Abstract

Changes in social and emotional behaviour are fairly common following paediatric traumatic brain injury (pTBI). Impairments in the ability to infer what others are thinking and feeling in order to predict their behaviour and emotions, so-called theory of mind (ToM) ability, may underlie some of the problems in social functioning that these patients experience. However, some argue that other cognitive deficits that may be present in pTBI, such as deficits in executive functioning and general intelligence, may account for the impairments in social functioning following a pTBI. Ten typically developing (TD), 10 mild pTBI and 10 moderate pTBI participants, aged 9-14, were compared on their affect recognition and affective inference abilities, after controlling for the effects of IQ and executive functioning. No significant group differences were found on the measures of affect recognition or affective mental inference ability. Furthermore, no relevant significant group differences were found on the measures of executive functioning and general intelligence. The inconsistent results found in this study are discussed in terms of the difficulties posed by neuropsychological test use and development in South Africa.

Introduction

Human beings rely on a broad range of complex social skills in order to negotiate daily life. Most of us take these skills for granted, as social interactions come about naturally. However, some people are inept at social interactions as they do not possess the cognitive skills required to interact successfully with other people (Baron-Cohen, Leslie, & Frith, 1985). One such group of people are those that have suffered a traumatic brain injury (TBI). Following a TBI, individuals often experience negative changes in their social behaviour. This can manifest as, for example, apathy and inadequate social judgement (Rowe, Bullock, Polkey, & Morris, 2001). These changes can have potentially serious consequences for both the patient and their family and friends. Many individuals with a TBI never return to work and lose many of their meaningful relationships (Milders, Fuchs, & Crawford, 2003).

Despite the potentially serious consequences for social functioning following a TBI, not much is known about the deficits that underlie the changes in social behaviour post-injury. Less is known about these underlying impairments in the paediatric TBI (pTBI) population, despite evidence suggesting that children and adolescents suffer worse social outcomes following a pTBI than the adult population (Harwood & Fergusson, 2001).

A deficit in theory of mind (ToM), which is the ability to infer the mental states of others in order to predict their behaviour and emotions, may account for the impairments in social behaviour experienced by those with a pTBI (Baron-Cohen et al., 1985; Bibby & McDonald, 2005). However, some argue that the general decline in executive functioning and intelligence following a pTBI may account for impairments in social behaviour (Milders et al., 2003). It is important that these different accounts are investigated further in order to increase our understanding of the factors that contribute to the difficulties experienced by pTBI patients in social interactions.

This study therefore looked at how one aspect of ToM, the ability to infer the affective mental states of others, was affected following a pTBI. Some research has indicated that ToM has an emotion recognition aspect (Baron-Cohen et al., 1985). Therefore, the effects of a pTBI on emotion recognition ability were also investigated. Specifically, this study aimed to determine whether, after the effects of executive functioning and IQ were controlled for, 1) individuals with a pTBI were more impaired at recognising basic emotions from facial expressions than typically developing (TD) participants and 2) individuals with a pTBI were more impaired at inferring the affective mental states from eye expressions than TD participants. Before the study can be discussed in full, TBI needs to be adequately defined.

Traumatic Brain Injury

TBI is most commonly defined as a change in brain performance that is the result of a piercing or blunt force to the head (Bruns & Hauser, 2003). TBI is classified in one of two ways: closed, where the head is hit violently but is not penetrated; and open, where an object penetrates the brain tissue (Tabish, Lone, Afzal, & Salam, 2006).

TBI is also classified according to the level of severity of the injury: mild, moderate or severe. A mild TBI is most commonly defined as a loss of consciousness for no longer than 30 minutes, confusion, post-traumatic amnesia (PTA) of up to one hour, if at all, and a Glasgow Coma Scale (GCS) score of 13-15 half an hour after injury (Carroll, Cassidy, Holm, Kraus, & Coronados, 2004) . A moderate TBI is established if there is a loss of consciousness that exceeds 20 minutes, PTA for a minimum of one hour and a maximum of twenty four hours, and a GCS score of 9-12. Lastly, a severe TBI is established if there is a loss of consciousness for more than 6 hours, PTA for more than 24 hours and a GCS score of 8 and lower (Anderson, Catroppa, Haritou, Morse & Rosenfeld, 2005).

The severity of the TBI is an important predictor of social and cognitive outcomes. Patients with more severe TBIs suffer worse social and cognitive outcomes than those with a mild TBI (Ietswaart, Milders, Crawford, Currie, & Scott, 2008). This may be the reason why participants with a moderate to severe TBI are used more frequently in research than those with a mild TBI. However, research indicates that 15% of patients with a mild TBI experience increased negative consequences post-injury, including deficits in social functioning (Guerrero, Thurman & Sniezek, 2000). It is therefore important to investigate the effects of mild TBI on social functioning further, as patients with a mild TBI are thought to recover without any lasting deficits and are rarely put forward for specialist intervention.

TBI is extremely common among the paediatric population (Bruns & Hauser, 2003). 80% of the TBIs sustained by children are mild and continuing sequelae are thought to only occur in a few cases. While diverse, the major causes of pTBI in South Africa are motor vehicle accidents (MVAs) and violence. MVAs tend to result in closed TBIs, which cause diffuse brain damage. While the damage is diffuse, the anterior structures of the brain, such as the frontal lobes, are particularly vulnerable to injury due to the fact that they are likely to take the full force of the impact (Crocker & McDonald, 2005).

The frontal lobes are critical to the neural networks supporting social cognition and are thought to have an extended developmental course, continuing into the second and third decades of life.

It is not surprising then that a TBI sustained during childhood or adolescence can have negative effects on social functioning. Young patients are going through constant developmental change, which may be interrupted following a pTBI (Gil, 2003). Young patients with a pTBI may find it harder to acquire developmentally appropriate social skills, which will affect them more in the long term than older patients who have already acquired those developmentally appropriate skills (Middleton, 2001).

Despite the lasting effects pTBI can have on social functioning, limited research, if any, has been done on the underlying factors contributing to impairments in social functioning in the South African paediatric population. This research is important as children and adolescents experience negative social consequences following a pTBI. For example, children and adolescents with pTBI find it hard to maintain friendships and become less popular with their peers post-injury. Of further importance is research that suggests that individuals with pTBI perceive social consequences as more crucial to their quality of life than cognitive and behavioural consequences (Warschausky, Argento, Hurvitz & Berg, 2003).

Theory of Mind

ToM refers to the ability to infer what others may be thinking and feeling in order to predict their behaviour and emotions (Baron-Cohen et al., 1985). ToM is therefore important for successful social interaction. Two types of inferences can be made in order to display adequate ToM ability: epistemic and affective inferences. Epistemic inferences are made about the knowledge and beliefs of others, while affective inferences are made about the emotional states of others (Stone, 2003).

A broad range of tasks are used to measure ToM ability. These tasks tap into the different mental state attributions. False-belief tasks tap into epistemic mental states and are the most common tests used to measure ToM ability. These tests are used to determine whether the person understands that somebody else's beliefs may not represent the reality of the situation (Bibby & McDonald, 2005). The conventional false-belief task depicts an object being transferred from one place to another without an individual knowing about it. The participant is then asked where they think the individual will look for the object. Participants display an adequate understanding that the individual's belief does not represent the reality of the situation if they answer the question correctly (Boron-Cohen, Leslie, & Frith, 1985).

Second-order false beliefs are tested using stories that depict a belief about a belief. These usually take the form of "Sally thinks that Anne thinks that..." (Bibby & McDonald, 2005). Participants need to demonstrate an adequate understanding of what one person thinks of another person's mental state in order to display adequate ToM ability.

However, the demands that false-belief tasks place on other cognitive skills unrelated to ToM ability may be the underlying reason for poor performance on the task (Channon & Crawford, 2000). False belief tasks place demands on cognitive skills such as memory and the ability to understand implicit language (Bibby & McDonald, 2005; Stone, Baron-Cohen, & Knight, 1998). Therefore, poor performance on the task may occur if the child is not able to remember the story or does not understand the questions that they are being asked. In this way, false-belief tasks resemble problem-solving tasks and may thus not be measuring an underlying ToM ability per se, but rather performance may be affected by deficits in other cognitive abilities.

Due to the problems with false-belief tasks as illustrated above, certain non-verbal ToM tests, which tap into affective mental state attributions, may be more suitable for measuring ToM ability in pTBI patients as they do not place as many demands on cognitive functions. The Reading the Mind in the Eyes test, which was used in this study, is said to be a measure of pure mental inferential ability as it does not have a problem-solving or memory component. In this test, subjects are shown photographs of the eye area and they have to deduce from this what the individual in the photograph may be feeling or thinking (Baron-Cohen, Jolliffe, Mortimore & Robertson, 1997).

Theory of Mind Following TBI

Although limited in the paediatric population, recent research has started to identify the factors that underlie poor social functioning in the context of TBI. There is a growing body of evidence that suggests that the ability to accurately infer the mental states of others is crucial to social success. Given that individuals exhibit increased problems with social behaviour following a TBI, and that there is frontal lobe involvement, it is argued that the impairments in social functioning following a TBI are the result of a deficit in ToM ability.

Indeed, TBI participants have been found to be significantly impaired on both epistemic and affective inference tasks compared to healthy controls (Bibby & McDonald, 2005; Crocker & McDonald, 2005; Rowe et al., 2001; Stone et al., 1998; Tonks et al., 2007; Turkstra, McDonald, & DePompei, 2001; Turkstra, Dixon, & Baker, 2004).

It is generally accepted that affective mental inference ability has an emotion recognition component (Baron-Cohen et al., 1985). If emotion recognition ability is impaired, it is likely that affective mental inference ability will also be impaired. Therefore, in order to accurately infer the affective mental states of others, one must be able to recognise the emotions that are communicated in social settings. However, the literature is unclear about the exact nature of the relationship between affect recognition and affective mental inference in the context of pTBI.

Research suggests that pTBI participants are significantly poorer at recognising basic emotions from facial expressions and/or tone of voice than typically developing participants (Crocker & McDonald, 2005; Green, Turner & Thompson, 2004; McDonald & Saunders, 2005; Milders, Fuch and Crawford, 2003). In particular, TBI participants have demonstrated impairments in recognising negative emotions (Hopkins et al., 2002; Jackson & Moffat, 1987). Affective mental inference tasks, such as the "Reading the Mind in the Eyes test", have an emotion recognition component; therefore, some argue that affective mental inference tasks may reflect deficits in emotion recognition ability (Henry et al., 2006; Ietswaart, Milders, Crawford, Currie, & Scott, 2008).

Some evidence for this exists within the literature. Within the paediatric population, Snodgrass and Knott (2005) found that 12 moderate to severe pTBI participants were significantly impaired on a more advanced ToM task (Reading the mind in the eyes) relative to healthy controls. Furthermore, the pTBI participants were also found to be significantly impaired on an emotion recognition task relative to the healthy participants. As emotion recognition was found to correlate with ToM ability, it is difficult to say whether poor performance on the ToM task was due to a concurrent deficit in both emotion recognition and ToM ability, or whether poor performance could be better explained by a deficit in emotion recognition only.

Similarly, Milders et al. (2003) found that 17 moderate to severe adult TBI participants performed more poorly than the healthy controls on both an affective inference task (Reading the mind in the eyes) and an emotion recognition task. However, the latter effect size was much larger and was the only one to reach statistical significance. This may provide evidence for the argument that poor performance on affective mental inference tasks may not be due to a specific ToM deficit. If it was due to a specific ToM impairment then performance on the 'Eyes test' would have to be disproportionally impaired to performance on the emotion recognition task. The opposite was shown in this case.

However, the results of this study need to be treated with caution as the authors did not correct for an increased Type 1 error rate after multiple comparisons were performed.

In contrast, Henry et al. (2006) found evidence in their study with adult TBI participants to support the hypothesis that emotion recognition and ToM are located in distinct neural networks. As Brune (2005) notes, “the link of ToM to other social cognitive capacities such as emotion recognition represents an underexplored field of research” (p. 38). Indeed, to my knowledge, no published studies to date have investigated the relationship between affect recognition and the ability to make affective mental inferences in the South African pTBI population. There is a clear need for this research as illustrated above.

Due to the presence of additional cognitive deficits that are often associated with pTBI, it has been suggested that poor performance on ToM tasks may not be due to a specific deficit in ToM ability per se, but may rather be due to deficits in other cognitive abilities. pTBI participants have been shown to have cognitive deficits in executive functions such as problem-solving, planning, self-monitoring and inhibition (Carlson, Moses, & Claxton, 2004; Henry et al., 2006). Hughes and Russel (1993) argue that poor performance on ToM tasks reflect executive dysfunction as the measures impose demands on control processes such as cognitive flexibility and response inhibition.

Furthermore, Carlson and colleagues (2004) argue that two executive function skills, namely inhibitory control and working memory, are crucial to successful social cognition. Working memory enables you to hold more than one perspective in mind and inhibitory control enables you to suppress immaterial perspectives. Therefore, a deficit in executive functioning may underlie the impairments in social functioning following pTBI.

However, the literature to date remains unclear about the relationship between ToM ability and executive dysfunction in the context of TBI. In their study with 16 adult TBI participants, Henry and colleagues (2006) found a high correlation between performance on a measure of executive function and theory of mind. In contrast, Rowe and colleagues (2001) found that while 30 severe adult TBI patients were significantly impaired on both ToM tasks and tests of executive functions compared to healthy controls, no correlation could be found between executive functioning and ToM. Similar contradictory results have been found in other studies (Channon & Crawford, 2000; Hughes, 1998). No study to date has investigated the relationship between executive functioning and ToM in the South African pTBI population. This research is important as it bears on the development and implementation of specialist programmes to help pTBI patients function better in society.

Furthermore, it has been suggested that the demands that ToM tasks place on general intelligence, specifically cognitive abilities such as memory, may confound the results (Keenan, 1998). It is therefore important that the effects of IQ are controlled for as individuals with pTBI have been shown to have deficits in general intellectual ability (Slaughter, Dennis, & Pritchard, 2002).

Specific Aims and Hypotheses

As has been shown, it is still unclear to what extent poor performance by pTBI patients on ToM tasks, specifically the Reading the Mind in the Eyes test, is due to impairments in ToM ability. The 'Eyes test' has an emotion recognition component and it has therefore been argued that poor performance may be largely due to deficits in basic emotion recognition. In order to provide evidence that poor performance on the 'Eyes test' is due largely to a ToM deficit, it must be shown that performance on the 'Eyes test' is disproportionally impaired relative to performance on a basic emotion recognition task. Furthermore, other cognitive deficits may affect performance on ToM tasks. It is therefore important that the effects of executive functioning and IQ are controlled for. These issues are important to address as the type of deficit found to be responsible for poor performance on ToM tasks will have a bearing on what kinds of interventions (to help pTBI patients function better in society) are developed and implemented.

This study therefore aimed to determine the effect of mild and moderate pTBI on affect recognition ability and the ability to infer affective mental states, once the effects of IQ and executive functioning had been controlled for. In particular, the specific hypotheses were:

1) The mild to moderate pTBI participants will be significantly impaired at recognising emotions from facial expressions compared to the TD participants (moderate pTBI < mild pTBI < TD).
2) The mild to moderate pTBI participants will be significantly impaired at recognising affective mental states from eye expressions compared to the TD participants (moderate pTBI < mild pTBI < TD).
3) The mild and moderate pTBI participants' scores on an affective measure of ToM will be disproportionally impaired relative to their scores on an emotion recognition task.
4) These effects will remain evident after the effects of executive functioning and IQ have been controlled for.

Method

Research Design and Setting

This study was part of a larger project that aimed to determine the effects of pTBI on ToM ability in adolescents. The study reported here consisted of a cross-sectional comparison of three groups: a mild pTBI group, a moderate pTBI group and a TD group. The design was quasi-experimental, as the participants were divided into groups according to the pre-existing criterion of a TBI being present. The groups were compared on their affect recognition ability, affective inference ability, executive functioning and IQ.

Testing took place at the Red Cross Children's Hospital and Groote Schuur Hospital. Participants were tested in a quiet room free from distractions.

Participants

Ethical approval for this study was granted by the Ethics Committee of the Department of Psychology at UCT as well as by the Faculty of Health Sciences Human Ethics Committee at UCT (see Appendix A). Permission was granted by the Western Cape Education Department to recruit participants from schools in the Western Cape (see Appendix B). Informed consent and assent was obtained from parents or legal guardians and participants respectively before testing began (see Appendix C).

Twenty children with a pTBI participated in this study (see Table 1). Specifically, 10 had a mild TBI and 10 had a moderate TBI. The participants were recruited from the Red Cross Children's Hospital as well as through personal referral.

Ten TD children participated in the study as controls. These participants were recruited from low-SES schools in the Western Cape. The intention was to match the TD participants to the mild and moderate pTBI participants on SES, age, home language, gender and ethnicity. SES, age and language have been found to be important predictors of performance on neuropsychological tests. Gender is important as ToM is thought to have an empathy component (Baron-Cohen et al., 1985). Furthermore, ethnicity is important as it is not entirely clear yet whether affect recognition and affective mental inference ability are culture-specific phenomena.

However, due to time constraints, I was unable to fully match the participants on all the variables mentioned above. In the end, the participants were matched on ethnicity and SES, with the exception of two participants. Furthermore, the participants were matched on age with the exception of one participant.

The participants were not matched on home language and gender. The demographic characteristics of the mild pTBI group (n=10), moderate pTBI group (n=10) and TD group (n=10) are presented in Table 1.

Table 1.

Demographic Characteristics of the pTBI and Typically Developing (TD) Groups

Demographic information	Mild (n=10)	Moderate (n=10)	TD (n=10)
Age range (Years: Months)	11:0-14:10	9:2-14:10	9:8-14:4
Age (Years)			
Mean (SD)	12 (0.94)	11.60 (1.90)	11.80 (1.48)
Sex			
Male: Female	7: 3	9: 1	6: 4
Home Language			
English: Afrikaans	10: 0	9: 1	6: 4
Ethnicity			
Coloured	10	10	10
Socio-economic status			
Medium: Low	1: 9	3: 7	1: 9

Inclusion and exclusion criteria. Participants with a developmental disorder or a history of infantile meningitis were excluded from the study. Participants with, or with a history of, any serious social deficits, such as conduct disorder (CD) or oppositional defiant disorder (ODD), were also excluded from the study. Furthermore, for the TD group, participants were excluded if they had a history of head injury.

Only mild and moderate pTBI participants were included in the study. Furthermore, mild and moderate pTBI participants were included if they were at least three months post-injury, as this is the time frame in which post-concussive symptoms are thought to resolve in the majority of cases (Anderson & Pentland, 1998). Lastly, participants were excluded if they were not fluent in either English or Afrikaans.

Measures

Affect recognition. The ability to recognise emotions from facial expressions was assessed using the Affect Recognition (AR) subtest from the NEPSY-II Social Perception domain (Korkman, et al., 2007). The NEPSY-II is a well-established, reliable and valid measure of affect recognition that is widely-used in the neuropsychological literature (D'Amato & Hartlage, 2008). The AR subtest consists of four tasks that assess the ability to recognize emotion from photographs of children's faces. The AR subtest is a non-verbal test as it does not have a language or verbal component. In the test, the participants were asked to point to the photograph of a child (amongst 4 or 6 other photographs of children's faces) that they thought *felt* the same as another photograph of a child that was pointed out to them. When instructing the participant on the task, it was stressed that they must point to a child that felt the same way rather than to a child that looked the same. This test does have a memory component in one of the tasks which may have confounded the results.

Affective mental state inference. The ability to infer the affective mental states of others from eye expressions was assessed using the Baron-Cohen, Wheelwright' and Spong's (2001) children's version of the Reading the Mind in the Eyes test. The literature has suggested that epistemic inference tasks may place demands on other cognitive abilities, such as memory or problem-solving abilities, which may confound the results (Bibby & McDonald, 2005, Stone et al., 1998). The Reading the Mind in the Eyes test may therefore be a more appropriate measure of ToM as it does not have a memory or problem-solving component and is said to be a measure of pure mental inferential ability. The test has been shown to be reliable and valid and has been designed for children aged 6 and above (Baron-Cohen et al., 1997).

In the test, the participants were required to look at 28 photographs of the eye region of males and females and decide which of the four words presented, one target and three foil words, best depicted what the person was feeling or thinking. This task is more complex than a basic emotion recognition task as both cognitive and affective words were presented.

Cognitive ability. The general intellectual ability and executive functioning of the TD and pTBI groups were assessed using three tests: the *Wechsler Abbreviated Scale of Intelligence* (WASI), the *Wechsler Intelligence Scale for Children* (WISC-IV^{UK}) and the *Delis-Kaplan Executive Function System* (D-KEFS).

The WASI is a well-established reliable and valid measure of intellectual ability that has been normed for individuals between the ages of 6 and 89 years (Wechsler, 1999).

The four-subtest format was used to obtain a Verbal IQ (VIQ) score and a Performance IQ (PIQ) score. VIQ was assessed by administering the Vocabulary and Similarities subtests, and PIQ was assessed by administering the Matrix Reasoning and the Block Design subtests. The full scale IQ (FSIQ) score was obtained by combining the VIQ score and the PIQ score. Only the FSIQ score was used as a measure of IQ as TBI has been shown to cause diffuse damage which may result in both reduced VIQ and PIQ.

The WISC-IV^{UK} is a well-established standardized measure of childhood intelligence (Watkins, Wilson, Kotze, & Carbone, 2006). Extensive validity and reliability evidence has also been given (Prifitera, Saklofske, & Weiss, 2005). The Coding and Symbol Search subtests were administered to assess processing speed. The Digit Span and Letter-Number Sequencing subtests were administered to assess working memory.

The D-KEFS is a standardized measure of key components of executive functions (EF), such as higher-level thinking and cognitive flexibility, which has been normed for individuals between the ages of 8 and 89 years (Delis et al., 2001). It consists of nine subtests, of which two were selected as a measure of EF: the Colour-Word Interference subtest and the Verbal Fluency subtest. These subtests were chosen as a measure of EF as pTBI has been shown to cause specific deficits in these areas. The Colour-Word Interference subtest measures the ability to inhibit a learned response, and the Verbal Fluency subtest assesses the ability to generate semantic categories.

Translation of the measures. The instructions for all the measures described above, except for the WASI, were translated into 'formal' or 'high-level' Afrikaans. Furthermore, the words depicting what the person is thinking or feeling in the Reading the Mind in the Eyes test were translated into formal Afrikaans. All the translations were done by the language lab at the University of Cape Town, forward once. The WASI was translated by Helen Ferret at the University of Stellenbosch.

Procedure

Informed consent was obtained from the participant's parent or legal guardian over the phone before a testing date was confirmed. Once informed consent was obtained, the parent or legal guardian was interviewed over the phone to assess the participant's social, medical and developmental history. If the participant was found to be suitable for the study, a testing date was confirmed with the parent or legal guardian.

On the day of testing, written informed consent and assent was obtained from the parent or legal guardian and participant respectively.

At the same time, the parent or legal guardian was also required to fill out a questionnaire that confirmed the participant's demographic information and SES status as well as identified any possible exclusion criteria (see Appendix D).

The tests were administered in the participant's home language (English or Afrikaans) and as part of a larger study. Testing took place in one session and lasted for approximately 3 hours. The participant was encouraged to take breaks as often as possible to control for fatigue effects. Drinks and snacks were provided during the breaks. The five tests were administered in counterbalanced order to further control for fatigue effects.

Once the testing was completed, the participants were debriefed and any questions they may have had about the testing procedure were answered.

Data Analysis

Detailed descriptive statistics were analyzed first to characterise the performance of the TD, mild and moderate pTBI groups on the measures of affect recognition and affective mental inference. The main analysis included a series of one-way analysis of variances (ANOVAs) to compare the performance of the different groups on the affect recognition and affective inference tasks. Whether between-group differences in full scale IQ, working memory, processing speed and executive functioning were present was then determined through the use of several one-way ANOVAs. All the statistical analyses were conducted on the SPPS version 18 software package.

All assumptions underlying the various tests were upheld, except for one instance. For the data on executive functions, the Mauchley's test of sphericity was significant. In order to adjust for the violation of sphericity, the Greenhouse-Geisser correction was used.

An increased possibility of making a Type 1 error occurred due to the number of analyses conducted. However, due to the small sample size, and the resultant poor power, as well as the preliminary/exploratory nature of the research, it was decided that adjusting the alpha level to control for Type 1 error would be overly conservative. Thus, the significance level was left at 0.05.

Results

The NEPSY-II Affect Recognition Subtest

Raw scores were used to compare the participants on affect recognition ability, as raw scores are more sensitive than scaled scores and the participants had similar ages. The highest score that could be obtained on the affect recognition task was 35.

A one-way analysis of variance indicated no effect for group on affect recognition ability ($F_{(2,27)} = 0.047$, $p = 0.954$, $\eta^2 = 0.004$). Therefore, the TD, mild and moderate pTBI groups did not differ significantly from one another on affect recognition ability.

In terms of the types of errors made, the most common errors made by both the TD group and the mild to moderate pTBI groups featured incorrectly attributing negative emotions (specifically disgust, anger and sadness) to facial expressions (see Table 2).

Table 2.

The Ability to Recognise Affect and the Types of Errors Made by Both the Typically Developing and pTBI Groups

Group	N	Affect recognition	Mean number of errors					
		Total correct	Happy	Sad	Neutral	Fear	Anger	Disgust
TD	10	25.70 (2.13)	0.22 (0.44)	2.55 (1.01)	1.80 (1.20)	1.00 (1.22)	2.67 (1.50)	3.00 (1.23)
Mild	10	25.50 (3.87)	0.33 (0.67)	2.89 (2.74)	1.40 (1.30)	1.11 (1.14)	2.67 (1.84)	2.22 (1.49)
Moderate	10	26.00 (4.14)	0.22 (0.44)	1.90 (0.90)	0.78 (0.67)	1.89 (1.36)	2.44 (1.74)	2.00 (1.22)

Note. Means are presented with standard deviations in parentheses.

The Reading the Mind in the Eyes Test

The more sensitive raw scores were used to compare the participants on affective inference ability. The highest score that could be obtained on the affective inference task was 28. A one-way analysis of variance indicated no effect for group on affective inference ability ($F_{(2,27)} = 0.058$, $p = 0.943$, $\eta^2 = 0.004$). Therefore, the TD, mild and moderate pTBI groups did not differ significantly from one another on affective inference ability.

Table 3

The Ability to Make Affective Inferences in the Typically Developing and pTBI Groups

Group	N	Affective inference
TD	10	16.40 (5.17)
Mild	10	15.70 (5.29)
Moderate	10	16.40 (5.38)

Note. Means are presented with standard deviations in parentheses.

General Intellectual Ability

Full scale IQ. As might be expected for this sample, the full scale IQ of the TD group fell outside of established Western population norms. A one-way analysis of variance indicated that the effect for type of group was non-significant (see Table 4). Therefore, the TD, mild and moderate pTBI groups did not differ significantly from one another on FSIQ.

However, the FSIQ score for the moderate pTBI group was unexpected as it was similar to the FSIQ score for both the mild pTBI group and the TD group.

Processing speed and working memory. A one-way analysis of variance indicated a significant effect for type of group on processing speed (see Table 4). Tukey's HSD post-hoc analysis indicated a significant difference between the TD group and the moderate pTBI group on processing speed (p = 0.02; see Table 4), with the TD group being significantly faster at processing than the moderate pTBI group.

However, a one-way analysis of variance indicated no effect for group on working memory (see Table 4). Therefore, the TD, mild and moderate pTBI groups did not differ significantly from one another on working memory.

Table 4.

IQ, Processing Speed, and Working Memory Means Between the Typically Developing (TD) and pTBI Groups

	TD (n=10)	Mild (n=10)	Moderate (n=10)	F	p	η^2
WASI						
Full Scale IQ	76.70 (6.83)	83.40 (17.83)	78.70 (9.13)	0.793	0.463	0.245
WISC-IV						
Working memory index	87.90 (9.06)	82.30 (17.58)	82.80 (17.54)	0.276	0.761	0.020

Processing speed index	91.30 (10.45)	84.10 (13.63)	76.20 (10.05)	4.390	0.022	0.245

Note. Means are presented with standard deviations in parentheses.

Executive Functioning

The more sensitive raw scores were used to compare the participants on the various executive function tasks as the participants had similar ages. A series of one-way ANOVAs were conducted to investigate differences between the groups on task types. Three tasks were selected as measures of EF (one from the verbal fluency subtest and two from the colour-word interference subtest). The tasks selected are consistent with the literature regarding specific executive functioning deficits in pTBI patients. The type of group was found to have no significant effect on the number of correct verbal responses given ($F_{(2,27)} = 1.991$, $p = 0.156$, $\eta^2 = 0.129$; see Table 5), the inhibition/switching task ($F_{(2,27)} = 1.430$, $p = 0.257$, $\eta^2 = 0.096$; see Table 5) and the number of errors made on the inhibition/switching task ($F_{(2,27)} = 0.336$, $p = 0.718$, $\eta^2 = 0.024$; see Table 5). Therefore, there were no significant differences in performance on the measures of EF between the TD and mild and moderate pTBI groups.

Table 5.

Performance on the D-KEFS Verbal Fluency and Colour-Word Inference Tasks by the Typically Developing (TD) and TBI Groups

Measure	TD (n=10)	Mild (n=10)	Moderate (n=10)
D-KEFS Verbal Fluency			
Total Correct Responses	62.20 (12.20)	60.90 (11.20)	50.40 (18.88)
D-KEFS Colour-Word Interference			
Inhibition /Switching [a]	84.70 (13.76)	94.00 (22.14)	101.60 (28.69)
Total Errors: Inhibition /Switching [a]	6.70 (4.45)	6.70 (4.21)	8.10 (4.56)

Note. Means are presented with standard deviations in parentheses.

[a] Better performance on the task is represented by a smaller mean.

Discussion

This study compared the performance of children with mild and moderate pTBIs to that of an age, SES and ethnicity matched control group on measures of affect recognition, affective inference, executive functioning and IQ. It was hypothesized that the mild and moderate pTBI children would be less accurate at recognising basic emotions and inferring affective mental states from facial expressions than their typically developing peers, after the effects of IQ and executive functioning had been controlled for. Furthermore, it was hypothesised that the moderate pTBI participants would show significantly larger deficits on the various measures mentioned above compared to the mild pTBI participants.

The general intellectual abilities and the executive functioning of the participants were assessed in this study as both have been put forward as important covariates of ToM task performance. However, no significant group differences were found on the measures of executive functioning, FSIQ and working memory. A significant difference in processing speed was found between the moderate pTBI and TD participants, which is in accordance with the literature. However, the significant difference in processing speed is unlikely to have had an effect on the results as the measures of affect recognition and affective inference do not have a speeded component.

The lack of significant differences in executive functioning and IQ between the mild pTBI, moderate pTBI and TD participants is not what was expected and is inconsistent with the literature. The literature suggests that pTBI, especially more severe forms thereof, has a negative effect on both executive functioning and general intelligence (Carlson, Moses, & Claxton, 2004; Henry et al., 2006).

However, the results for the executive function tasks were all in the expected direction. The inability to detect a significant difference on the executive function tasks between the groups may have been due to the small sample size used in this study, and the resultant poor power. A post-hoc power analysis yielded a power estimate of 0.08 for a small effect (η^2=0.129). This means that there was only a 8% chance of finding a significant small effect between the mild pTBI, moderate pTBI and TD participants on the inhibition switching task. This is highly problematic, but time constraints resulted in the small sample used in this study.

Furthermore, the results did not support the hypothesis that participants with mild and moderate pTBIs would be significantly impaired at recognising emotions from facial expressions compared to TD participants. Rather, the results indicated that there were no group differences between the TD, mild pTBI and moderate pTBI participants on affect recognition ability. These results are inconsistent with those reported in the literature. Research seems to suggest that pTBI participants are less accurate at recognising basic emotions from facial expressions than TD participants (Crocker & McDonald, 2005; Green, Turner & Thompson, 2004; McDonald & Saunders, 2005; Milders, Fuch and Crawford, 2003).

In terms of the type of emotion recognition errors made, the most common errors made by both the mild pTBI and moderate pTBI participants featured incorrectly interpreting positive stimuli as being negative. This is consistent with what is reported in the literature (Peterson, 1991). These errors of 'opposite polarity' in detecting facial expressions have been found to occur in pTBI. However, this finding most likely represents task difficulty as the TD participants also made the most errors by incorrectly attributing negative emotions to a positive facial expression.

Similarly, the results did not support the hypothesis that participants with mild and moderate pTBIs would be significantly impaired at inferring affective mental states from facial expressions compared to TD participants. Instead, the results indicated that there were no group differences between the TD, mild pTBI and moderate pTBI participants on affective mental inference ability. These findings are inconsistent with those reported in the literature. Research indicates that pTBI participants are less accurate at inferring affective mental states than TD participants (Bibby & McDonald, 2005; Crocker & McDonald, 2005; Rowe et al., 2001; Stone et al., 1998; Tonks et al., 2007).

A few possible reasons may exist for the inconsistent results found in this study. The small sample size, and the resultant poor power, may be the reason why a significant effect was not found on the executive function tasks as small effects were present. However, no effects were present for the affect recognition and affective inference tasks ($\eta^2 = 0.004$).

The lack of significant differences between the TD, mild pTBI and moderate pTBI groups may be related to the measures used to assess affect recognition ability and affective mental inference ability in this study. Despite being well-researched, the Reading the Mind in the Eyes test and the NEPSY-II AR subtest have not been standardized for use with the population used in this study. Furthermore, the Reading the Mind in the Eyes test and the NEPSY-II AR subtest have both been standardized for use with a Western population, which is typically high SES and has a higher level and quality of education. It is increasingly accepted that an interplay of socio-cultural factors, cognitive ability and personality affect performance on neuropsychological tests (Anderson, 2001; Nell, 2000). Specifically, variables such as SES, quality of education and level of education have been found to predict performance on neuropsychological tests (Howie, Sherman, & Venter, 2008; Magnusen & Duncan, 2006).

It is therefore perhaps not surprising that the TD group's mean score on the Reading the Mind in the Eyes test was lower than the mean score obtained by the TD group (N=12) that participated in the pilot study for the children's version of the Reading the Mind in the Eyes test (16.40 vs. 20.33 respectively; Baron-Cohen et al., 2001). Similarly, the TD group's mean score on the NEPSY-II AR subtest fell outside of established Western population norms.

It is important to note that all groups demonstrated extremely similar poor performance on both the Reading the Mind in the Eyes test and the NEPSY-II AR test. The nearly identical poor performance by all of the groups on the two tests suggests that the tests may not be an appropriate measure of affective mental inference ability and emotion recognition ability in this context. Thus, the two tests do not seem to be culturally-sensitive despite claims that non-verbal neuropsychological tests are 'culture-free' (Rosselli & Ardila, 2003).

The Reading the Mind in the Eyes test and the NEPSY-II AR subtest may not be appropriate for use with the population used in this study for a number of reasons. The NEPSY-II AR subtest has a memory component which may have had an effect on the results. Specifically, in one of the tasks, the participant is shown a photograph of a child's face which they are told to memorize. The photograph is removed after five seconds and the child is then asked to point to a photograph of one child (out of a possible six) that feels the same way as the child that they were just shown. The children used in the photographs are from different ethnic backgrounds which may be problematic for the memory task. Research suggests that there is an own-race recognition bias for the memory of human faces (Bryant & McCaffrey, 2006). Therefore, individuals remember the faces of their own race more accurately than faces of other races. The NEPSY-II AR subtest may thus be more appropriate for use with the South African population if the memory component was taken out of the test. It does not seem logical to have a memory component in an emotion recognition test.

Furthermore, the photographs of the eye regions used in the Reading the Mind in the Eyes test are all of white adult individuals. The test may be more appropriate for use with the population used in this study if it had photographs of the eye region of children from a diverse races.

Limited research could be found for the reliability and validity of the Reading the Mind in the Eyes test and the NEPSY-II AR test for use with non-Western populations. However, it has been found that the NEPSY-II is not an appropriate measure of language skills, attention and executive functions in a small Zambian sample of children aged 9-11 (Mulenga, Ahonen, & Aro, 2001). The results found in this study highlight the need for further research into the validity and reliability of the Reading the Mind in the Eyes test and the Nepsy-II AR subtest for use with South African children. Without it, research into the effects of pTBI on affect recognition and the ability to infer affective mental states in the South African population may not be meaningful or valid.

Language may have also had an effect on the results. The majority of the mild and moderate pTBI participants indicated that their home language was English, while the majority of the TD participants indicated that their home language was Afrikaans. This is highly problematic for a number of reasons. Firstly, it is still unclear to what extent home language, the medium of academic instruction and the language of test administration affects performance on neuropsychological tests. In this case, home language was used as the medium of test administration. However, some research indicates that individuals perform better on neuropsychological tests if they are tested in the medium of academic instruction (Briggs, 1990). It was not determined in this study whether the participants' home language was the same as their medium of academic instruction, which could be problematic as illustrated above.

Secondly, the method used to translate the tests may have had an effect on the results. The tests were translated into 'formal' or 'high-level' Afrikaans. However, language in South Africa is not a one size fits all. Numerous variations of Afrikaans are spoken in South Africa. In the Western Cape, a less formal idiom is spoken which often includes English words. Notably, while testing in Afrikaans, we were often asked to translate Afrikaans words into English as the participants did not understand what they meant. For example, in the Vocabulary subtest of the WASI, we were consistently asked to translate the word 'herstel' into English for the participants. The difficulty the participants had with some of the words in the WASI illustrate both the challenges posed in translating tests for use with a multi-lingual society as well as the need for further research in this regard. Indeed, the extremely poor performance by the TD group on the WASI suggests that language may have been an important contributing factor to the inconsistent results found in this study.

Even though the NEPSY-II AR test is thought to be a non-verbal test, the test instructions were formally translated into Afrikaans which may have had an effect on the results. Furthermore, the words describing what the person was thinking or feeling in the Reading the Mind in the Eyes test were formally translated into Afrikaans. It seems reasonable to suggest that if the participant did not understand a particular word he/she may have disregarded it and instead may have chosen a word that he/she was more familiar with. This would have had an obvious effect on the results. There is a clear need for further research into the effects of language on neuropsychological test performance in the context of South Africa as illustrated above.

Another reason for the inconsistent results found may be related to the severity of TBI used in this study. The majority of participants used in the literature have a severe TBI. This study was exploratory in the sense that mild to moderate TBI participants were used. It seems that the Reading the Mind in the Eyes test has only been used with moderate pTBI participants in one study (Snodgrass & Knott, 2006), but never with mild pTBI participants. Similarly, the NEPSY-II Affect Recognition test has never been used with mild or moderate pTBI participants. It may be that the Reading the Mind in the Eyes test and the NEPSY-II AR test are not sensitive in less severe cases of pTBI. More research is needed in this regard.

Limitations and Directions for Future Research

An important potential limitation of this study is the fact that some of the moderate pTBI participants have taken part in other studies before. Due to the fact that they are particularly difficult to recruit for research purposes, the moderate pTBI group were eventually sourced through other research projects. This may mean that the moderate pTBI participants were more familiar with the testing environment, which may have given them an added advantage over the mild pTBI and TD participants. Thus other qualitative variables, such as anxiety, may have confounded the results of this study.

Furthermore, it transpired that some of the moderate pTBI participants had already been tested with one of the general intelligence measures (WASI) in previous studies. While every effort was made to obtain the original data, it was not possible in some of the cases. In order to determine if possible retest effects were present, the original data of the WASI was compared to the corresponding data obtained in the current study. However, it was difficult to say whether retest effects were present. While some of the participants did perform better, others did not. Due to the problems outlined above, the results of the WASI for this group should be treated with caution. Furthermore, the fact that some of the moderate pTBI participants had already been tested with the WASI may be a contributing factor to this group's unexpected high FSIQ score.

With regards to future research, it would be useful to take a more holistic approach to research on ToM ability following pTBI. The Reading the Mind in the Eyes test assesses a very specific aspect of emotion recognition and interpretation through the limited area of the eye region. In real life social situations, individuals are presented with more clues about the thoughts and feelings of others, such as through posture or tone of voice. Therefore, research could determine if these added clues are necessary for ToM ability in pTBI patients.

It would also be interesting to determine how age at injury affects ToM ability. It has been found that individuals who acquire pTBI in the later stages of childhood, after the foundations for ToM skills have already been developed, are able to gain more social skills following pTBI than those that acquire pTBI in the early stages of childhood (Tukstra et al., 2000). It would be useful to determine if age of injury predicts social outcome in the South African paediatric population as this could be an important consideration for the formation and implementation of pTBI intervention programmes.

Conclusion

The ability to recognise emotions and make affective mental inferences are crucial ToM abilities and are thought to be important for successful social interaction. It has been suggested that both these affective processes may be impaired in individuals following a pTBI. However, this study was unable to determine whether affect recognition ability and/or affective mental inference ability are affected in the South African pTBI population. Furthermore, this study was unable to determine whether other cognitive deficits that may be present in pTBI, such as executive dysfunction, could account for impairments in social functioning post-injury.

While inconclusive, these findings are still extremely instructive. The results seem to suggest that the measures used in this study are not appropriate for use with the South African paediatric population. This is informative as the Reading the Mind in the Eyes test and the NEPSY-II AR subtest are thought to be ‘culture-fair’ as they are non-verbal tests. The findings in this study suggest otherwise and provide support for the growing body of literature that suggests that non-verbal tests are not culture free as is so often thought. Furthermore, language also seems to be an important contributing factor. This study illustrates the difficulties posed when translating measures for use with a multi-lingual population and illustrates the need for further research in this regard. It is important that appropriate measures are developed to assess affect recognition and affective inference ability in the South African pTBI population, as adequate research in this regard will provide invaluable information to help pTBI patients function better in society.