>p = 0.799</td>
</tr>
<tr>
<td>Glasgow Coma Scale Scorea</td>
<td>14.53 (0.64) (range: 13 - 15)</td>
<td>14.64 (0.50) (range: 14 - 15)</td>
<td>t = -0.512</td>
<td>p = 0.613</td>
</tr>
<tr>
<td>Laterality – Hand</td>
<td>3.10 (1.77)</td>
<td>3.04 (1.79)</td>
<td>t = 0.120</td>
<td>p = 0.905</td>
</tr>
<tr>
<td>HADS – Anxiety</td>
<td>9.35 (5.11)</td>
<td>8.41 (4.10)</td>
<td>t = 0.702</td>
<td>p = 0.487</td>
</tr>
<tr>
<td>HADS – Depression</td>
<td>7.05 (4.11)</td>
<td>7.52 (4.45)</td>
<td>t = -0.369</td>
<td>p = 0.714</td>
</tr>
</tbody>
</table>

aN = 29. For the 18 subjects where the GCS score is not available, mild TBI severity was defined by either a loss of consciousness (LOC) < 30 minutes, or post-traumatic amnesia (PTA) < 24 hours. Abbreviation: HADS – Hospital Anxiety and Depression Scale
Table 9: Comparison of social information processing data between cognitively impaired and intact mild TBI subjects after controlling for age

<table>
<thead>
<tr>
<th></th>
<th>Cognitively impaired mild TBIs (n=20) Mean (SD)</th>
<th>Cognitively intact mild TBIs (n=27) Mean (SD)</th>
<th>MANCOVAs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>DF</td>
<td>F</td>
</tr>
<tr>
<td>Social Perception [Wilks’ λ = 0.808, F(4,41)=2.442, p=0.062, partial η²=0.192]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FAB AD</td>
<td>16.70 (2.13)</td>
<td>1</td>
<td>0.027</td>
</tr>
<tr>
<td>FAB NA</td>
<td>17.45 (1.96)</td>
<td>1</td>
<td>2.710</td>
</tr>
<tr>
<td>FAB PA</td>
<td>18.75 (1.16)</td>
<td>1</td>
<td>1.076</td>
</tr>
<tr>
<td>FAB MA</td>
<td>16.20 (1.99)</td>
<td>1</td>
<td>9.727</td>
</tr>
<tr>
<td>Social Cognition [Wilks’ λ = 0.598, F(9,33)=2.465, p=0.028, partial η²=0.402]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RMET</td>
<td>23.80 (3.66)</td>
<td>1</td>
<td>3.028</td>
</tr>
<tr>
<td>Yoni Task 1st Cog</td>
<td>9.11 (1.94)</td>
<td>1</td>
<td>0.179</td>
</tr>
<tr>
<td>Yoni Task 1st Aff</td>
<td>9.00 (1.75)</td>
<td>1</td>
<td>0.138</td>
</tr>
<tr>
<td>Yoni Task 2nd Cog</td>
<td>7.15 (2.35)</td>
<td>1</td>
<td>6.013</td>
</tr>
<tr>
<td>Yoni Task 2nd Aff</td>
<td>7.05 (2.26)</td>
<td>1</td>
<td>3.569</td>
</tr>
<tr>
<td>IRI – FS</td>
<td>14.15 (5.05)</td>
<td>1</td>
<td>0.189</td>
</tr>
<tr>
<td>IRI – PT</td>
<td>19.65 (4.44)</td>
<td>1</td>
<td>0.728</td>
</tr>
<tr>
<td>IRI – EC</td>
<td>21.45 (4.12)</td>
<td>1</td>
<td>0.444</td>
</tr>
<tr>
<td>IRI – PD</td>
<td>13.15 (5.54)</td>
<td>1</td>
<td>3.543</td>
</tr>
</tbody>
</table>

Abbreviations: FAB – Florida Affect Battery; AD – Affect Discrimination; NA – Name Affect; PA – Pick Affect; MA – Match Affect; RMET – Reading the Mind in the Eyes Test. IRI – Interpersonal Reactivity Index; FS – Fantasy Scale; PT – Perspective Taking; EC – Empathic Concern; PD – Personal Distress
Table 9: Comparison of social information processing data between cognitively impaired and intact mild TBI subjects after controlling for age, continued

<table>
<thead>
<tr>
<th>Social Regulation [Wilks’ λ = 0.737, F(7,37)=1.890, p=0.099, partial η²=0.263]</th>
<th>Cognitively impaired mild TBIs (n=14) Mean (SD)</th>
<th>Cognitively intact mild TBIs (n=33) Mean (SD)</th>
<th>MANCOVAs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>df</td>
<td>F</td>
<td>p</td>
</tr>
<tr>
<td>Ultimatum 5/5</td>
<td>1.70 (0.57)</td>
<td>1.81 (0.48)</td>
<td>1</td>
</tr>
<tr>
<td>Ultimatum 4/6</td>
<td>1.50 (0.69)</td>
<td>1.59 (0.75)</td>
<td>1</td>
</tr>
<tr>
<td>Ultimatum 3/7</td>
<td>2.60 (2.58)</td>
<td>3.26 (2.81)</td>
<td>1</td>
</tr>
<tr>
<td>Ultimatum 2/8</td>
<td>2.25 (2.36)</td>
<td>2.22 (2.58)</td>
<td>1</td>
</tr>
<tr>
<td>Ultimatum 1/9</td>
<td>1.10 (1.80)</td>
<td>1.73 (2.34)</td>
<td>1</td>
</tr>
<tr>
<td>GDT</td>
<td>1.20 (12.72)</td>
<td>9.04 (9.05)</td>
<td>1</td>
</tr>
<tr>
<td>IGT</td>
<td>4.40 (26.44)</td>
<td>10.59 (25.58)</td>
<td>1</td>
</tr>
</tbody>
</table>

Abbreviations: GDT – Game of Dice Task; IGT – Iowa Gambling Task; BDS – Behavioral Dyscontrol Scale
3.4 Return to work, social information processing, and non-social cognition

To examine the association between vocational outcome on the one hand and social information processing abilities and non-social cognition on the other, comparisons were undertaken between mild TBI subjects who had returned to work and those who had not. At the time of assessment, 33 mild TBI subjects had not returned to work (70.2%). There were no differences in years of education, time since the injury, and other demographic, injury-related, neurologic, and psychiatric variables between mild TBI subjects who returned to work and those who had not. Demographic, neurologic, and psychiatric comparisons between these two groups are shown in Table 10.

Comparisons of non-social cognitive measures and social information processing variables between individuals who had returned to work and those who had not are shown in Table 11 and Table 12. There were significant differences between those two groups in the attention and working memory domain ($F = 2.954, p = 0.043$), as well as the social regulation domain ($F = 2.409, p = 0.038$). Specifically, mild TBI subjects who had not returned to work performed significantly poorer on the DS backward ($p = 0.008, \text{partial } \eta^2 = 0.148$), and the Ultimatum Game $1/\$9$ unfair trial ($p = 0.022, \text{partial } \eta^2 = 0.114$). Mild TBI subjects who had returned to work and those who had not also had matched performances on the control social information processing tests (FAB Person Discrimination test: Mean = 19.71 [SD = 0.83] vs. Mean = 19.67 [SD = 0.82], respectively, $F = 0.030, p = 0.864$; Yoni Task first-order physical trials: Mean = 9.79 [SD = 0.43] vs. Mean = 9.77 [SD = 0.67], respectively, $F = 0.015, p = 0.902$; and Yoni Task second-
order physical trials: Mean = 9.93 [SD = 0.27] vs. Mean = 9.47 [SD = 1.05], respectively, F = 2.259, 
$p = 0.140$).

Looking at the association between return to work and global cognitive impairment, there was a significant difference in the global cognitive impairment rate between individuals who had returned to work and those who had not ($\chi^2=10.228$, $p=0.001$). Of the 14 mild TBI subjects who had returned to work, 1 (7.1%) had global cognitive impairment compared to 19 out of the 33 (57.6%) mild TBI subjects who were back at work.
<table>
<thead>
<tr>
<th></th>
<th>Mild TBI Subjects Not Returned to Work – mean (SD) /frequency (%)</th>
<th>Mild TBI Subjects Returned to Work – mean (SD) /frequency (%)</th>
<th>t-test/χ²</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (Years)</td>
<td>42.73 (11.39)</td>
<td>38.00 (11.37)</td>
<td>t = 1.302</td>
<td>p=0.199</td>
</tr>
<tr>
<td>Sex (% female)</td>
<td>21 (63.6%)</td>
<td>8 (57.1%)</td>
<td>χ² = 0.175</td>
<td>p=0.675</td>
</tr>
<tr>
<td>Years of Education</td>
<td>16.76 (2.14)</td>
<td>17.50 (3.16)</td>
<td>t =-0.940</td>
<td>p=0.352</td>
</tr>
<tr>
<td>Time since the injury (days)</td>
<td>175.76 (105.35)</td>
<td>239.36 (152.20)</td>
<td>t =-1.425</td>
<td>p=0.171</td>
</tr>
<tr>
<td>Glasgow Coma Scale Scoreᵃ</td>
<td>14.50 (0.60)</td>
<td>14.86 (0.38)</td>
<td>t =-1.866</td>
<td>p=0.080</td>
</tr>
<tr>
<td>Laterality – Hand</td>
<td>2.94 (2.00)</td>
<td>3.36 (1.01)</td>
<td>t =-0.740</td>
<td>p=0.463</td>
</tr>
<tr>
<td>HADS – Anxiety</td>
<td>9.24 (5.07)</td>
<td>7.79 (2.75)</td>
<td>t = 1.268</td>
<td>p=0.212</td>
</tr>
<tr>
<td>HADS – Depression</td>
<td>7.67 (4.38)</td>
<td>6.50 (4.03)</td>
<td>t = 0.854</td>
<td>p=0.397</td>
</tr>
</tbody>
</table>

ᵃN = 29. For the 18 subjects where the GCS score is not available, mild TBI severity was defined by either a loss of consciousness (LOC) < 30 minutes, or post-traumatic amnesia (PTA) < 24 hours.

Abbreviation: HADS – Hospital Anxiety and Depression Scale
Table 11: Comparison of non-social cognition data between mild TBI subjects who had returned to work and those who had not

<table>
<thead>
<tr>
<th></th>
<th>Mild TBI Subjects Not Returned To Work (n=33) Mean (SD)</th>
<th>Mild TBI Subjects Returned to Work (n=14) Mean (SD)</th>
<th>MANOVAs and ANOVA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>df</td>
<td>F</td>
<td>p</td>
</tr>
<tr>
<td><strong>Attention / Working memory</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wilks’ λ=0.826, F(3, 42)=2.954, p = 0.043, partial η²=0.174</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D2 CP</td>
<td>1</td>
<td>3.039</td>
<td>0.088</td>
</tr>
<tr>
<td>DS Forward</td>
<td>1</td>
<td>2.779</td>
<td>0.103</td>
</tr>
<tr>
<td>DS Backward</td>
<td>1</td>
<td>7.640</td>
<td>0.008</td>
</tr>
<tr>
<td><strong>Memory</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wilks’ λ = 0.903, F(4,38)=1.017, p=0.411, partial η²=0.097</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Doors Test</td>
<td>1</td>
<td>2.403</td>
<td>0.129</td>
</tr>
<tr>
<td>VSRT – LTS</td>
<td>1</td>
<td>0.914</td>
<td>0.345</td>
</tr>
<tr>
<td>VSRT – CLTR</td>
<td>1</td>
<td>0.485</td>
<td>0.490</td>
</tr>
<tr>
<td>VSRT – Delay</td>
<td>1</td>
<td>1.468</td>
<td>0.233</td>
</tr>
<tr>
<td><strong>Language</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wilks’ λ = 0.919, F(2,43)=1.902, p=0.162, partial η²=0.081</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BNT</td>
<td>1</td>
<td>3.892</td>
<td>0.055</td>
</tr>
<tr>
<td>Semantic Fluency – Animal</td>
<td>1</td>
<td>0.247</td>
<td>0.622</td>
</tr>
<tr>
<td><strong>Executive Function</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wilks’ λ = 0.859, F(5,37)=1.215, p=0.322, partial η²=0.141</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phonemic Fluency – FAS</td>
<td>1</td>
<td>4.571</td>
<td>0.039</td>
</tr>
<tr>
<td>TMT B</td>
<td>1</td>
<td>3.186</td>
<td>0.082</td>
</tr>
<tr>
<td>TMT B-A</td>
<td>1</td>
<td>3.087</td>
<td>0.086</td>
</tr>
<tr>
<td>Stroop Test</td>
<td>1</td>
<td>1.900</td>
<td>0.176</td>
</tr>
<tr>
<td>BDS</td>
<td>1</td>
<td>1.297</td>
<td>0.261</td>
</tr>
<tr>
<td><strong>Visuomotor Orientation</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>JLO</td>
<td>1</td>
<td>1.128</td>
<td>0.294</td>
</tr>
</tbody>
</table>

Abbreviations: CP – Concentration Performance; DS – Digit Span; VSRT – Verbal Selective Reminding Test; LTS – Long Term Storage; CLTR – Consistent Long Term Retrieval; BNT – Boston Naming Test; TMT – Trail Making Test; BDS – Behavioral Dyscontrol Scale; JLO – Judgment of Line Orientation.
Table 12: Comparison of social information processing data between mild TBI subjects who had returned to work and those who had not

<table>
<thead>
<tr>
<th></th>
<th>Mild TBI Subjects Not Returned To Work (n=33) Mean (SD)</th>
<th>Mild TBI Subjects Returned to Work (n=14) Mean (SD)</th>
<th>df</th>
<th>F</th>
<th>p</th>
<th>Partial η²</th>
<th>Observed Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Social Perception [Wilks’ λ = 0.838, F(4,42)=2.032, p=0.107, partial η²=0.162]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FAB AD</td>
<td>16.76 (2.03)</td>
<td>16.86 (1.83)</td>
<td>1</td>
<td>0.042</td>
<td>0.839</td>
<td>0.001</td>
<td>0.055</td>
</tr>
<tr>
<td>FAB NA</td>
<td>17.79 (1.67)</td>
<td>18.07 (1.38)</td>
<td>1</td>
<td>0.338</td>
<td>0.564</td>
<td>0.007</td>
<td>0.088</td>
</tr>
<tr>
<td>FAB PA</td>
<td>18.88 (1.14)</td>
<td>19.29 (0.73)</td>
<td>1</td>
<td>1.588</td>
<td>0.214</td>
<td>0.034</td>
<td>0.234</td>
</tr>
<tr>
<td>FAB MA</td>
<td>16.82 (1.93)</td>
<td>18.43 (1.22)</td>
<td>1</td>
<td>7.688</td>
<td>0.008</td>
<td>0.146</td>
<td>0.774</td>
</tr>
<tr>
<td>Social Cognition [Wilks’ λ = 0.803, F(9,34)=0.929, p=0.513, partial η²=0.197]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RMET</td>
<td>24.55 (3.64)</td>
<td>26.57 (4.64)</td>
<td>1</td>
<td>2.263</td>
<td>0.140</td>
<td>0.051</td>
<td>0.312</td>
</tr>
<tr>
<td>Yoni Task 1&lt;sup&gt;st&lt;/sup&gt; Cog</td>
<td>9.23 (1.76)</td>
<td>8.86 (2.03)</td>
<td>1</td>
<td>0.176</td>
<td>0.677</td>
<td>0.004</td>
<td>0.069</td>
</tr>
<tr>
<td>Yoni Task 1&lt;sup&gt;st&lt;/sup&gt; Aff</td>
<td>9.16 (1.70)</td>
<td>8.71 (2.33)</td>
<td>1</td>
<td>0.511</td>
<td>0.479</td>
<td>0.012</td>
<td>0.107</td>
</tr>
<tr>
<td>Yoni Task 2&lt;sup&gt;nd&lt;/sup&gt; Cog</td>
<td>7.91 (2.12)</td>
<td>8.86 (1.70)</td>
<td>1</td>
<td>1.097</td>
<td>0.301</td>
<td>0.025</td>
<td>0.176</td>
</tr>
<tr>
<td>Yoni Task 2&lt;sup&gt;nd&lt;/sup&gt; Aff</td>
<td>7.56 (2.09)</td>
<td>8.79 (1.58)</td>
<td>1</td>
<td>2.370</td>
<td>0.131</td>
<td>0.053</td>
<td>0.325</td>
</tr>
<tr>
<td>IRI – FS</td>
<td>14.79 (5.68)</td>
<td>12.29 (5.61)</td>
<td>1</td>
<td>1.718</td>
<td>0.197</td>
<td>0.039</td>
<td>0.249</td>
</tr>
<tr>
<td>IRI – PT</td>
<td>18.64 (5.62)</td>
<td>19.21 (4.17)</td>
<td>1</td>
<td>0.077</td>
<td>0.783</td>
<td>0.002</td>
<td>0.058</td>
</tr>
<tr>
<td>IRI – EC</td>
<td>20.67 (4.88)</td>
<td>22.14 (3.30)</td>
<td>1</td>
<td>0.780</td>
<td>0.382</td>
<td>0.018</td>
<td>0.139</td>
</tr>
<tr>
<td>IRI – PD</td>
<td>11.70 (6.73)</td>
<td>9.86 (4.17)</td>
<td>1</td>
<td>0.702</td>
<td>0.407</td>
<td>0.016</td>
<td>0.130</td>
</tr>
</tbody>
</table>

Abbreviations: FAB – Florida Affect Battery; AD – Affect Discrimination; NA – Name Affect; PA – Pick Affect; MA – Match Affect; RMET – Reading the Mind in the Eyes Test. IRI – Interpersonal Reactivity Index; FS – Fantasy Scale; PT – Perspective Taking; EC – Empathic Concern; PD – Personal Distress
Table 12: Comparison of social information processing data between mild TBI subjects who had returned to work and those who had not

| Social Regulation [Wilks’ λ = 0.693, F(7,38)=2.409, p=0.038, partial η²=0.307] | MANOVAs |
|---|---|---|---|---|---|
| Mild TBI Subjects Not Returned To Work (n=33) | Mean (SD) | Mild TBI Subjects Returned to Work (n=14) | Mean (SD) | df | F | p | Partial η² | Observed Power |
| Ultimatum 5/5 | 1.70 (0.59) | 1.93 (0.27) | 1 | 2.937 | 0.094 | 0.063 | 0.388 |
| Ultimatum 4/6 | 1.45 (0.75) | 1.79 (0.58) | 1 | 1.462 | 0.233 | 0.032 | 0.219 |
| Ultimatum 3/7 | 2.67 (2.59) | 3.71 (2.92) | 1 | 0.417 | 0.522 | 0.009 | 0.097 |
| Ultimatum 2/8 | 1.82 (2.21) | 3.21 (2.81) | 1 | 1.374 | 0.247 | 0.030 | 0.209 |
| Ultimatum 1/9 | 1.03 (1.85) | 2.54 (2.47) | 1 | 5.653 | 0.022 | 0.114 | 0.643 |
| GDT | 3.76 (12.58) | 10.29 (7.05) | 1 | 3.391 | 0.072 | 0.072 | 0.437 |
| IGT | 4.42 (22.66) | 16.29 (31.52) | 1 | 1.218 | 0.276 | 0.027 | 0.191 |

GDT – Game of Dice Task; IGT – Iowa Gambling Task; BDS – Behavioral Dyscontrol Scale
CHAPTER 4. DISCUSSION

The current study demonstrated that social information processing abilities, including social perception, social cognition, and social regulation, were not impaired in individuals with mild TBI. The results of the study also suggest a strong association between non-social cognition and social cognition abilities, based on the poorer performances on social cognition tasks in cognitively impaired mild TBI individuals compared to those who were cognitively intact. This suggests that impairment in social cognition could be linked to non-social cognitive impairment following mild TBI.

The main objective of the present study was to explore social information processing abilities in individuals with mild TBI. To this extent, findings do not support the first hypothesis outlined earlier, namely that mild TBI subjects would demonstrate difficulties in social information processing when compared to healthy control subjects. Here the results demonstrate that mild TBI subjects performed at the same level as the healthy control subjects on measures of facial affect perception, first- and second-order cognitive and affective theory of mind, global empathy, risk-taking behaviours, and socioeconomic decision makings under unfair situations.

The present results differ from previous research, albeit in individuals with moderate to severe TBI, where impairments in several social information processing domains were noted across studies. For example, using the same subtests of FAB, Biszak and Baddage (2014) found an impairment rate of 51% in facial affect recognition in a group of mostly severe TBI subjects, 42% of which performed 2.0 SD below the normative group mean. Green et al. (2004) also showed that a group of moderate to severe TBI subjects performed significantly less accurately.
compared to healthy control subjects on the naming affect and affect discrimination subtests of the FAB. Similarly, theory of mind ability was shown to be impaired in adults with moderate to severe TBI when compared to healthy control subjects with large effect sizes using the RMET (Honan et al., 2015; Muller et al., 2010; Turkstra, 2008). Reduced abilities to empathize cognitively and emotionally have also been shown using the IRI following severe TBI (de Sousa et al., 2010). Finally, TBI subjects with varying severities were found to have marked decision making deficits using the IGT (Bonatti et al., 2008; Fujiwara et al., 2008; Levine et al., 2005).

Contrary to these results, the current study demonstrates that mild TBI subjects performed on par with the healthy control subjects on all measures of social information processing.

One reason for the difference between the current results and that of the published literature is the injury severity. The existing literature is overwhelmingly weighted towards moderately and severely injured subjects. Put simply, the current study implies that very mild TBI may not be associated with deficits in social information processing. Here it is worth noting that the mild TBI sample reported here falls at the mildest end of the severity spectrum with a mean GCS of 14.59, assessed on average 6-month post-injury. Whether the same result would be found in a mildly injured TBI group with a GCS closer to 13 or 14 assessed at an earlier time remains unclear and a subject of future research.

When comparing non-social cognition between the mild TBI and healthy control groups, the former group performed significantly poorer on measures of executive function. This is in line with findings from previous research. Cognitive impairments are common following mild TBI and are a part of what the DSM-5 terms a neurocognitive disorder (Belanger, Curtiss, Demery, Lebowitz, & Vanderploeg, 2005; Schretlen & Shapiro, 2003). Deficits can be widespread,
involving several domains such as attention, processing speed, and executive functioning (Belanger et al., 2005; Frencham, Fox, & Maybery, 2005). While the mild TBI literature suggests deficits in cognition are transient with recovery generally taking place over a 3-6 month period (Belanger et al., 2005; Schretlen & Shapiro, 2003), a few studies have also shown persistent deficits in certain cognitive domains past the 3-6 month window. For example, using a comprehensive battery of cognitive measures, Konrad et al. (2011) reported significant impairments in attention, memory, and executive function in a group of mild TBI subjects assessed on average 6 years post-injury. In particular, the authors reported significant differences between the mild TBI subjects and the healthy controls on many of the same tests used in the current study, including the TMT A and B, and the phonemic fluency test. Similarly, Vanderploeg et al. (2005) assessed a group of mild TBI on average 8 years post-injury and found these individuals had impairments in subtle aspects of working memory and attention compared to matched healthy controls. In a meta-analytic review that included only studies with mild TBI patients assessed beyond 3 months post-injury, it was also found that measures of attention had significant, albeit small, effect size (Binder, Rohling, & Larrabee, 1997). The results of the present study are therefore in agreement with the literature summarised above. On average, subjects were tested 6 months post injury (ranging from 2 months to one year). While some cognitive domains were not found to be impaired relative to their matched controls, perhaps denoting recovery, executive functioning remained impaired. Here it should be noted that while many of the tests were placed under the executive function domain, they also measure other non-social cognitive functions. For example, the TMT A and B are often considered measures of attention in addition to executive function. Therefore, the observed
impairment in executive function could also reflect poorer functioning in other non-social
cognitive domains.

Importantly, care was taken to control for the possible confounding effects of anxiety and
depression both on non-social cognition and social information processing when analyzing the
data. Depression and anxiety are common mood symptoms in people with TBI of all severities.
It is estimated that the rate of posttraumatic depression ranges from 10% to 77%, and the rate
of anxiety ranges from 24% to 70% (Moore, Terryberry-Spohr, & Hope, 2006; Silver, McAllister,
& Arciniegos, 2009). Similar high rates were observed in the current sample, with clinically
significant depression and anxiety present in 44.7% and 57.4%, respectively, well above the
rates of 10.0% and 16.7% elicited in the healthy control group.

Depression and anxiety both can impact cognition negatively. For example, Rapoport et al.
(2005) found that individuals with major depression following mild and moderate TBI scored
significantly poorer on indices of working memory, processing speed, verbal memory, and
executive function compared to those without major depression. Fann et al. (2001) also found
improvement in psychomotor speed, cognitive flexibility, and recent memory ability in
individuals with mild TBI and depression following an 8-week anti-depressant treatment. The
presence of anxiety disorders, including Post-Traumatic Stress Disorder (PTSD), Generalized
Anxiety Disorder (GAD), and Obsessive-Compulsive Disorder (OCD) could also be associated
with poorer cognitive functioning. For example, Gould et al. (2014) reported slower information
processing speed, and impaired working memory and executive function in individuals with
anxiety disorders following moderate to severe TBI than those without. Spitz et al. (2013) also
found poorer performance on memory, executive function, and attention and information
processing speed tasks associated with higher anxiety and depression levels as measured by HADS following TBI with varying severities. Here the results show that although comparisons between-group did not change on a domain level by anxiety and depression, the strength of the significance differed. Furthermore, looking at the individual tests, although the mild TBI subjects performed significantly poorer on the IGT, such difference was not observed after controlling for anxiety and depression. Therefore, the current study demonstrates significantly poorer performances in executive function in the mild TBI group, which could not be accounted for by variances caused by mood states.

Turning to the second hypothesis outlined at the beginning of the methodology, the current study demonstrates an association between impairment in non-social cognition and difficulties in social cognitive abilities. In the present study, mild TBI subjects were deemed to be mildly cognitively impaired if they have failed two or more cognitive domains, a cut-off used to avoid defining cognitive impairment unidimensionally as noted earlier. When comparing mild TBI subjects with global cognitive impairment to those who were cognitively intact, the former were also more impaired in social cognition, specifically on the second order cognitive ToM trials of the Yoni Task. This suggests that deficits in social cognition may be integral to non-social cognitive dysfunction, and that cognitively impaired individuals can carry additional problems that may add to their burden post-injury. Furthermore, individuals who were cognitively impaired did not perform more poorly on control tests, such as the neutral person discrimination subtest of the FAB, or the physical trials of the Yoni Task. This suggests that deficits seen on social cognition tasks were not due to an inability to perceive facial features or understand the task instructions.
Such results further underline the ongoing discussion regarding the relationship between non-social cognitive processes and social cognition abilities. Looking at the TBI literature, the relationship between non-social and social cognition remains inconclusive, given the contradictory findings to date. One opinion is that social cognition is complex in nature, likely requiring multiple non-social cognitive functions. Evidence supporting this comes from several studies independently demonstrating theory of mind being specifically linked with executive functioning and working memory (Bibby & McDonald, 2005; Henry, Phillips, Crawford, Ietswaart, et al., 2006; Milders et al., 2006). To this extent, the present study corroborates this association between non-social cognitive function and social cognition. Indeed, deficits in social cognition were only present in those mild TBI subjects who, as a group, also showed more impairment in the traditional cognitive domains.

The counter view to the above argument is represented in studies that have demonstrated a disconnection between non-social and social cognition in people with a TBI. For example, Spikman et al. (2012) found no significant correlations between performances on social cognition measures and non-social cognitive tasks, concluding that deficits in social cognition could not be accounted for by difficulties in information processing speed, attention, memory, and executive function. Muller et al. (2010) also reported the absence of correlations between executive function and ToM abilities. Interestingly, Bibby and McDonald (2005) reported working memory to be a predictor of second-order ToM deficits, but not first-order ToM deficits, in a group of severe TBI subjects. This suggests that there may be two distinctive types of impairments in social cognition, one of which arises from deficits specific to social processes, while the other arises from dysfunction in non-social cognitive processes.
The current results support this view. Looking at the specific tests in the social cognition domains, those with global cognitive impairment showed significant or close to significant impairments on the more complex second-order theory of mind trials of the Yoni Task, but were spared deficits on the simpler first-order theory of mind trials. This suggests that the more difficult the task, the greater the demand placed on other cognitive processes to solve the problem. However, the matched performances on simpler social tests also suggest there are specific social processes that remain intact in spite of cognitive deficits in mild TBI. Taken together, the current data tell a coherent story, suggesting that in a mild TBI population, impairments in social cognition are more likely to arise in the context of non-social cognitive dysfunction rather than as a primary phenomenon.

It must be acknowledged that while the current study demonstrates a clear association between global cognitive impairment and social cognition deficits in individuals with mild TBI, the data cannot establish causality. The findings could be interpreted as impaired non-social cognition leading to a reduced ability to process social information adequately. Alternatively, it could be persuasively argued that mild TBI damages the closely located neuroanatomical structures that underlie non-social and social cognitive abilities. At the very least, however, the present results do suggest some involvement of non-social cognitive abilities in social cognition constructs.

Interestingly, the social perception and social regulation domains did not differ between those who were cognitively impaired and intact, although significant difference was present in the FAB Matching Affect test of the FAB. This suggests that social perception and regulation abilities could be independent of non-social cognitive processes. The literature here, however, is
equivocal. For example, using three emotion recognition tasks including the FAB affect naming subtest, Yim et al. (2013) demonstrated an association between impairments in facial affect recognition and difficulties in speed of information processing and memory in a group of adults with moderate to severe TBI. Similarly, Allerdings and Alfano (2006) found that performances on emotion recognition tasks were significantly correlated with measures of language and verbal learning in individuals with moderate to severe TBI. However, Rosenberg et al. (2015, 2016) found that information processing speed, working memory, and abstract reasoning did not predict performances on emotion recognition tasks. Rather, only injury severity and task difficulty were significant predictors. Looking at social regulation, performances on the IGT has been shown to correlate with working memory and executive function in individuals with TBI subjects of varying severities (Bonatti et al., 2008; Levine et al., 2005). Counterbalancing this is a review examining decision making abilities as measured by the IGT and executive function and working memory in multiple populations including neurological and psychiatric disorders, and non-clinical child and adult samples (Toplak, Sorge, Benoit, West, & Stanovich, 2010). The authors concluded that only a small proportion of the studies reported a significant relationship between performances on the IGT and working memory and executive function (Toplak et al., 2010). Looking at other tests of social regulation, a number of studies have reported an association between performance on the GDT and executive functioning in people with Korsakoff syndrome (Brand, Fujiwara, et al., 2005), pathological gambling (Brand, Kalbe, et al., 2005), Parkinson’s disease (Brand, Labudda, & Kalbe, 2004), and in healthy individuals with no history of neurological or psychiatric disease (Starcke, Pawlikowski, Wolf, Altstötter-Gleich, & Brand, 2011), although task performance was not found to be associated with other
neuropsychological indices (Brand, Franke-Sievert, Jacoby, Markowitsch, & Tuschen-Caffier, 2007; Cogo et al., 2014). Given the complexity of the social perception and social regulation domains, and the diversity in the tasks used to measure constructs of these domains across studies, future effort is needed to determine their association with non-social cognition.

Finally, the study was able to address, in part, the third hypothesis of whether changes in social information processing and non-social cognitive abilities are implicated in one index of functional outcome following mild TBI, namely returning to work. Sustaining a TBI is associated with difficulties returning to work, with some studies estimating that this occurs in 25% to 50% of individuals with a mild TBI 3- to 12-month post-injury (Doctor et al., 2005; Friedland & Dawson, 2001; Kristman et al., 2010). This percentage is lower than the percentage reported here (70.2%), a possible artifact of the current study design. Given that the cognitive assessment for the current study was approximately 3 hours, it was possible that individuals who had not returned to work were more inclined to participate. Importantly, the current results demonstrate that returning to work is associated with attention and working memory abilities, as well as social regulation abilities. Indeed, significant between-group differences were observed in these two domains when comparing mild TBI individuals who had returned to work and those who had not. Furthermore, an association between mild global cognitive impairment and returning to work was also observed, as only 7.1% of those who returned to work had global cognitive impairment, in contrast to a markedly higher impairment rate of 57.6% in those who had not returned to work. While cognizant of the many factors that may influence vocational functioning post-injury, the results demonstrate in part that combined non-social and social cognitive deficits may introduce more challenges when it comes to resuming work.
Limitations and Future Directions

The results of the current study should be read with certain limitations in mind. First, small sample sizes for subgroup analyses (cognitively impaired versus intact, and returned to work versus no return) could lead to possible type 2 errors. Furthermore, the relatively smaller percentage of male subjects in the current sample relative to the TBI clinic population may introduce an element of bias into the data. The smaller male sample of the current study could be a result of the exclusion criteria applied. The current study excluded individuals with a history of pathological gambling, alcohol abuse, and/or substance abuse, all of which reportedly to have significant gender differences, with prevalence rates higher in males than females (Merikangas & McClair, 2012; Raylu & Oei, 2002). At the same time, there has been some evidence suggesting the association between sex and social information processing in TBI. For example, in a recent study by Rigon et al. (2016), the authors found that females with TBI significantly outperformed males with TBI on a dynamic emotion recognition task. Furthermore, only males with TBI performed significantly poorer on the emotion recognition task in comparison to the healthy control group. Turkstra (2008) also reported female participants with TBI scored higher on social cognitive measures than male TBI participants. As such, future replication studies with bigger sample sizes and more inclusive of male subjects are needed.

Another limitation is the sampling procedure that may introduce selection bias to the current study. Given the mild TBI subjects recruited in the current study were patients returning for follow-up appointments in an outpatient clinic, it was possible that they were experiencing more persisting symptoms and may therefore not represent the general mild TBI population. At the same time, it should be noted that a substantial number of individuals who have had a mild
TBI never seek treatment in a medical setting, which could also have influenced the representativeness of the current study sample. Ideally, future studies should examine social information processing abilities in a non-clinic, population-based random mild TBI sample. Finally, the method used to identify healthy control subjects, namely a telephone screening interview, was also not without limitations for it relied on the veracity of volunteers when it came to divulging a past history of psychiatric or major medical illnesses.

The choice of tests used to explore social information processing in the current study may present another potential limitation. The current study utilized social information processing tests with static visual stimuli as a first-stage investigation. As previous studies in moderate to severe TBI have suggested, the static visual presentation of stimuli may not most adequately reflect the complexity of real-world situations, where social interactions are much more rapidly changing and multimodal (McDonald & Saunders, 2005; C. Williams & Wood, 2010b; Zupan & Neumann, 2013). As such, future studies should explore social information processing in mild TBI by utilizing tests with dynamic and multimedia stimuli, to observe changes in settings mimicking real-world situations.

Given the preliminary nature of the current study, future research is also needed to address additional facets of social information processing. For example, studies have yet to explore the perception of vocal prosody, the understanding of pragmatics, the recognition of social faux pas, and communication abilities in individuals with mild TBI. As these processes are integral to daily social functioning and interaction, future studies investigating them can potentially provide additional insights in understanding the factors that influence real world indices of outcome.
Additionally, the effects of different demographic variables such as ethnicity and socioeconomic status and their interaction with the multiple facets of social cognition has yet to be explored.

Finally, future studies should include brain imaging to investigate the neuroanatomical and functional correlates of social information processing in mild TBI. While CT and conventional MRI metrics may lack the sensitivity to detect structural changes in mild TBI, diffusion tensor imaging has been shown to be sensitive to the subtle diffuse axonal injury that typically occur in mild TBI (Hulkower, Poliak, Rosenbaum, Zimmerman, & Lipton, 2013; Niogi & Mukherjee, 2010). However, there remains to be a lack of literature examining the association between diffuse axonal injury and social information processing. In addition, fMRI activation studies using some of the social information processing paradigms mentioned here will help tease out the neural pathways that determine responses in mild TBI. These warrant a need for future research.

Conclusion

In conclusion, the present study stands as one of the first to comprehensively investigate social information processing following mild TBI. The results demonstrate that social information processing, including facial affect perception, theory of mind, empathy, and socioeconomic decision making abilities were not impaired in general. However, when the TBI group was divided into those with and without non-social cognitive deficits, the former were found to perform more poorly in the social cognition domain. This is especially true for the more complex tasks. This suggests that deficits in social cognition may arise as a consequence of non-social cognitive impairment. Furthermore, the combination of non-social cognitive and social information processing difficulties may introduce more challenges for individuals when it comes
to a return to work. Future studies are needed to replicate these results, and extend our understanding of how social information processing might be affected in people with mild TBI and the degree to which this can compromise outcome.
REFERENCES


Andersson, S., Gundersen, P. M., & Finset, A. (1999). Emotional activation during therapeutic


Neuropsychology, 21(6), 742–750. https://doi.org/10.1037/0894-4105.21.6.742


https://doi.org/10.1080/02699050500110033


https://doi.org/10.1037/0022-3514.44.1.113


https://doi.org/10.1080/13803395.2012.667067

https://doi.org/10.1136/jnnp.65.6.899

https://doi.org/10.1192/bjp.174.4.360


https://doi.org/10.1017/S1355617712001440

https://doi.org/10.1017/S1355617712001440

https://doi.org/10.1017/S1355617712001440

https://doi.org/10.1017/S1355617712001440

https://doi.org/10.1017/S1355617712001440


recognition task: A paradigm to measure the perception of facial emotional expressions at different intensities. *Perceptual and Motor Skills, 104*(2), 589–598.


https://doi.org/10.1080/02699050500443558 [doi]


https://doi.org/10.1016/j.cortex.2009.08.014


https://doi.org/10.3109/02699052.2015.1035326


https://doi.org/doi:10.1176/appi.books.9781585624201.js01


https://doi.org/10.1080/13803395.2015.1115824


https://doi.org/10.1089/neu.2013.2997

https://doi.org/10.1097/HTR.0000000000000033


https://doi.org/10.1176/appi.neuropsych.17.1.61


Neuropsychology Laboratory.


https://doi.org/10.3758/s13415-016-0437-0

https://doi.org/10.3109/02699052.2015.1005135


https://doi.org/10.1017/S1355617713000672

https://doi.org/10.1159/000322454


https://doi.org/10.1080/09540260310001606728 [pii]


https://doi.org/10.1016/j.neuropsychologia.2007.05.021


https://doi.org/10.1080/02699050802027059


Neuropsychological Society, (11), 228–236.


https://doi.org/10.1016/j.apmr.2010.06.009

https://doi.org/10.1017/S1355617708080326

https://doi.org/10.1080/02699050902970786


https://doi.org/10.3109/02699052.2013.794975


131