Associations between TBI, facial emotion recognition, impulse control and aggression in delinquent and vulnerable young people

Submitted by **Sanna Tanskanen**, to the University of Exeter as a thesis for the degree of Doctor of Clinical Psychology, May 2015

I certify that all material in this thesis which is not my own work has been identified and that no material has previously been submitted and approved for the award of a degree by this or any other University.

Signature …………………………………………………………

Author’s Declaration

The literature review was completed independently by the author. In terms of the empirical work, 26 participants were recruited as a part of a previous masters project at University of Exeter titled: “Storm, Stress and Broken Brains: The Influence of Traumatic Brain Injury on Socio-Emotional Processing in Delinquent Adolescents” (Miriam Cohen, 2013). Furthermore, data from 59 students collected from local schools were added to the author’s project as a control group. This data was collected as a part of another study by the School of Psychology at University of Exeter in July 2014. The author tested a total of 21 participants for this project between September and November 2014. All other aspects of the study were completed by the author including data entry, analysis and write up.

Table of Contents

List of Tables

LITERATURE REVIEW

EMPIRICAL PAPER

List of Figures

Literature Review

Empirical Paper

SCHOOL OF PSYCHOLOGY

DOCTORATE IN CLINICAL PSYCHOLOGY

LITERATURE REVIEW

A Review of Theory of Mind Abilities in Children and Adolescents with Traumatic Brain Injury (TBI)

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Target Journal: Journal of the International Neuropsychological Society

Word Count: 4225 (excluding abstract, table of contents, list of figures, tables, references, footnotes, appendices)

Submitted in partial fulfillment of requirements for the Doctorate Degree in Clinical Psychology, University of Exeter

Abstract

Objectives. Children with traumatic brain injury (TBI) are at an increased risk for psychosocial difficulties. Theory of mind (ToM), which refers to an ability to make accurate inferences about the mental states of others, is often impaired following TBI. Such deficits are suggested to contribute to problems in social interaction. This review aimed to provide an overview of how ToM abilities are currently operationalised and how it is measured in young people with TBI.

Method. Systematic search of four databases was conducted using an advanced combination of search terms. A total of 18 papers were included.

***Results*.** Current research operationalizes ToM as cognitive, affective and conative. First- and second order cognitive ToM abilities appear to be impaired following early childhood TBI, but are better preserved at later age of injury. The more complex, cognitive-affective and conative ToM abilities were shown to be impaired in the TBI groups across the studies. The studies indicated that these more complex ToM abilities were more vulnerable to moderate to severe TBI in childhood, whereas mild to moderate TBI led to less widespread deficits. The overall quality of the reviewed studies was rated as weak to moderate.

Conclusions. Based on the reviewed studies, ToM abilities can be impaired following childhood TBI. This review also highlighted a wide range of measures currently used to assess these abilities in young people and a lack of clearly agreed operational definitions of ToM constructs in the literature. Better consensus and comprehensive assessment batteries are needed to evaluate these skills in children and young people after TBI. Recommendations for future research were made.

Key words: theory of mind, mentalizing, traumatic brain injury, childhood.

Introduction

Traumatic brain injury (TBI) is the leading cause of disability and mortality in children and working age adults (Fleminger & Ponsford, 2005). Typical injury patterns arise due to the acceleration-deceleration forces, whereby the pathology is commonly concentrated in the ventrolateral, medial- and orbital frontal, as well as the ventromedial temporal lobes (e.g. Bigler, 2007). These areas, which are considered important for the “social brain network”, are particularly vulnerable to damage following childhood TBI (e.g., Bigler et al., 2013). The “social brain” enables us to recognise others (including facial expressions and bodily gestures) and to make inferences about the mental states of other people (including beliefs, feelings, intentions) in relation to ourselves (Brothers, 2002; Frith, & Frith, 2007). This ability helps us to predict behaviour of others and guides flexible social interaction (Adolphs, 2001; Stone, Baron-Cohen, & Knight, 1998).

There are at least two different routes to understanding the minds of other people that involves sharing the other person’s feelings (i.e., empathy) and making cognitive inferences about the other person’s mental states (Hein & Singer, 2008). The latter ability is commonly referred to as “Theory of Mind” (ToM), “mentalizing” (Frith & Frith, 2003), or “mind reading” (Baron-Cohen, 1995). ToM is comprised of several functions involving memory, joint attention, complex perceptual recognition (e.g., face and gaze processing), language and executive functions (including tracking of intentions, goals and moral reasoning), as well as emotion processing involving emotion recognition and empathy (Korkmaz, 2011). Furthermore, ToM abilities are shaped by the complex interaction of biopsychosocial factors, such as brain development and social environment (Korkmaz, 2011).

Research on developmental disorders has suggested that ToM is dissociable from other cognitive functions. For instance, individuals with autism appear to have a selective impairment of ToM while other functioning is relatively intact (e.g., Stone, Baron-Cohen, & Knight, 1998). In contrast, selective sparing of ToM ability has been found in individuals with impaired general intellectual functioning, such as William's syndrome and Down's syndrome (Happe, 1999). A recent systematic review concluded that although executive function and ToM appear tightly associated, no executive sub-processes could be specifically linked with ToM performances (Aboulafia-Brakha, Christe, Martory, & Annoni, 2011).

Therefore, ToM is not a monolithic process, but entails both cognitive and affective processing (e.g., Brothers & Ring, 1992; Hein & Singer, 2008; Shamay-Tsoory & Aharon-Perez, 2007; Shamay-Tsoory, Tibi-Elhany, & Aharon-Peretz, 2006). "Cognitive ToM" refers to cognitive perspective taking, in other words, the ability to understand beliefs held by others, whereas the "affective ToM" refers to emotional states and functions involving affective influence, such as empathy (e.g., Dennis et al., 2013). A Tri-Parte model has been suggested to highlight different levels of ToM constructs, which are conceptualised as cognitive, affective and conative constructs (Dennis et al., 2013c; Table 1).

Table 1. The Tri-Parte Model of Theory of Mind

Construct of ToM	**Brief Description**
Cognitive ToM	Refers to “mindreading” aspect of ToM, concerned with cognitive beliefs and reading the information content of people’s minds.
Affective ToM	Concerned with *emotional expression* from facial expressions and *emotive communication*, in which the expression on the face is consciously pantomimed or even deceptive. This includes emotions or speech prosody and the communication of deceptive or discordant emotions in order to communicate an emotion other from the one felt.
Conative ToM	A form of social communication in which one person tries to influence the mental and emotional state of another (e.g., ironic criticism and empathic praise).

It is suggested that these cognitive and affective ToM systems are subserved by dissociable, yet interacting prefrontal networks (Abu-Akel & Shamay-Tsoory, 2011). Although the neural basis of ToM is not yet fully understood, the cognitive ToM processes have been shown to engage regions of the superior temporal sulcus (pSTS), temporo-parietal junction (TPJ), as well as the temporal poles and the medial prefrontal cortex (e.g., Frith & Frith, 2003, 2006). Whereas the affective ToM network primarily engages the ventromedial and orbitofrontal cortices, the ventral anterior cingulate cortex, the amygdala and the ventral striatum (Abu-Akel & Shamay-Tsoory, 2011). A recent meta-analysis suggested that rostral prefrontal cortex, corresponding to Broadmann’s area 10, is associated with mentalizing tasks (Gilbert et al., 2006).

Development and Assessment of ToM in Children

ToM competencies develop incrementally and several measures have been developed to test these abilities in children. Joint and shared attention to goal-directed and intentional action is present from 3 months but becomes more refined between the ages of 9 and 18 months (Scaife & Bruner, 1975), and by 18 months children begin to show clear signs of sensitivity to other people's intentions (Baron-Cohen, 1995). The "first-order" false belief tasks that require an ability to engage in perspective taking with scenarios that involve deception and ignorance are typically passed between the ages of 3 and 6 (Frith & Frith, 2003; Perner & Wimmer, 1983). For instance, the classic "first-order" ToM test, the Sally and Anne Test, is typically passed by the age of 3 or 4, whereas children with autism either pass this test at a later age or not at all (Baron-Cohen, Leslie, & Frith, 1986). The "second-order" false belief ToM tasks require an understanding that two people think sequentially (e.g., John *thinks* that Mary *thinks)*, which is typically mastered by the age of 6 or 7 in typically developing children (Perner & Wimmer, 1985). Children with high functioning autism may pass these tests, but not until their adolescence years (Liddle & Nettle, 2006).

Success on "third-order", more advanced ToM tasks require the ability to understand more complex aspects of social interactions and non-literal communication such as metaphors, jokes, irony, and sarcasm (Walz, Yeates, Taylor, Stancin, & Wade, 2010). Children are typically able to master complex ToM judgments in reference to sarcasm around the age of 6 to 9 years (Perner & Wimmer, 1985) and Faux Pas by the ages of 9 to 11 years (Baron-Cohen, O'Riordan, Stone, Jones, & Plaisted, 1999). The most widely used advanced-level ToM tests include Happe's Strange Stories Test (Happe, 1994) and the

Faux Pas Recognition Test (Baron-Cohen, O'Riordan, Stone, Jones, & Plaisted, 1999). Another advance-level ToM measure, The Reading the Mind in the Eyes Test, uses visual tasks that are less demanding on the executive functioning and has also been modified to children (Baron-Cohen, Wheelwright, Scahill, Lawson, & Spong, 2001a). Also dynamic and behavioural tests have been developed to assess ToM abilities in acted or naturally occurring social interactions (e.g., movie clips, Roeyers, Buysse, Ponnet, & Pichal, 2001; online-game, Keysar, Lin, & Barr, 2003). These more complex cognitive-affective ToM abilities continue to develop through late childhood and adolescence (Choudhury, Blakemore, & Chapman, 2006; Dumontheil, Apperly, & Blakemore, 2010), which corresponds to structural and functional brain development (Blakemore, 2008).

The Aims for This Review

ToM abilities, as well as many other cognitive skills required for social information processing, including executive functions and working memory, continue to develop throughout childhood into early adulthood (e.g., Janusz et al., 2002; Stuss & Anderson, 2004; McDonald, English, Randall, Longman, Togher, & Tate, 2013; Yeates et al., 2004, 2007). Therefore, injury to the immature brain is suggested to have more serious and persisting effects than similar injuries sustained in adulthood (Anderson, Godfrey, Rosenfeld, & Catroppa, 2012). Thus, children with TBI are considered at increased risk for social impairment (e.g., Yeates et al., 2004). However, the underlying mechanisms are not well understood, but it is hypothesised that damage to the "social brain", including ToM and socio-emotional processing, might be important contributing factors to such difficulties.

There have been reviews and meta-analysis of social cognition and ToM in adults with TBI (e.g., McDonald, 2013; Martin-Rodreguez & Leon-Carrion, 2010; Aboulafia-Brakha et al., 2011) but not in children. Therefore, the focus of this review is first of all to explore how ToM is defined operationally and how it is measured within the context of childhood TBI. This review will then move onto examining whether ToM abilities are affected by childhood TBI.

Method

Research Questions

The research questions are: (1) How is ToM operationally defined and measured in the context of childhood TBI? (2) Are ToM abilities impaired after childhood TBI?

Search Strategy and Information Sources

A systematic search of published peer reviewed articles from 1900 to 2015 was conducted in March 2015. The following databases were searched: Web of Science, EBSCO HOST, NICE Healthcare Databases and OvidSP that include PsycINFO, PsycARTICLES, Medline PubMed. The following search terms were used to search titles, abstracts and key words:

1) ("Youth" OR "Child" OR "Juvenile" OR "Adolesc*" OR “paediatric” OR “pediatric”) AND

2) ("Head injur*" OR "Brain injur*" OR "traumatic brain injur*") AND

3) ("theory of mind" OR "affective theory of mind" OR “conative theory of mind” OR “cognitive-affective theory of mind” OR “social communication” OR “social affective communication” OR “mentalizing”)

Eligibility Criteria

The following inclusion criteria were used: (a) a distinct TBI sample, (b) a clear measure of TBI severity, (c) TBI acquired in childhood (<18 years), (d) a measure of ToM. Studies were excluded if (a) not published in English, (b) was a review article, (c) full text was not available, (d) considered other neurological disorders (e.g., ABI, stroke, tumours), neurodevelopmental conditions (e.g., autism, learning disability) or mental health conditions (e.g., schizophrenia).

Data Extraction and Quality Assessment

This review was conducted using the PRISMA reporting protocol (Moher, Liberati, Tetzlaff, & Altman, 2009) to ensure standardized, non-biased approach to the review. The search findings were firstly screened for titles and then abstracts, and finally the full contents of the paper were scanned and assessed according to the inclusion criteria (see Figure 1 for process). Those that did not meet the criteria were rejected at each stage. Key information was then extracted from the included studies using a data extraction form (see Appendix A). A further manual search of the obtained reference lists was conducted to identify additional relevant articles. Eighteen papers were included for the review (Table 2). The quality of studies were assessed using the Effective Public Health Practice Project (EPHPP) “Quality Assessment Tool” (Thomas, Cliska, Dobbins, & Micucci, 2004; Appendix B), which is reported to have better psychometric properties[1] than the Cochrane Collaboration Risk of Bias tool (Armijo-Olivo, Stiles, Hagen, Biondo, & Cummings, 2012). Global quality rating (weak, moderate, strong) was based on the scoring of the following components: selection bias, study design, confounders and data collection

[1] EPHPP was found to have better inter-rater agreement for individual component domains as well as for final quality grade.

methods.

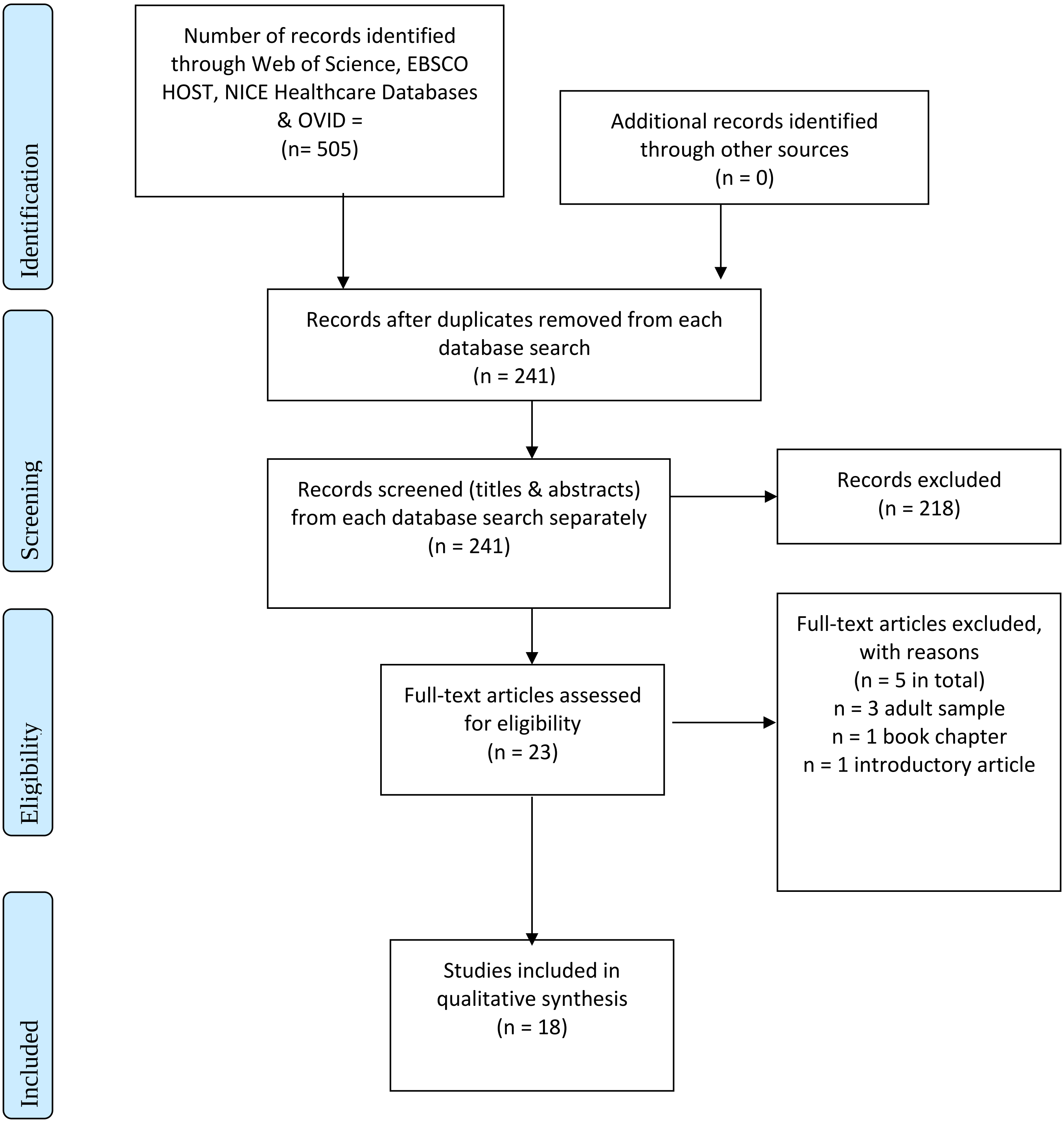

Figure 1. Search strategy, process of identification, screening, eligibility and outcome at each stage based on PRISMA 2009 flowchart.

Table 2. Summary of the Reviewed Studies

Study	Study aims	Design	Sample characteristics	Measures	Main findings related to ToM	Evaluation & Quality Assessment
1. Bigler et al., 2013	To examine the influence of TBI on social behaviour in children by investigating performance on a range of ToM tasks and collecting data on peer relations and friendships in the classroom	Between group, MRI study	**Location of study:** Canada & USA **Sampling:** Children recruited from a larger multi-site outcome (SOBIK) study, sequential cases were selected. MRI studies conducted at least 1-year post injury. **Inclusion criteria:** All children were 8-13 years and injured between 12 and 48 months prior to testing. For TBI group, MRI-identified presence of generalized atrophy involving fronto-temporal areas or focal lesions in these areas. **TBI group (*n*=12):** - 9 boys, 3 girls - 8 Severe TBI; GCS 3-7 - 1 Mod. TBI; GCS 12 - 3 Complicated mild	**ToM measures:** - Jack & Jill Test (Cognitive ToM) - Emotional and Emotive Faces Task (EEFT; Affective ToM) - Literal Truth, Ironic Criticism and Empathic Praise Task (Conative ToM) **Other measures:** - Classroom peer nominations: - Extended Class Play measure (ECP) - WASI	• TBI group performed worse on tasks of social-emotional processing compared to OI group. • Almost half the children with TBI were impaired on the cognitive ToM task, more than half had difficulties with affective ToM, and circa 75% were impaired on conative ToM.	**Strengths:** Included a matched control group and MRI scan to confirm lesion severity and location. **Limitations:** Small sample size, heterogeneous sample regarding lesion locations. **Global quality rating: Moderate**

Study	Study aims	Design	Sample characteristics	Measures	Main findings related to ToM	Evaluation & Quality Assessment
			TBI; GCS 13-15 **Control group (*n*=12):** - Children with OI, matched on age & gender; no head trauma			
2. Dennis, Agostino, Taylor, Bigler, Rubin et al., 2013a	To compare emotional expression and emotive communication in children with TBI and OI groups	Between group design	**Place of study:** USA **Sampling:** Naturalistic sample of previously hospitalized children. All participants' tested a min. of 1-year post-injury. **Exclusion criteria:** hx of >1 serious injury, injury resulting from abuse or assault, premorbid neurological disorder or IQ <70, hx of severe psychiatric disorder, sensory/motor impairment. **TBI group (*n*=78):** - Age range 8-13 - 55 Mild/moderate TBI (*M*ean age: 10.64); GCS score 9-12 for	**ToM measures:** - Emotional and Emotive Faces Task (EEFT) **Other measures:** - WASI	• TBI groups performed sig. worse on the EEFT task than OI group, and chose cognitively less sophisticated strategies for emotive communication. • Severe TBI group had more deficits in anger, fear and sadness; produced socially inappropriate responses reflecting more severe affective ToM deficit.	**Strengths:** OI and mild TBI control groups. Examined core emotional dimension of arousal. Group differences were not due to task difficulty. **Limitations:** Retrospective study design. Due to age range (8-13), cannot generalize findings to preschoolers or adolescents. Limited power due to small sample size to explore complex interactions among

Study	Study aims	Design	Sample characteristics	Measures	Main findings related to ToM	Evaluation & Quality Assessment
			moderate, 13-15 for mild. - 23 Severe TBI (*M*age 10.05); GCS <8 **Control group (*n*=56):** - Age range 8-13 (*M*age 10.67) - Matched for age at injury, sex, race, SES - OI, fractures without LOC or brain injury			variables. Less than 60% agreement rate to participate in study. **Global quality rating: Weak**
3. Dennis, Purvis, Barnes, Wilkinson, & Winner, 2001	To examine how 6- to 15-year-old children with TBI or typically developing, interpret scenarios involving literal truth, ironic criticism, and deceptive praise	Between group design	**Study location:** Canada **Sampling:** Controls identified from local schools. Sampling method not explained for TBI group. **Inclusion criteria:** Typical school performance (controls) **Exclusion criteria:** LD, neurological disorders **TBI group (*n*=26)** - 13 mild TBI (*M*age at testing 11.6; *M*age at injury 7.6); 3	**ToM measure:** - The Irony and Deception Task, including Literal Truth, Ironic Criticism, and Deceptive Praise Scenarios **Other measures:** - WASI	• Children with severe TBI had overall poorer mastery of task involving literal truth, ironic criticism, and deceptive praise. • Even mild TBI impaired the ability to understand the intentionality underlying deceptive praise.	**Strengths** Control group of typically developing peers. Robust TBI classification used. **Limitations** Fewer participants in control group. Unequal gender spread. SES background variables not reported. Less than 60% agreement rate to participate in study.

Study	Study aims	Design	Sample characteristics	Measures	Main findings related to ToM	Evaluation & Quality Assessment
			females; mean GCS: 14.3; negative neuroimaging findings - 13 severe TBI (*M*age at testing 11.3, *M*age at injury 7.3); 6 females; mean GCS 5.8; positive neuroimaging findings **Control group (*n*=16)** - *M*age 11.5 (*SD* 2.4) - 7 females			**Global quality rating: Weak**
4. Dennis, Simic, Agostino, Taylor, Bigler et al., 2013b	To compare children with TBI and OI controls on three forms of conative communication, literal truth, ironic criticism and empathic praise	Between group, matched case control study	**Study location:** Canada & USA **Sampling:** Naturalistic hospital sample. Children in both groups were 8-13 years, injured between 12 to 63 months before testing. All children were injured after age of 3, most after 4 years of age. Groups differed on SCI (sig. higher for OI group, severe TBI lowest) and	**ToM measures:** - The Literal Truth, Ironic Criticism and Empathic Praise Task **Other measures:** - WASI	• Group differences were noted on indirect speech acts involving conation (e.g., irony and empathy), but not structurally and linguistically identical direct speech acts. • The school-aged children with TBI showed specific deficits in	**Strengths:** Matched control group used. The working memory demands and content were equal throughout the task to counter for IQ and working memory abilities. **Limitations:** Only studied ironic and empathic utterances but did

Study	Study aims	Design	Sample characteristics	Measures	Main findings related to ToM	Evaluation & Quality Assessment
			in the mechanism of injury. **Exclusion criteria**: hx of >1 serious injury, injury resulting from abuse or assault, premorbid neurological disorder or LD, hx of severe psychiatric disorder, sensory/motor impairment. **TBI group (*n*=71):** - 50 Mild/moderate TBI; 9-15 GCS - 21 Severe TBI; 3-8 GCS **Control group (*n*=57):** - Previously hospitalized children for OI		understanding conative statements. • Deficits in children with mild/moderate TBI were less widespread and more selective than for the severe TBI group.	not measure other forms of empathy (e.g., altruism), nor obscure forms of irony, or irony that reveals speaker emotion rather than affecting hearer emotion. Only comprehension but not expression of irony and empathy was studied. Included only school aged children, so cannot generalized into preschoolers or adolescents. There was no measure of how conative deficits might impact on social adjustment. Less than 60% agreement rate to participate in study. **Global quality rating: Weak**

Study	Study aims	Design	Sample characteristics	Measures	Main findings related to ToM	Evaluation & Quality Assessment
5. Dennis, Simic, Bigler, Abildskov, Agostino et al., 2013c	To study neural and behavioural aspects of the three forms of dyadic communication involving ToM (cognitive, affective, conative) in children with TBI by analyzing the pattern of brain lesions using voxel-based morphometry in five large-scale functional networks	Between groups design	**Location of study:** Canada & USA **Sampling:** Naturalistic hospital sample. Children in both groups were 8-13 years, were injured between 12 to 63 months before testing. All children were injured after age of 3, most after 4 years of age. **Exclusion criteria**: hx of >1 serious injury, injury resulting from abuse or assault, premorbid neurological disorder or LD, hx of severe psychiatric disorder, sensory/motor impairment. **TBI group (*n*=82):** - 57 Mild/moderate TBI; GCS 9-15 - 25 Severe TBI; GCS 3-8 **Control group (*n*=61):**	**ToM measures:** - The Jack & Jill task (cognitive ToM) - The Emotional & Emotive Faces Task (EEFT) - The Ironic Criticism and Empathic praise task **Other measures:** - MRI brain imaging - WASI	• Children with TBI have difficulty in Cognitive, Affective and Conative ToM • Affective and Conative ToM have a lower threshold for perturbation and are more vulnerable to even milder forms of TBI. • Childhood TBI damaged both large scale brain networks and networks concerned with mentalizing and empathy.	**Strengths:** Included both behavioural ToM tasks and investigation of neural networks. Included well-matched OI control group. **Limitations:** MRI investigation cannot conclude anything about the function of the networks during ToM tasks. Less than 60% agreement rate to participate in study. **Global quality rating: Weak**

Study	Study aims	Design	Sample characteristics	Measures	Main findings related to ToM	Evaluation & Quality Assessment
			- OI children who had sustained fractures requiring hospitalization			
6. Dennis, Simic, Taylor, Bigler, Rubin,Vannatta et al., 2012	To study ToM in children with TBI on new three-frame Jack & Jill cartoon measuring intentional thinking.	Between group design	**Location of study:** USA and Canada **Sampling:** Multi-site study. Naturalistic sample of children previously hospitalized for either TBI or OI. Age range of 8 to 13 years. All children were injured after age of 3 years. **Exclusion criteria**: hx of >1 serious injury, injury resulting from abuse or assault, premorbid neurological disorder or LD, hx of severe psychiatric disorder, sensory/motor impairment. **TBI group (*n*=79)** - 56 mild/moderate TBIs; GCS 9-15 - 23 severe TBIs; GCS 3-8	**ToM measure:** - The Jack and Jill Task **Other measures:** - WASI	• Overall accuracy was higher in children with OI than those with TBI • Severe TBI group showed larger decline in accuracy on ToM trials • Specific deficits in ToM was suggested for severe TBI group	**Strengths** Used OI control group. **Limitations** Only included one form of cognitive ToM task. Unequal group sizes in TBI groups. Did not compare TBI severity with SCI and injury mechanism. Less than 60% agreement rate to participate in study. **Global quality rating: Weak**

Study	Study aims	Design	Sample characteristics	Measures	Main findings related to ToM	Evaluation & Quality Assessment
			Control group (*n*=61) - OI children			
7. McDonald, English, Randall, Longman, Togher, & Tate, 2013	To examine whether social perception abilities (e.g., emotion perception, ToM and comprehension for direct and indirect speech) is impaired for adolescents with TBI compared to typically developing peers on TASIT task.	Between group design	**Location of study:** Australia **Sampling:** Naturalistic sample. TBI group recruited through hospitals, TD group from general community. **Exclusion criteria** for both groups: psychosis, sensory deficits, history of pre-injury leaning or intellectual difficulties. **Inclusion criteria:** TBIs sustained at least 9 months before testing **TBI group (*n*=16):** - 11 males, 5 females - Aged 13-19 years - 7 Moderate TBI; GCS 9-12 and/or PTA between 1-7 days - 9 Severe TBI; GCS 8>, PTA 7< days, LOC >24h	**ToM measure(s):** - The Awareness of Social Inference Test (TASIT): - TASIT 1: *The Emotion Evaluation Test* - TASIT 2: *Social Inference – Minimal (SI-M)* - TASIT 3: *Social Inference – Enriched (SI-E)* **Other measures:** - WASI - BFRT - RCMAS - CDI for <18 y - Depression subscale of DASS for 18< y - SCQ - RCQ	• TBI group on average were no different to their TD peers on TASIT 1 (emotion recognition) and TASIT 3 (recognising lies and sarcasm when provided with additional cues). • TBI group performed worse on TASIT 2, which required interpretation of sarcastic and sincere conversational exchanges with few cues. • Within the TBI group, poor performance on TASIT correlated with both relative and self-reported communication	**Strengths:** TASIT is considered a valid task of social cognition and communication in adults and has norms for 13-15 year olds. Matched control group. Questionnaires had acceptable psychometric qualities. **Limitations:** Small sample size, heterogeneous sample with regards to SES, nature and severity of injury and age of injury. Also effect sizes were small. **Global quality rating: Moderate**

Study	Study aims	Design	Sample characteristics	Measures	Main findings related to ToM	Evaluation & Quality Assessment
			Control group (*n*=16) - Matched on age, gender, education		difficulties at home.	
8. McLellan & McKinlay, 2013	To examine deficits in emotion perception for adults who had experienced TBI during childhood and investigate relationship between emotion perception skills, empathy and ToM	Between groups design comparing moderate/severe TBI group with mild TBI group and orthopedic group	**Place of study:** New Zealand **Sampling:** A random selection of participants previously recruited for a larger study. Minimum of 5 years post injury. **Inclusion criteria for mod/severe TBI:** clinical diagnosis of TBI, skull fracture, evidence of lesion on tomography, cerebral haemorrhage, or PTA > 24h **Inclusion criteria for mild TBI:** clinical diagnosis, LOC<20, PTA<1h, no evidence of skull fracture or lesion on tomography **TBI group (*n*=33):** - 15 moderate/severe TBI; 9 females; aged:	**ToM measures:** - Faux pas test **Other measures:** - Emotion sensitivity task - Facial expression recognition task (Japanese and Caucasian Facial Expression of Emotion [JACFEE]) - Interpersonal Reactivity Index (IRI)	• Moderate/severe TBI group was worse at expression recognition compared to mTBI and OI control group • Moderate/Severe TBI group were less sensitive to meaningful differences between genuine and posed displays of emotion • Sensitivity was closely related to the more complex social capacities for empathy and affective ToM in the moderate/severe TBI group • Those who were more sensitive to	**Strengths:** OI and mild TBI control groups. Random selection of participants. Used a measure of emotion sensitivity task. **Limitations:** Small sample size. Heterogeneous TBI group. No measures of social functioning. **Global quality rating: Moderate**

Study	Study aims	Design	Sample characteristics	Measures	Main findings related to ToM	Evaluation & Quality Assessment
			18-30 years - 18 a mild TBI; 9 females; aged 18-30 **Control group (*n*=19):** - Orthopedic controls (12 female, 18-27 years) had sustained fractured limb as a child		emotion in facial displays demonstrated better understanding of the affective intentions of others and reported greater empathy for others.	
9. Robinson et al., 2014	To examine whether executive function and ToM mediate the effects of pediatric TBI on social adjustment	Cross-sectional between groups design	**Location of study:** Canada and USA **Sampling:** Data was extracted from a larger, cross sectional project that compared social outcomes of 8-13 year old children with TBI and OI. Children were tested 2.5 years post injury. **Exclusion criteria:** history of more than one injury, premorbid neurological disorder or mental retardation, injury from child abuse or assault, history of severe psychiatric	**ToM measures:** - Jack & Jill test (cognitive) - Emotional and Emotive Faces Task (EEFT; affective) - The Ironic criticism and empathic praise task (conative) **Other measures:** - WISC-IV: cancellation and symbol search - TEA-Ch: Walk/Don't Walk, Code Transmission and Creature	• Children with severe TBI performed worse on executive function and ToM tasks • Children with severe TBI were rated by parents as having more behavioural symptoms and worse communication and social skills • The impact of TBI on children's social adjustment is likely mediated by its effects on EF and ToM.	**Strengths:** Used multiple, independent methods for assessing EF, ToM and social adjustment. comprehensive Measured 3-levels of ToM. **Weaknesses:** The groups differed significantly in terms of SES and injury mechanism. Small sample size for severe TBI group limited statistical power in

Study	Study aims	Design	Sample characteristics	Measures	Main findings related to ToM	Evaluation & Quality Assessment
			disorder requiring hospitalization, sensory or motor impairment, special education input, medical contraindication to magnetic resonance imaging. **TBI group (*n*=60):** - 19 severe TBI; GCS <8 - 41 complicated mild/ moderate TBI; GCS 13-15, GCS 9-12 **Control group (*n*=57):** - OI of fractures without LoC or other indicators of TBI. - matched on sex, race, age at injury and age at participation	Counting subtests Measures completed by parents: - ABAS – II - BASC-2		subgroup analyses. Parental measure provided a possibly biased indicator of social functioning. Less than 60% agreement rate to participate in study. **Global quality rating: Weak**
10. Ryan, Catroppa, Cooper, Beare, Ditchfield, Coleman et al., 2014	To study the differential influence of age-at-insult and brain pathology on ToM in a sample of children and	Prospective, longitudinal study, between groups design, matched control, MRI (SWI) study	**Location of study:** Australia **Sampling:** Naturalistic TBI sample recruited from a hospital and tested at 6- and 24 months. It was not reported how and where	**ToM measures:** - Emotional and Emotive faces Task (EEFT; affective ToM) - Ironic critic and empathic praise task (Conative ToM)	• Adolescent TBI was related to deficit in conative and affective ToM at 6- and 24-month post-injury that were related to more diffuse neuropathology	**Strengths:** Enough power. Examined whether ToM impairments at two different post-injury time points where related to neuroanatomical

Study	Study aims	Design	Sample characteristics	Measures	Main findings related to ToM	Evaluation & Quality Assessment
	adolescents with TBI		control group was recruitment from. **Inclusion criteria:** age 5-16 at recruitment, documented evidence of closed HI, clear evidence of injury severity from medical records, no previous history of TBI, or neurological or developmental disorders, no prior intervention for social impairments. **TBI group (*n*=112):** - 58 Mild TBI; GCS 13-15; no evidence of mass lesion on CT or MRI - 13 Mild complicated TBI; GCS 13-15, evidence of mass lesion on CT or MRI - 22 Moderate TBI; GCS 9-12 - 13 Severe TBI; GCS 3-8 - Divided into age groups: Middle	**Other measures:** - MRI scans including Susceptibility-Weighted Imaging (SWI) between 2 and 8 weeks postinjury	and a greater number of SWI lesions. • Late childhood TBI group demonstrated a time-dependent emergence of social cognitive impairment linked to diffuse neuropathology. • Middle childhood TBI group performance was comparable to control group and was unrelated to SWI pathology.	location, extent and microhemorrhagic lesions using SWI. Looked at both injury severity and age at injury. **Limitations:** No neuropsychological tests administered. The scope for longitudinal follow-up was limited. **Global quality rating: Moderate**

Study	Study aims	Design	Sample characteristics	Measures	Main findings related to ToM	Evaluation & Quality Assessment
			childhood 5-9 years (n=41); late childhood 10-11 years (n=39); adolescence 12-15 years (n=32) **Control group (*n*=43):** - Matched for age, gender and SES			
11. Ryan, Catroppa, Cooper, Beare, Ditchfield et al., 2015	To evaluate the post-acute effects of TBI on first-order ToM, and to examine relations between TBI and macrostructural damage using susceptibility weighted imaging (SWI).	Prospective, between groups design, SWI study	**Location of study:** Australia **Sampling:** TBI group was recruited at time of injury and represented consecutive admissions to the hospital. Recruitment of control group was not specified. **Inclusion criteria:** All participants between age between 5-16. Documented evidence of TBI, medical records determining injury severity, no history of developmental or neurological disorders, non- accidental injury or previous TBI, no prior	**ToM measure:** - Jack & Jill task **Other measures:** - SWI imaging	• Children with severe TBI demonstrated significantly poorer cognitive ToM ability compared to control group and children with mild-moderate injuries. • ToM deficits were associated with diffuse neuropathology and parietal lobe lesions.	**Strengths:** Prospective 6-month follow up post injury. Age-matched control group. Used sensitive imaging technique (SWI) to detect even microhaemorrhagic lesions. **Weaknesses:** No cognitive tests used. Groups differed on age and control group had higher SES. In some instances, very superficial contusions might have not been

Study	Study aims	Design	Sample characteristics	Measures	Main findings related to ToM	Evaluation & Quality Assessment
			intervention for social impairment. **TBI group (*n*=112)** - **91 Mild/Moderate TBI group** including: - 58 mild TBI; GCS 13-15, no mass lesion on CT or clinical MRI - 13 mild-complicated TBI; GCS 13-15, evidence of mass lesion - 22 moderate TBI; GCS 9-12, and/or mass lesion or other evidence of injury on CT/MRI, and/or neurological impairment - **13 severe TBI group**; GCS 3-8, and/or mass lesion or other evidence of injury on CT/MRI, and/or neurological impairment **Control group (*n*=43)** - Matched on age, typically developing sample			detected due to artifact from the overlying skull. Relatively narrow focus on post-injury ToM deficits. Only one ToM task was used to investigate only cognitive ToM ability. **Global quality rating: Moderate**
12. Scheibel, Newsome,	To examine structures	Between groups desing, fMRI	**Location of study:** USA	**ToM measure:** - Animated social	• TBI group showed activation of many	**Strengths** fMRI imaging,

Study	Study aims	Design	Sample characteristics	Measures	Main findings related to ToM	Evaluation & Quality Assessment
Wilde, McClellan, Hanten et al., 2011	mediating ToM in adolescents with moderate to severe TBI on an animated social attribution task with functional magnetic resonance imaging (fMRI). Comparisons with typically developing peers.	study	**Sampling:** Selected from large cohort of TBI patients followed in Texas. Naturalistic study **Inclusion criteria:** age 13-19, severity of injury, ability to follow task instructions and restrain movement during scanning **TBI group (*n*=9)** - Moderate to severe TBI; GCS 3-12 - Mean GCS 5.56 - 5 males, 4 females **Control group (*n*=9)** - Matched on age and gender, typically developing peers	attribution task (SAT) **Other measures:** - WASI - The Grey Oral Reading Test (GORT)	of the same areas compared to control group, but their activation was generally more intense and excluded the medial prefrontal cortex • Regression analysis indicated a negative relation between ToM-related activation and white matter integrity • There was a positive relation between activation and lesion volume	matched control group **Limitations** Small sample size, could not perform multiple comparisons, or explore relationship between brain activation, lesion location, SAT performance and other cognitive measures and social competence. **Global quality rating: Moderate**
13. Snodgrass & Knott, 2006	To examine deficits in mentalizing or ToM in children with TBI	Case control, between groups design comparing TBI with matched controls	**Place of study:** UK **Sampling:** Recruited from regional neurosurgical service & regional outpatient service. Naturalistic study.	**ToM measures:** - The Sally Ann Test - The Deception vs. Sabotage 'One Box' Task - The Reading the Mind in the Eyes	• Control group scores sig. higher on emotion recognition test • No difference between the groups on Sally Ann Test (first –	**Strengths:** Matched sample group. Known frontal lobe damage in the TBI group. Different ToM measures ranging in difficulty.

Study	Study aims	Design	Sample characteristics	Measures	Main findings related to ToM	Evaluation & Quality Assessment
			Exclusion criteria: penetrating head wounds or other previous head injury requiring hospital admission, pre-morbid LD, developmental or psychiatric disorder **TBI group (*n*=12)** - 7 males, 5 females - Age 6 – 12 - 8 Severe TBI; GCS 3-8 - 4 Moderate TBI; GCS 9-12 - Documented frontal lobe damage (scan findings and medical notes) at least 1 year prior to study **Control group (*n*=12)** - Matched for age, sex and verbal ability	Test (children's version) **Other measures:** - Basic emotion recognition tests (adapted from Ekman & Friesen) - The British Picture Vocabulary Scale – II - Digit span forwards and backwards (WISC-III) - Story sub-test (Rivermead Behavioural Memory Test for Children; RBMT)	order ToM test) • Analysis of frequencies showed that there were no differences between the groups on the deception task, but the number of participants failing the 'sabotage task' in the TBI group was sig. higher, which is a more advanced ToM test • TBI group were sig. worse on the Eyes Test	**Limitations:** Small sample size. The measures used for attention and memory were not standardized and might have not been sensitive enough to detect differences between the groups. **Global quality rating: Moderate**
14. Stronach & Turkstra, 2008	To examine conversations of adolescents TBI and typically developing	Between groups design	**Location of study:** USA **Sampling:** From area schools and local sources, trauma	**ToM measures:** - Video tape task based on structure of TASIT - Included stimuli	• Adolescents with TBI had poorer ToM performance and used sig. fewer cognitive state terms than	**Strengths** Control group of typically developing peers **Limitations**

Study	Study aims	Design	Sample characteristics	Measures	Main findings related to ToM	Evaluation & Quality Assessment
	peers on ToM and the use of cognitive state terms		hospitals. Opportunistic. **Exclusion/Inclusion:** no history of language or LD, or special education needs, gifted status or psychiatric or neurologic disorders. Allocation to groups based on performance on ToM test. **TBI group (*n*= 16)** - 8 TBI-High ToM group - *M*age 17.32; 6 males - 8 TBI-Low ToM group; *M*age 17.37; 5 males - 8 mod/11 severe TBI - Age at injury 3,6-20,10 - Age at time of testing 13,6-21,10. **Control group (*n*=8)** - Matched on age and etchinicity - *M*age 17.22, 5 males	that required First Order and Second Order ToM **Other measures:** - Conversation elicitation task (total 3 mins) - Analysed with Systematic Analysis of Language Transcripts (SALT)	control group or peers with TBI who had age-typical scores on the ToM test.	Conversation elicitation task was uncontrolled as participants were allowed to choose their topics. Small sample size. **Global quality rating: Moderate**
15. Turkstra, Dixon, & Baker, 2004	To compare adolescents with TBI to typically developing peers on a	Between group design	**Location of study:** USA **Sampling:** Recruited as part of a larger study. Control group from local	**ToM measure** - Video tape task based on structure of TASIT - Included stimuli	• Adolescents with TBI showed impairments in social cognition relative to peers. • The difference	**Strengths:** Age, gender and SES matched control sample. **Limitations:**

Study	Study aims	Design	Sample characteristics	Measures	Main findings related to ToM	Evaluation & Quality Assessment
	social cognition task		schools. TBI group from local trauma centres and support groups. Included if TBI was sustained at least 6 months prior testing or at age 2 or older. Opportunistic sample. **Exclusion criteria for both:** history of language or LD, special education needs, gifted status, neurological or psychiatric disorder. **TBI group (*n*=23):** - 19 males (*M*age= 16, range: 13-22) - Age at injury 3,5-20,10 - 6 moderate, 17 severe TBIs **Control group (*n*=48)** - 22 males (*M*age= 18, range: 13 – 21)	that required First Order and Second Order ToM **Other measures:** - Social skills questionnaire developed for the study to identify social communication behaviour the adolescents considered important in everyday lives.	between groups was greater for the Second Order task than for the First Order task. • TBI and control group shared many basic beliefs about social rules and roles.	Small sample size. Use of novel, unvalidated questionnaire. ToM task was not designed to separate effects of cognitive factors, e.g., WM, inhibition control. Participants were injured after 2 years of age, watershed for acquisition of ToM abilities. No cognitive screen used. **Global quality rating: Weak**
16. Turkstra, Williams, Tonks, & Frampton, 2008	To examine social processes such as emotion recognition and	Between group design	**Location of study:** USA **Sampling:** Not explained	**ToM measures:** - The Strange Stories Test - The Faux Pas Test	• The adolescents with TBI were sig. less able than their peers to generate context-	**Strengths:** Inter-rater reliability established at 95%.

Study	Study aims	Design	Sample characteristics	Measures	Main findings related to ToM	Evaluation & Quality Assessment
	mental state attribution in adolescents with TBI		**Exclusion criteria** for both groups: no history of psychiatric disorder, neurological disorders affecting the brain, language or leaning disability diagnosis, or receipt of tutoring or special education services. **TBI group (*n*=9):** - Ages 13-21 (*Mage*= 19.3) - 6 males, 3 females - 8 with severe TBI, 1 with mild injury - 6 months to 10 years post injury at testing **Control group (*n*=9):** - Age and gender matched - Mean age 18.4 (*SD* = 29.80)	**Other measures:** - The Comprehensive Assessment of Spoken Language (CASL)	appropriate responses in everyday pragmatic situations. • No significant differences were found between TBI and control groups for the Faux Pas Test, or the Strange Stories Test.	**Limiations:** Sampling method was not explained, or how severity of TBI was determined. Small sample size and lack of statistical power. Participants ranged 6 months to 10 years post injury, and differed in the age of injury. Did not include any neuropsychological tests. CASL has not been developed for the assessment of acquired cognitive impairments, thus reliability and validity for this population is unknown. **Global quality rating: Weak**
17. Walz, Yeates, Taylor, Stancin, &	To examine post-acute effects of	Between groups design	**Location of study:** USA	**ToM measure:** -ToM battery included two	• 3-year-olds with TBI performed more poorly than	**Strengths** OI control group. Tested for

Study	Study aims	Design	Sample characteristics	Measures	Main findings related to ToM	Evaluation & Quality Assessment
Wade (2009)	childhood TBI on first-order ToM skills, comparing 3- to 5- year-old children following TBI with OI controls.		**Sampling:** From inpatient admissions, children's hospitals and a general hospital. Opportunistic sampling. Children assessed within 3 months post injury. **Inclusion criteria:** Age at injury between 3 and 5 years, 11 months. **Exclusion:** history of child abuse as a cause of injury, language at home. Autism, LD, or neurological disorders. **TBI group (*n*=59)** - 42 with moderate TBI - 17 with severe TBI - Overnight admission and either GCS score < 13 or a GCS 13-15 with evidence of TBI-related brain abnormalities on CT or MRI. **Control group (*n*=86)** - Children with OI	appearance-reality tasks (e.g. discrepancy between real and apparent identity – candle that looks like an apple), three false contents tasks (e.g. milk carton containing crayons), two false location tasks (Sally & Anne Task) and two control tasks, and memory/ comprehension question **Other measures:** - Differential Ability Scale (DAS) - General Conceptual Ability (GCA)	3-year-olds with OI on an appearance-reality task. • The severe TBI group was impaired on false-contents task compared to moderate TBI and OI groups. • Age and IQ were strong predictors of ToM performance, but not as strong for children with TBI	cognitive confounds and IQ level. **Limitations** Lack of information regarding PTA. Limited sample for evaluating TBI severity and age. **Global quality rating: Moderate**

Study	Study aims	Design	Sample characteristics	Measures	Main findings related to ToM	Evaluation & Quality Assessment
18. Walz, Yeates, Taylor, Stancin, & Wade, 2010	To examine the long-term effects of TBI on ToM skills of children between the ages of 5 and 7 years at the time of injury, and to compare performance with OI controls.	Between groups design	**Location of study:** USA **Sampling:** From inpatient admissions, children's hospitals and a general hospital. Opportunistic sampling. Children assessed within 3 months post injury. **Inclusion criteria:** Age at injury between 3 and 6 years, 11 months, age at least 6 years at the 1-year post-injury assessment. **Exclusion:** history of child abuse as a cause of injury, language at home. Autism, LD, or neurological disorders. **TBI group (*n*=42)** - 30 moderate TBIs; *M*age 5.89 - 12 severe TBIs, *M*age 6.92 - Overnight admission and either GCS score < 13 or a GCS 13-15	**ToM measures** - First order: Sally and Ann Test, including false-location task and control task - Second order: John and Mary story - Third order: Happe's stories & three physical control stories **Other measures:** - Differential Ability Scale (DAS)	• Children with severe TBI performed below developmental level at first- and second order ToM tasks. • Stagnation or lack of development of ToM skills and regression of existing ToM skills for severe TBI group was suggested • OI and moderate TBI group mastered first- and second-order tasks. • Findings were not solely contributable to lower verbal or cognitive abilities	**Strengths** Included OI control group and cognitive screen. **Limitations** Small severe TBI sample. Absence of brain imaging at 1 year follow up, lack of information about PTA. **Global quality rating: Moderate**

Study	Study aims	Design	Sample characteristics	Measures	Main findings related to ToM	Evaluation & Quality Assessment
			abnormalities shown on CT or MRI. - DAS verbal IQ 93 **Control group (*n*=52)** - *M*age 5.84 - DAS verbal IQ 105			

Note: Adaptive Behavior Assessment System – Second Edition (ABAS-II); Behavioral Assessment System for Children – Second Edition (BASC-2); Benton Facial Recognition Task Short Form (BFRT); Children's Depression Inventory (CDI); Depression subscale of the Depression Anxiety Stress Scales (DASS); Glasgow Coma Scale (GCS); Head injury (HI); Learning Disabilities (LD); Loss of Consciousness (LoC); orthopedic injury (OI); Revised Children's Manifest Anxiety Scale (RCMAS); Relative Communicative Questionnaire (RCQ); Post-Traumatic Amnesia (PTA); Socioeconomic Composite Index (SCI); The Self Communicative Questionnaire (SCQ); Socio-Economic Status (SES); Susceptibility-Weighted Imaging (SWI); Test of Everyday Attention for Children (TEA-Ch); Typically Developing (TD); Wechsler Abbreviated Scale of Intelligence (WASI); Wechsler Intelligence Scale for Children – Fourth Edition (WISC-IV)

Results

Systematic search of four databases that followed the process outlined in Figure 1 resulted in 18 papers being included for this review.

Design

All reviewed studies had between-groups designs comparing children and/or adolescents who had acquired TBI in childhood or young adulthood (≤22 years) with either typically developing (TD) or orthopedic injury (OI) peers. Only one research group used a prospective longitudinal design (Ryan et al., 2014, 2015), whereas the rest used cross-sectional designs. Therefore, causal inferences cannot be concluded.

Participants

Studies 1-6 and 9 were conducted by the same research group and used a subset of the same participants from a larger study. Likewise, studies 10-11, 14-16 and 17-18 were also by the same group and appeared to use the same participants. Approximately[2] 346 TBI participants and 294 control participants were described across the studies. The sample sizes in the TBI groups ranged from 9 to 112 participants and the age range were between 3 and 30 years at the time of testing. All the participants had sustained TBI in childhood or adolescence, apart from two studies where injury had occurred up to the age of 20 or 22 years (Stronach & Turkstra, 2008; Turkstra, Thomas, Dixon, & Baker, 2004). Furthermore, McLellan and McKinlay (2013) assessed participants in

[2] The largest sample size per research group was included to calculation to avoid duplication of participants in the total sum.

adulthood. Therefore, depending on the study aims, time since injury varied from 3 months to several years.

Majority of studies classified TBI severity based on the Glasgow Coma Scale (GCS; Teasdale & Jennett, 1974). Two studies (Turkstra et al., 2008; Stronach & Turkstra, 2008) did not explain how injury severity was determined, but provided injury categories. Majority of the studies also used CT or MRI scans to ascertain lesion tomography, checked medical records for lowest GCS score and a few studies also checked post-traumatic amnesia (PTA) ratings. TBI severity categories were described as follows: severe (GCS < 8 or GCS <13), moderate (GCS 9-12), moderate-severe (GCS 3-11), mild-moderate (GCS 9-15), mild (GCS 13-15), and mild-complicated (GCS 13-15) with additional evidence of mass lesion on CT scan.

Exclusion criteria across most of the studies included a history of psychiatric disorders, neurodevelopmental disorders, language impairments, learning disabilities or pre-existing social problems. Furthermore, some studies excluded participants if the injuries had occurred from child abuse or neglect. The participants in the TBI groups were mainly recruited through opportunistic sampling from local hospitals or community neurology services, whereas in few studies, the participants were recruited from pre-existing research databases. The TD control groups were mainly recruited from local schools, whereas the OI controls were recruited from the same hospital sites as TBI participants.

Measures

A plethora of measures were used to examine ToM abilities (see Table 2). Four studies also employed emotion recognition tasks in addition to ToM tests, such as Benton Facial Recognition Task Short Form (BFRT; Levin, Hamsher, & Benton, 1975), Emotion Sensitivity Task (McLellan, Johnston, Dalrymple-Alford, & Porter, 2010) Japanese and Caucasian Facial Expression of Emotion (JACFEE; Matsumoto & Ekman, 1988), Basic Emotion Recognition Test (adapted from Ekman & Friesen, 1976). Majority of studies used Wechsler Abbreviated Scale of Intelligence (WASI; Wechsler, 1999), or some other cognitive test, whereas four studies did not report using any cognitive screens.

Method of Analysis

All studies used parametric statistics that included t-tests, analysis of variance (ANOVA), and multivariate analysis of variance (MANOVA). Some studies also used logistic regression modeling and Chi square tests. Furthermore, associations between different measures used were mainly studied with Pearson's correlations. Three studies used magnetic resonance imaging (MRI) scans to relate lesion location and severity to task performance.

Quality of Studies

Based on the EPHPP criteria[3], eleven studies achieved a global quality rating of "moderate" and seven were rated as "weak". Main weaknesses were related to data collection methods (e.g., unknown validity and reliability of ToM measures), selection bias and confounding variables.

Review question 1: How is ToM Operationally Defined and Measured in the Context of Childhood TBI?

Originally, ToM research was concerned with assessing first-, second- and third-order ToM abilities. However, emerging evidence from neuroscience regarding the affective and cognitive networks has expanded ToM research to incorporate measures of emotional understanding from language, facial

[3] See http://www.ephpp.ca/PDF/QADictionary_dec2009.pdf

expressions and social communication. ToM is suggested to consist of cognitive, affective and conative constructs and subsequently specific measures have been developed to investigate these (see Appendix C).

Review Question 2: Are ToM Abilities Impaired After Childhood TBI?

First-, second- and third-order ToM abilities.

A few studies investigated first- and second- order cognitive ToM abilities in early and middle childhood TBI samples. One study found that compared to controls, children with TBI (6-12 years) were significantly worse on the advanced cognitive ToM tests, but not on the first-order ToM tests (Snodgrass & Knott, 2006). Another study reported that 3-year-olds with moderate and severe TBIs performed worse compared to OI controls on first-order, false belief ToM task measuring discrepancy between what the child expects and reality (Walz, Yeates, Taylor, Stancin, & Wade, 2009). However, compared to children with moderate TBI and OI controls, those with severe TBI were also found impaired on another first-order, false contents task. Related study by Walz et al. (2010) with 5 to 7-year-old children demonstrated that those with severe TBI performed below developmental level at first- and second-order ToM tasks, whereas those with moderate TBI passed these tasks.

Adolescents (13-22 years) with TBI showed greater impairment on a social cognition task for the second-order as compared to first-order ToM task relative to peers (Turkstra, Thomas, Dixon, & Baker, 2004). A further study using the same task and some of the same participants revealed that those adolescents with TBI who demonstrated poorer ToM performance used significantly fewer cognitive state terms compared to control group and TBI peers with age typical scores (Stronach & Turkstra, 2008). In a related publication, adolescents with TBI were significantly less able to generate context-appropriate responses in everyday pragmatic situations than their peers (Turkstra, Williams, Tonks, & Frampton, 2008). According to the authors, their study lacked power to detect differences between the groups on the Faux Pas and Strange Stories tests.

Cognitive, affective, and conative ToM abilities.

A research group from North America using largely the same sample (studies 1-6, 9) reported that compared to controls, 8-13 year-old children with TBIs showed significant impairments in cognitive (Dennis et al., 2012), affective (Dennis et al., 2013a) and conative (6-15 years, Dennis et al., 2001; Dennis et al., 2013b) ToM tasks. Further publications from this group concluded that affective and conative ToM appeared more vulnerable to impairment even after milder forms of TBI (Bigler et al., 2013; Dennis et al., 2013c). Furthermore, Robinson et al. (2014) found that severe TBI was associated with poorer overall ToM ability[4], executive function and social adjustment. Another research group found that cognitive ToM was significantly poorer for severe TBI group (5-16 years) compared to the mild-moderate TBI or OI groups (Ryan et al., 2015). Furthermore, adolescents with TBI (12-15 years) from the same sample demonstrated deficits in conative and affective ToM (Ryan et al., 2014).

Moreover, a study that investigated the relationships between emotion perception skills, empathy and ToM found that adult survivors of moderate to severe childhood TBI were worse at facial expression recognition compared to mild TBI and OI controls (McLellan & McKinlay, 2013). They concluded that those with greater sensitivity to emotion showed better understanding of the

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[4] Consisting of composite score across performance on cognitive, affective and conative ToM tasks

affective intentions of others and reported greater empathy. Similarly, another study that examined associations between social perception abilities, including ToM, reported that the TBI group (13-19 years) performed worse on a social communication task that required interpretation of sarcastic and sincere conversational exchanges with few cues (McDonald et al., 2013).

Findings from the MRI and fMRI studies.

Four of the aforementioned studies used brain-imaging techniques to investigate relationship between lesion location, severity, and ToM performance. Childhood TBI was found to have damaged large-scale brain networks concerned with mentalising and empathy, and lesions in the mirror neuron empathy network (MNEN) predicted lower conative ToM involving ironic criticism and empathic praise (Dennis et al., 2013c). Whereas MRI case studies by Bigler et al. (2013) highlighted that no simple association existed between either injury severity, or focal or generalized pathology involving frontotemporolimbic regions, thus indicating multiple neural pathways to social impairment.

Prospective SWI studies by Ryan et al. (2014, 2015) found that deficits in cognitive, conative and affective ToM abilities at 6- and 24-months post-injury was related to more diffuse neuropathology and to greater number of lesions. Furthermore, late childhood TBI group (10-11 years) showed a time-dependent emergence of social cognitive impairments that was linked to diffuse neuropathology, whereas the performance of the middle childhood TBI group (5-9 years) was comparable to the control group and unrelated to lesion pathology (Ryan et al., 2014).

An fMRI study by Scheibel et al. (2011) reported that the TBI group showed activation of many of the same areas during the Animated Social

Attribution Task (SAT) as the control group. However, the activation was more intense and excluded the medial prefrontal cortex typically activated during ToM tasks in previous studies (e.g., Schultz et al., 2003 as cited in Scheibel et al., 2011).

Discussion

Surmising from the reviewed studies, the outcome of ToM abilities following childhood TBI depend on the severity and age at injury. A key suggested factor for first- and second-order ToM impairments is age at injury between 3 and 6 years, which is before the watershed for developing these skills. In their study, Walz et al. (2010) suggested that ToM impairments on the first- and second-order tasks indicated developmental stagnation and regression of putatively developed false-belief skills following severe TBI. It has been argued that in other studies where first-order ToM deficits have not been found included children who had incurred injuries much later in life.

Only a small number of studies have investigated the association between childhood TBI and the more complex ToM abilities that require more sophisticated mentalizing and emotional understanding. The studies that examined these more advanced, cognitive-affective ToM abilities, reported impairments in these skills following childhood TBI, whereas the first- or second-order cognitive ToM abilities were not necessarily impaired. In these studies, deficits were also reported on emotion recognition tasks. A few studies suggested that affective and conative ToM are more vulnerable to even milder forms of TBI (e.g., Dennis et al., 2013).

The heterogeneous nature of TBIs makes it difficult to establish conclusive brain-behaviour links. Furthermore, characterisation of ToM and social cognition deficits is not straightforward, especially following TBI. Assessment of these complex processes place demands on perceptual, language, memory and executive abilities. Research suggests that poor performance on ToM tasks following childhood TBI is likely to be associated with impairments in communication skills and executive functions, such as language, working memory, and cognitive inhibition (e.g., Dennis et al., 2009; Yeates et al., 2007). Therefore, it is difficult to tease apart pure ToM impairments from cognitive deficits. Thus, larger samples are needed to examine the effects of TBI on outcomes such as ToM, as these skills emerge within relatively narrow time window and vary substantially with post-injury differences in neural reorganization and skill development (e.g., Anderson, Catroppa, Morse, Haritou, & Rosenfeld, 2005).

Strengths and Weaknesses of the Literature

The studies had several limitations. The overall quality of the studies was rated as weak to moderate mainly due to participant selection bias and unknown psychometric properties of the ToM measures used. Some lacked statistical power due to small sample sizes. In addition, variability with regards to age of injury, lesion location, nature of injury, as well as differences in other factors such as SES makes it difficult to generalise from the findings. Furthermore, conceptualising and defining ToM constructs is widespread, which was reflected in a range of measures used by the studies.

Majority of studies used static and verbal measures of ToM (e.g., false belief stories), whereas some used dynamic and behavioural tests that were concerned with measuring more complicated ToM abilities. Furthermore, most of the ToM measures have only been used experimentally and therefore their psychometric properties have not been formally evaluated with TBI populations.

Additionally, some of the measures have been developed to assess individuals with autism spectrum disorders and therefore might not be sensitive for children with TBI. Furthermore, only one study group used a prospective follow-up design, whereas the rest were cross sectional. Future studies should employ prospective longitudinal designs to track the course of ToM abilities in children following TBI.

Strengths and Weaknesses of This Review

Although ToM abilities are an extensively researched area, this review is unique as it was concerned with synthesising research that has investigated ToM abilities following childhood TBI. An extensive and systematic search was conducted for this review, and the quality of papers was thoroughly assessed. However, this review had a narrow focus and employed several exclusion criteria. Therefore, the review findings are not generalizable for other neurological conditions or acquired brain injury in childhood. Furthermore, sensitivity checks could have optimised the search strategy[5]. A further limitation was to include three papers (14-16) that included some participants who had sustained their TBIs up to the age of 22. This might have biased the interpretation of the findings in this review.

Future Directions for Research

Currently, ToM is a broad umbrella term that includes various constructs and is often used interchangeably with “social cognition”. This review highlighted the need for greater consensus regarding operational concepts and measures to assess ToM abilities in children following TBI. It has been argued

[5] Note: for example, the terms “mind reading”, “social cognition” and “TBI” were omitted from the search strategy.

that narrow use of measures is not sufficient and that both static and dynamic-behavioural tests yield a more comprehensive understanding of the strengths and weaknesses of complex ToM abilities (e.g., Korkmaz, 2011). Therefore, an important area for future research is the development of comprehensive ToM assessment batteries to evaluate these skills in children with TBI.

Considering the importance of social and behavioural competence to academic success and emotional well-being (e.g., Ewin-Cobbs, Fletcher, Francis, Davidson, & Miner, 1997), a better understanding of the relationship between ToM skills and social competence would be another important area of future research. Recovery from childhood TBI is complicated and hard to predict, but some predictors of long-term outcomes are pre-injury ability, age at injury, injury severity, levels of communication skills, SES and family dysfunction (e.g., Anderson, Godfrey, Rosenfeld, & Catroppa, 2012; Ryan et al., 2014; Yeates et al., 2004). Future research should incorporate these factors into their designs to isolate the effects of TBI from various background factors that might better explain variation in ToM abilities and outcomes.

Conclusions

ToM abilities appear susceptible to damage following childhood TBI. ToM is a complex, multi-level construct that develops incrementally throughout childhood and adolescence, and is critical for successful social communication and interaction. Age, severity and location of injury are important contributory factors to ToM deficits in children with TBI. Research suggests that depending on the age at injury, the lower-level first- and second-order ToM abilities might be relatively spared compared to the higher-level cognitive, affective and conative abilities, which are considered more vulnerable to even milder forms of injury. Furthermore, younger age at injury is suggested to lead to developmental stagnation. However, it is not yet well understood how ToM deficits translate to behavioural difficulties and social problems, which is a suggested area for future research with longitudinal designs. Another important area for research is the development of comprehensive ToM assessment batteries to elicit a full profile of strengths and weaknesses.

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Appendices

Appendix A. Data Extraction Form

Data Extraction Form

Reference number:

Title:

Author(s):

Source:

Date: **Volume:** **Pages:**

Aim(s) of the study:

Setting & Geographical Location:

Study Design:

Population

Population characteristics (e.g., N, TBI severity):

Method of TBI classification:

Sampling method:

Power calculation presented: Y/N **Outcome:**

Inclusion criteria:

Exclusion criteria:

Control group characteristics:

Measures

Measures used:

Were measures validated?

Results

Method(s) of analysis:

Adequate reporting of data, parametric assumptions:

Theory of Mind specific results:

Conclusions

Theory of Mind related conclusions in TBI:

Strengths of the study:

Limitations of the study:

Appendix B. Quality Assessment Tool for Quantitative Studies (EPHPP)

QUALITY ASSESSMENT TOOL FOR QUANTITATIVE STUDIES

EPHPP
Effective Public Health Practice Project

COMPONENT RATINGS

A) SELECTION BIAS

(Q1) Are the individuals selected to participate in the study likely to be representative of the target population?

1 Very likely
2 Somewhat likely
3 Not likely
4 Can't tell

(Q2) What percentage of selected individuals agreed to participate?

1 80 - 100% agreement
2 60 – 79% agreement
3 less than 60% agreement
4 Not applicable
5 Can't tell

RATE THIS SECTION	STRONG	MODERATE	WEAK
See dictionary	1	2	3

B) STUDY DESIGN

Indicate the study design

1 Randomized controlled trial
2 Controlled clinical trial
3 Cohort analytic (two group pre + post)
4 Case-control
5 Cohort (one group pre + post (before and after))
6 Interrupted time series
7 Other specify ____________________
8 Can't tell

Was the study described as randomized? If NO, go to Component C.

No Yes

If Yes, was the method of randomization described? (See dictionary)

No Yes

If Yes, was the method appropriate? (See dictionary)

No Yes

RATE THIS SECTION	STRONG	MODERATE	WEAK
See dictionary	1	2	3

C) CONFOUNDERS

(Q1) Were there important differences between groups prior to the intervention?

1 Yes
2 No
3 Can't tell

The following are examples of confounders:

1 Race
2 Sex
3 Marital status/family
4 Age
5 SES (income or class)
6 Education
7 Health status
8 Pre-intervention score on outcome measure

(Q2) If yes, indicate the percentage of relevant confounders that were controlled (either in the design (e.g. stratification, matching) or analysis)?

1 80 – 100% (most)
2 60 – 79% (some)
3 Less than 60% (few or none)
4 Can't Tell

RATE THIS SECTION	STRONG	MODERATE	WEAK
See dictionary	1	2	3

D) BLINDING

(Q1) Was (were) the outcome assessor(s) aware of the intervention or exposure status of participants?

1 Yes
2 No
3 Can't tell

(Q2) Were the study participants aware of the research question?

1 Yes
2 No
3 Can't tell

N/A

RATE THIS SECTION	STRONG	MODERATE	WEAK
See dictionary	1	2	3

E) DATA COLLECTION METHODS

(Q1) Were data collection tools shown to be valid?

1 Yes
2 No
3 Can't tell

(Q2) Were data collection tools shown to be reliable?

1 Yes
2 No
3 Can't tell

RATE THIS SECTION	STRONG	MODERATE	WEAK
See dictionary	1	2	3

F) WITHDRAWALS AND DROP-OUTS

(Q1) Were withdrawals and drop-outs reported in terms of numbers and/or reasons per group?

1 Yes
2 No
3 Can't tell
4 Not Applicable (i.e. one time surveys or interviews)

(Q2) Indicate the percentage of participants completing the study. (If the percentage differs by groups, record the lowest).

1 80 -100%
2 60 - 79%
3 less than 60%
4 Can't tell
5 Not Applicable (i.e. Retrospective case-control)

RATE THIS SECTION	STRONG	MODERATE	WEAK	
See dictionary	1	2	3	Not Applicable

G) INTERVENTION INTEGRITY

(Q1) What percentage of participants received the allocated intervention or exposure of interest?

1 80 -100%
2 60 - 79%
3 less than 60%
4 Can't tell

N/A

(Q2) Was the consistency of the intervention measured?

1 Yes
2 No
3 Can't tell

(Q3) Is it likely that subjects received an unintended intervention (contamination or co-intervention) that may influence the results?

4 Yes
5 No
6 Can't tell

H) ANALYSES

(Q1) Indicate the unit of allocation (circle one)

community organization/institution practice/office individual

(Q2) Indicate the unit of analysis (circle one)

community organization/institution practice/office individual

(Q3) Are the statistical methods appropriate for the study design?

1 Yes
2 No
3 Can't tell

(Q4) Is the analysis performed by intervention allocation status (i.e. intention to treat) rather than the actual intervention received?

1 Yes
2 No
3 Can't tell

GLOBAL RATING

COMPONENT RATINGS

Please transcribe the information from the gray boxes on pages 1-4 onto this page. See dictionary on how to rate this section.

A	**SELECTION BIAS**	**STRONG**	**MODERATE**	**WEAK**	
		1	2	3	
B	**STUDY DESIGN**	**STRONG**	**MODERATE**	**WEAK**	
		1	2	3	
C	**CONFOUNDERS**	**STRONG**	**MODERATE**	**WEAK**	
		1	2	3	
D	**BLINDING**	**STRONG**	**MODERATE**	**WEAK**	N/A
		1	2	3	
E	**DATA COLLECTION METHOD**	**STRONG**	**MODERATE**	**WEAK**	
		1	2	3	
F	**WITHDRAWALS AND DROPOUTS**	**STRONG**	**MODERATE**	**WEAK**	
		1	2	3	Not Applicable

GLOBAL RATING FOR THIS PAPER (circle one):

1	STRONG	(no WEAK ratings)
2	MODERATE	(one WEAK rating)
3	WEAK	(two or more WEAK ratings)

With both reviewers discussing the ratings:

Is there a discrepancy between the two reviewers with respect to the component (A-F) ratings?

No Yes

If yes, indicate the reason for the discrepancy

1 Oversight
2 Differences in interpretation of criteria
3 Differences in interpretation of study

Final decision of both reviewers (circle one):

1 STRONG
2 MODERATE
3 WEAK

Appendix C. Summary of Theory of Mind Measures Used by the Included Studies

Summary of the ToM and Social Cognition Tasks Used by the Included Review Papers

Construct (level of ToM)	ToM Task	Brief description	Study reference
Cognitive ToM (First order)	The Sally and Ann Test (Baron-Cohen, Leslie, & Frith, 1986)	The assessment uses two dolls as protagonists examining understanding of false-location. The task involves making inferences and predicting behaviour based on a character's false belief. Examiner uses a puppet "Sally" to put candy in a jar and who then leaves. A different puppet called "Ann" comes in and takes the candy and eats it. Then "Sally" comes back and the child is asked: "Where does Sally think the candy is?	• Snodgrass & Knott, 2006 • Walz, Yeates, Taylor, Stancin, & Wade, 2009 • Walz, Yeates, Taylor, Stancin, & Wade, 2010
Cognitive ToM (Second order)	The Deception vs. Sabotage "One Box" Task (Sodian & Frith, 1992)	A test of deception that assesses the ability to manipulate a competitor's beliefs in order to reach a desired outcome, such as keeping sweets from a puppet competitor either by deception (manipulate beliefs by telling a lie) or sabotage (manipulating behaviour).	• Snodgrass & Knott, 2006
Cognitive ToM (Second order)	The Jack and Jill test (Dennis et al., 2012)	Jack and Jill cartoon task that measures intentional thinking separate from contingent task demands. In the key ToM trials, which require intentional thinking, Jack switches a black ball from one hat to another of a different color, but Jill does not witness the switch; in the otherwise identical non-ToM trials, the switch is witnessed.	• Bigler et al., 2013 • Dennis et al., 2012 • Dennis et al., 2013c

Cognitive (Second Order)	John and Mary Story (Perner & Wimmer, 1985) “New” story (Sullivan et al., 1994)	Standard story: John and Mary story, two children see an ice cream truck at the park while they are playing. Later, each child is independently informed that the truck has moved from the original spot to the school, but neither child knows that the other person knows. Children are asked if John knows that Mary knows where the ice cream truck is (second-order ignorance) and where John thinks Mary went to buy an ice-cream cone (second-order belief). “New story”: A mother deliberately misinforms her son about what he will receive for his birthday, because she wants to surprise him. Unbeknownst to the mother, her son actually discovers the true birthday present. Later, when speaking to the child’s grandmother, the mother is asked whether the child knows what he is getting for his birthday (second-order ignorance) and then what the child thinks he is getting (second-order belief).	• Walz, Yeates, Taylor, Stancin, & Wade, 2010
Cognitive (Meta-representation)	The Social Animation Task – modified version (Scheibel et al., 2011)	Participants watch films illustrating interactions among geographic shapes programmed in E-Prime and presented by MRA fMRI stimulus delivery system. Two conditions with eight films in each. Each film contain the same three white geometric objects (i.e., triangle, circle, diamond) that move against a black background. During social condition, there was a box in the centre of the background that opened as if it was a door, and the shapes moved as if they were able to open or shut the door, enter the box, and chase or drag other shapes inside. Subjects were asked following the film clips: “Do you think the figures are friends?” This requires meta-representational thought. The participant creates a representation of the figure’s representation of each other. Therefore, concept of ToM in this	• Scheibel et al., 2011

		task broadly means engagement in meta-representation.	
Cognitive-Affective ToM (Advanced, Third order)	The Reading the Mind in the Eyes Test - children's version (Baron-Cohen, Wheelwright, Scahill, Lawson, & Spong, 2001b)	Participants are asked to view photographs of the eye region of the face and select which of four words (one target, three foil words) best describes what the person is feeling and thinking. Both affective and non-affective words are included.	• Snodgrass & Knott, 2006
Cognitive ToM (Third order)	The Faux Pas Test (Baron-Cohen, O'Riordan, Stone, Jones, & Plaisted, 1999)	Participants are required to identify faux pas in short narratives (e.g., Did Joe know that Mike was in the cubicle [when he made the insulting comment about Mike]?). Includes 10 stories with faux pas and 10 without.	• McLellan & McKinlay, 2013 • Turkstra et al., 2008
Cognitive ToM (Third order)	The Strange Stories Test (Happe, 1994)	Participants are presented with a spoken story accompanied by a line drawing, and asked to identify the meaning of inferential language such as irony, persuation, or polite lies.	• Turkstra et al., 2008 • Walz, Yeates, Taylor, Stancin, & Wade, 2010
Affective ToM (Third order)	The Emotional and Emotive Faces Task (EEFT; Dennis et al., 2013a)	This task evaluates emotions actually felt (emotional expression; EE) and emotions expressed for social purposes (emotive communication; EC). Five emotions (happiness, sadness, fear, disgust, anger) are studies in terms of EE and EC. The task involves 25 short narratives (5 for each emotion) involving discrepancy between a character's "inside" feeling and "outside" facial expression. The participant is asked to choose a face from a display of facial expressions with a neutral face at the centre, surrounded by faces expressing a mild and strong expression of each emotion.	• Bigler et al., 2013 • Dennis et al., 2013a • Dennis et al., 2013c • Ryan et al., 2014

Conative ToM (Third order)	The Literal Truth, Ironic Criticism and Empathic Praise Task (Dennis, Purvis, Barnes, Wilkinson, & Winner, 2001).	Participants are presented with six pictured situations: (a) tidying a room, (b) baking a cake, (c) raking a leaf pile, (d) building a block tower, (e) erasing a blackboard, (f) fixing a bike, each presented in three forms: literal praise, ironic criticism and empathic praise. They were told the goal of the task (e.g., to build a tower), shown the outcome of the task in a picture and informed of the speaker's character (e.g., "she liked to chat and talk to people"; "she liked to bug and annoy people"; "she liked to cheer people up") and what the speaker said to the hearer (e.g., "you made a great a tower"). An audiotape of the speaker's utterances were played for each scenario. The key measures are comprehension accuracy for Literal Truth (transparent relation between words and meaning), Ironic Criticism (obscure relation between words and meaning, and a negative intention towards the hearer), and Empathic Praise (opaque relation between words and meaning, and a positive intention towards the hearer).	• Bigler et al., 2013 • Dennis, Purvis, Barnes, Wilkinson, & Winner, 2001 • Dennis et al., 2013b • Dennis et al., 2013c
Conative ToM (Third order)	The Ironic Criticism and Empathic Praise Task (Dennis et al., 2001)	Measures conative ToM using vignettes that assess the child's ability to understand the use of indirect speech act to influence the mental and emotional state of the listener. Each vignette involves (1) conative ToM trials requiring the child to identify the beliefs and intentions underlying referentially opaque communication involving irony and empathy, compared to (2) otherwise identical control items that have comparable domain-general cognitive demands but do not require conative ToM processing.	• Dennis et al., 2001 • Ryan et al., 2014
Social cognition/	The Awareness of Social	Task includes short audiovisual vignettes of emotional displays	• McDonald, Flanagan,

social perception (Third order)	Inference Test (TASIT; McDonald, Flanagan, & Rollins, 2011)	and everyday interactions and comprises of three parts: *TASIT 1: The Emotion Evaluation Test (EET)* Measures recognition of emotions presented in audiovisual displays. Contains 28 professionally acted vignettes, depicting four instances of each of the six primary emotions and neutral. As the scripts are ambiguous, judgments about emotions must be made based on non-verbal cues (e.g., facial expression, vocal tone and body language). *TASIT 2: Social Inference – Minimal (SI-M)* Assesses the ability to identify sincere and sarcastic comments (15 items). *TASIT 3: Social Inference – Enriched (SI-E)* Measures ability to identify sarcasm and lies (16 items).	& Rollins, 2013 • Turkstra, Thomas, Dixon, & Baker, 2004 (adapted version of TASIT) • Stronach & Turkstra, 2008 (adapted version of TASIT)

SCHOOL OF PSYCHOLOGY

DOCTORATE IN CLINICAL PSYCHOLOGY

EMPIRICAL PAPER

TITLE: Associations between TBI, facial emotion recognition, impulse control and aggression in delinquent and vulnerable young people

Trainee Name: **Sanna Tanskanen**

Primary Supervisor: **Professor Huw Williams**

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Target Journal: Journal of the International Neuropsychological Society

Word Count: 8277 (excluding abstract, table of contents, list of figures, references, footnotes, appendices)

Submitted in partial fulfillment of requirements for the Doctorate Degree in Clinical Psychology, University of Exeter

Abstract

Objectives: There is evidence that childhood traumatic brain injury (TBI) is associated with increased risk of offending and violent crime. This study aimed to explore associations between TBI in a group of delinquent and vulnerable young people (VYP) at risk of offending, and facial emotion recognition (FER) abilities, inhibition control (Stop-IT) and self-reported reactive-proactive aggression (RPQ). ***Methods:*** There were two studies. The first study used a cross sectional between group design to compare 45 VYP (with and without TBI) and a control group of 59 students on FER task measuring emotion recognition accuracy of six basic emotions. The second study examined differences between TBI and non-TBI groups in the VYP sample (*N*=21) on a Stop-IT task, FER accuracy and self-reported reactive-proactive aggression. ***Results:*** A history of TBI was reported by 60% of the VYP group (48.9% with loss of consciousness [LoC]), whereas 30% of the control group reported a history of TBI (25.4% with LoC). The VYP group (with and without TBI) demonstrated a similar pattern of reduced overall FER accuracy that was significantly different to the control group. Compared to the control group, The VYP groups (with and without TBI) were less accurate on recognising anger, disgust, sadness and surprise, but not happy and fear. There were no significant differences between the TBI- and non-TBI groups. The second study did not find any significant differences between the TBI and non-TBI groups on overall FER accuracy, Stop-IT performance, and RPQ scores. There were also no significant associations between these measures. ***Conclusions:*** Future research requires larger samples that enable investigating the association between different severity of TBI, FER and inhibition control ability. Better and more youth-friendly measures are also needed.

Introduction

Longitudinal studies indicate that traumatic brain injury (TBI) in childhood is linked with increased risk of later offending and violent crime (e.g., Timonen et al., 2012). The prevalence rate of TBI in adult prisoners is estimated at 60.3% (Shiroma, Ferguson, & Pickelsimer, 2010) and between 49.7% and 72.1% among incarcerated youth (Hughes et al., 2015). These rates are significantly higher compared to the general population (between 2.0 - 38.5%; Farrer & Hedges, 2011). Socio-emotional deficits, such as impaired emotion recognition, as well as neurobehavioural impairments, such as impulsivity and aggression, are common among offenders, as well as typical sequelae of TBI. However, research has yet to establish the nature of the association between these emotion regulatory functions and offending, and whether TBI might contribute to such impairments in offending youth. Therefore, this study will explore the associations between TBI, emotion recognition, impulse control and aggression in a sample of delinquent youth and vulnerable young people at risk of offending.

Traumatic Brain Injury (TBI)

TBI is a serious public health problem (Stoddard & Zimmerman, 2011) and a leading cause of mortality and disability in children and working age adults (Fleminger & Ponsford, 2005). TBIs are caused by a sudden trauma to the head that disrupts brain functioning, and are estimated to affect ten million people worldwide each year (Langlois, Rutland-Brown, & Wald, 2006). Common causes include traffic accidents, falls, sporting injuries and assaults (Williams, Potter, & Ryland, 2010). Both genders are at equal risk under the age of five, but males are considered at increased risk from adolescence (Yates, Williams, Harris, Round, & Jenkins, 2006; Langlois et al., 2006). Other typical risk factors for TBI among young people include social deprivation and urban location (Yates et al., 2006).

TBI leads to multifocal and diffuse neuropathology. Typically pathology is localised in the ventrolateral, medial and orbital frontal lobes and the ventromedial temporal lobes (Bigler, 2007), which are implicated in executive ability and social cognition (Tasker et al., 2005; Wilde et al., 2005). Diffuse axonal injuries (DAI) to the corpus callosum, brainstem, and the grey-white matter junctions of the cerebral cortex are also common (e.g., Meythaler, Peduzzi, Eleftheriou, & Novack, 2001). TBIs are commonly categorised as “mild”, “moderate” and “severe”, typically determined by the duration of loss of consciousness (LoC), with LoC of less than 30 minutes indicating a mild TBI (mTBI; World Health Organization, 2001). Commonly used measures are the Glasgow Coma Scale (GCS; Teasdale & Jennett, 1974) and Post-Traumatic Amnesia (PTA; Meares, Shores, Taylor, Lammel, & Batchelor, 2011) scales.

Moderate to severe TBIs are associated with more severe immediate and long-term impairments on physical, cognitive and psychosocial functioning (e.g., Hoofien, Gilboa, Vakil, & Donovick, 2001; Stambrook, Moore, Peters, Deviane, & Hawrylyk, 1990). Recent neuroimaging has found that even mTBIs result in brain changes, such as inefficiencies in the neural networks due to loss of conduction in the white matter tracts (Bigler, 2013). Sports injury research suggests that such effects are more prominent with repeat injury, which is likely to be associated with deficits in executive and memory skills (Collins et al., 1999; Gardner, Shores, & Batchelor, 2010; Williams, Potter, & Ryland, 2010).

Neurocognitive Outcomes and Socio-Emotional Processing following Childhood TBI

Childhood TBI is an important health problem, predominantly affecting the frontal lobes, which are involved in a number of higher-order cognitive, affective, and social functions. However, the prefrontal cortex (PFC) develops until the age of 25 (Giedd, 2004; Steinberg, 2008, 2010). Therefore, injury to the “immature brain” may derail ongoing brain development and lead to failure in developing skills at an age appropriate rate (Beauchamp & Anderson, 2010; Yeates et al., 2004). Several neurocognitive and psychosocial difficulties related to frontal lobe dysfunction in children with TBI are reported. For example, impaired executive function (EF) is common, which has implications for self-regulation, inhibition control and social cognition (Levin & Hanten, 2005; Sinopoli & Dennis, 2007). Furthermore, attention deficits, irritability, aggressiveness and oppositional behaviour (Max, Robin, & Lindgren, 1997; Fletcher, Ewin-Cobbs, & Miner, 1990), as well as organic personality changes and psychological adjustment problems with externalizing behaviours have been identified (Max, Robertson, & Lansing, 2001; Poggi et al., 2005). The most commonly observed personality changes were characterised as labile, aggressive and disinhibited subtypes (Max, Robertson, & Lansing, 2001).

Childhood TBI has been associated with negative social outcomes (e.g., Yeates et al., 2004). However, the nature of these difficulties is not well understood. It has been postulated that impairments in identifying emotional expression from faces might contribute to social communication difficulties (e.g., MacDonald, 2003; Ryan et al., 2013). Facial emotion recognition (FER) plays an important role in effective social competence as it underlies the ability to infer mental states of others (e.g., Knox & Douglas, 2009; Watts & Douglas, 2006).

Therefore, impairment to emotion processing early in development is suggested to disrupt normal socialization (Blair, Colledge, Murray, & Mitchell, 2001) and misinterpretation of social cues is linked to inappropriate social responses, such as reacting aggressively or violently to social situations (e.g., Dodge, Laird, Lochman & Zelli, 2002). Interestingly, conduct disorder and antisocial behavior in children and adolescents has been associated with impairments in emotion recognition (Bowen & Dixon, 2010; Fairchild, van Goozen, Calder, Stollery, & Goodyear, 2009; Sato, Uono, Matsuura, & Toichi, 2009).

Emerging research has identified deficits in emotion recognition (e.g., Tonks, Williams, Frampton, Yates, & Slater, 2007; Schmidt, Hanten, Li, Orsten, & Levin, 2010; Tlutos et al., 2011) and impairments in developing empathy in children and adolescents with TBI (e.g., Tonks et al., 2008; Tonks et al., 2009). However, little is known about the long-term impact of these impairments. Recent findings indicated that survivors of severe childhood TBI were significantly poorer in emotion perception in adulthood, compared to controls (Ryan et al., 2014). Furthermore, Ryan et al. (2013) demonstrated that childhood TBI was associated with greater social communication difficulties in young adult survivors, which in turn was associated with more frequent externalizing behaviours and poorer emotion perception. These findings were mapped onto the Heuristic Model of Social Competence (HMSC; Yeates et al., 2007). According to this model, poor emotion perception reduces interpersonal effectiveness, which in turn produces psychological distress that is reflected in externalizing behaviours (e.g., aggression, intrusive conduct, rule breaking). As discussed above, what remains unclear is whether childhood TBI might contribute to impairments in FER in offending youth.

TBI and Offending Behaviour

It is difficult to establish causal links between TBI and crime as the risk factors overlap (e.g. low SES, male sex, engagement in risky behaviours). Therefore, it is difficult to determine whether brain injury leads to increased likelihood of delinquency or if the lifestyle of the delinquent youths put them more at risk for acquiring TBIs (Perron & Howard, 2008; Rantakallio, Koiranen, & Möttönen, 1992). However, it is suggested that childhood TBI can alter the life trajectory for some individuals by increasing the risk of probability for offending.

Evidence for causal links is provided by longitudinal population studies. Findings from two related Finnish birth cohort studies showed that childhood TBI was associated with increased risk of criminal convictions and violent crime in youth and adult males (Rantakallio, Koiranen, & Möttönen, 1992; Timonen et al., 2002). More compelling evidence was provided by a 35-year follow-up population study in Sweden with a TBI sample of 22,914 (Fazel, Lichtenstein, Grann, & Langstrom, 2011). It was found that 8.8% of the TBI sample had committed violent crime, compared with 3.3% of population controls, thus reflecting a significantly increased risk for violent crime. The risk of offending attenuated somewhat after adjusting for familial and substance abuse factors.

TBI is highly prevalent in offenders (e.g., Hughes et al., 2015) with a significant proportion reporting multiple “head injuries”, which may lead to greater “dosage” of injury over time (Davies, Williams, Hinder, Burgess, & Mounce, 2012; Williams et al., 2010). Furthermore, TBI with LoC and repeat injuries is associated with recidivism and more violent crimes (e.g., Williams et al., 2010; Kenny & Lennings, 2007). TBI was suggested to increase disinhibition of aggressive impulses especially in the presence of hazardous alcohol use, thus increasing the risk of severe violence in offending behaviour (Kenny &

Lennings, 2007). LoC has also been strongly associated with early onset and "life course persistent" offending trajectories (Raine et al., 2005). Therefore, preliminary findings suggest that severity and frequency of TBI might be associated with more convictions and violent crime.

The link between brain injury and crime is suggested to reflect damage to the frontal lobes, which can lead to poor decision-making and social judgment, over-reaction to provocative stimuli and impulsive behaviour (Turkstra, Jones, & Toler, 2003). Frontal lobe injury has been linked with increase in impulsive, reactive aggression (Brower & Price, 2001; Wood & Thomas, 2013), violence (Turkstra, Jones, & Toler, 2003), and reduced capacity for empathy (Jolliffe & Farrington, 2001). Interestingly, persistent offenders are typically characterised as lacking affective empathy, which may reflect impairments in the social brain system (Blair, 2007; Decety, Skelly, & Kiehl, 2013). It is argued that recognising distress cues in others is important for eliciting empathy, social bonding and inhibiting aggressive responses (Marsh, Ambady, & Kleck, 2005). Antisocial populations have consistently demonstrated specific impairments in recognising negative emotions in others, such as sad and fearful expressions (e.g., Blair & Marsh, 2008; Bowen, Morgan, Moore, & van Goosen, 2014; Dolan & Fullam, 2006; Gery, Miljkovitch, Berthoz, & Soussignon, 2009; Hoaken, Allaby, & Earle, 2007; Jones, Foster, & Skuse, 2007; Robinson et al., 2012). The Integrated Emotion Systems (IES) model suggests that amygdala is the primary locus of dysfunction in psychopathic individuals, while orbitofrontal cortex dysfunction is associated with impulsive aggressive behaviour (Blair, 2005).

Impaired neuropsychological functioning is suggested to contribute to the aetiology of aggression and violent behaviour (Brower & Price, 2001), and problems with cognition and EF are commonly observed amongst offenders (e.g. Hoaken, Allaby, & Earle, 2007). In a large prison study (*N*=224) inmates who exhibited reduced behavioural inhibition and inability to shift responses to new information (on a Stop-Change task), were significantly more likely to drop out early from treatment programs and less likely to report improvement in aggressive reactions to provocation (Fishbein et al., 2009). History of TBI was related to poorer treatment gains and inhibition control. Furthermore, it was reported that those with TBIs reported more psychological problems and higher levels of both proactive and reactive aggression. Reactive aggression is typically characterised as fear-induced, irritable, and hostile emotion-driven defensive response to provocation (Dodge, 1991) that is related to lack of inhibition, reduced self-control and increased impulsivity (Atkins, Stoff, Osborne, & Brown 1993). Whereas proactive aggression, typically associated with psychopathy, is driven by external reward and characterised as goal-orientated and predatory (Dodge, 1991). Therefore, aggressive antisocial behaviour appears to be influenced by poor impulse control and impaired emotion recognition in adults. However, the association of these processes is not well understood in delinquent youth, nor is it established whether childhood TBI might play a role in these functions.

Current Study

Considering the high prevalence of TBI among young offenders and the mounting evidence of FER impairments in pediatric TBI- and antisocial populations, this study aims to examine whether delinquent and vulnerable youth report high rates of TBI and whether a substantial “dosage” of TBI is associated with deficits in FER, especially in recognising negative emotions. Impairments in recognising emotions from faces are suggested to contribute to social communication difficulties. Successful social communication also requires cognitive-executive and social-affective functions, which are often impaired following TBI. Deficits in impulse control and emotion regulation are common sequelae of TBI and have been linked with aggressive, antisocial behaviour and poorer treatment gains in adult offenders. However, it remains unclear whether poor impulse control is associated with deficits in FER and aggression in delinquent and vulnerable youth. Therefore, the second part of this study is exploratory and aimed to investigate whether the delinquent and vulnerable young people show deficits in impulse control and poorer emotion recognition, and whether these impairments may be reflected in higher scores of self-reported aggression. Due to the exploratory nature of the study, it is explored whether any degree of TBI may contribute to such deficit.

Aims and Hypotheses

Study 1:

1) Compared to a non-offender control group, the VYP group with and without TBI will demonstrate poorer overall accuracy on the FER task. The TBI- subgroup is predicted to demonstrate poorer performance compared to the non-TBI and the control groups.
2) Compared to the control group, the VYP group, especially the TBI-subgroup, will demonstrate poorer accuracy for recognising negative emotions (disgust, fear, angry, sad) than positive emotions (happy, surprise).

Study 2:

3) In this exploratory study poorer performance on impulse control task is predicted to be associated with worse accuracy on FER task and higher scores on self-reported measure of reactive-proactive aggression. Individuals with any degree of TBI are predicted to perform worse.

Method

Participants

Study 1 participants were 45 vulnerable young people (VYP) recruited opportunistically through five Youth Offending Teams (YOTs) and Targeted Youth Support (TYS) teams, and from two Pathways to Independence[1] (P2I) providers in South West England. The YOT/TYS participants were between the ages of 10 and 19 and had either criminal convictions or cautions. Participants were excluded if they had learning disability (LD), significant current mental health difficulties (e.g., psychosis), or posed a high risk of violence to self or others. The inclusion and exclusion criteria were largely the same with P2I participants, apart from age (between 16 and 24) and history of criminal convictions or cautions was not required.

Twenty-seven participants were recruited from YOTs and TYS in May 2013 by an MSc student (Cohen, 2013) and 21 participants were recruited by the author from YOTs and P2Is between September and November 2014. Two participants were excluded from the author's sample in Study 1, as these were duplicates from the MSc project (see Appendix A). A control group of 59 students was recruited as a part of separate research project at University of Exeter in July 2014. The inclusion criteria for the control group were capacity to give informed consent and age between 15 and 18. The participants were also identified as typically developing by the school. The exclusion criteria were current diagnosis of acquired brain injury, complicated mild TBI and/or moderate to severe TBI, mental health difficulties or LD.

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[1] P2I provides housing, advice and support for vulnerable young people in care, or leaving care, young offenders, homeless youth and young parents, to name but a few.

Design

Study 1 used a cross-sectional, between groups design to compare VYP (with and without TBI) group with the control group. Study 2 had a between group (TBI vs. non-TBI) design. The VYP TBI-group was the primary independent variable (IV) and the dependent variables (DV) were the outcomes on tasks measuring emotion recognition, impulsivity and self-reported aggression.

Measures

See Table 1 for measures. The computer experiments for this study were ran on a 19-inch screen Dell precision M4700 laptop.

Table 1. Outline of Measures Administered in the Different Studies

Measure type	MSc Project (May 2013) YOT/TYS group	Current Study (September – November 2014) YOT/P2I group	Control group* (July 2014) Control group
Emotion Recognition Task	• Facial Emotion Recognition Task	• Facial Emotion Recognition Task	• Facial Emotion Recognition Task
Neuropsychological Tests	• WASI Vocabulary • WASI Block Design • Stroop • Trail Making A & B	• WASI Vocabulary • WASI Block Design	• WASI-II Matrix design
Background Questionnaire	• Neurodisability section of the CHAT • Demographics (age, gender, ethnicity)	• Neurodisability section of the CHAT • Demographics (age, gender, ethnicity)	• Neurodisability section of the CHAT • Demographics (age, gender)
Other tasks/ questionnaires	-	• STOP-IT Task • Reactive-Proactive Questionnaire	-

Information collected from the YOT ASSET or P2I assessment	• Offence history (including offences, seriousness score (SS) for primary offence, age at first conviction, number of previous convictions, risk of reoffending) • Substance misuse (yes/no)	• Offense history (including offences, SS for primary offence, age at first conviction, number of previous convictions) • Substance misuse including type of substance used • Mental health diagnosis • Living arrangements • Highest level of education	• Participants asked about Youth Justice Referral

Note: * This data collection was part of a larger study, here only measures relevant for this study are outlined. *Abbreviations:* Comprehensive Health Assessment Tool (CHAT); Wechsler Adult Intelligence Scale (WASI)

Facial Emotion Recognition Task (FER).

A computer-based FER task aiming to assess accuracy of facial emotion recognition of six basic emotions was presented on E-Prime Software, (Bamford et al., 2015) and completed by all the 46 VYP and 59 control participants. This task consists of a linear morph sequence of facial images depicting six universal facial expressions including happy, sad, angry, frightened, surprised and disgusted (Ekman, 1972). Each emotion has fifteen equally spaced images along the linear morphed sequence that change incrementally from ambiguous to unambiguous facial expressions (Figure 1). The participants were presented a total of 90 facial images in a random order displayed for 150ms. Each trial begins with a centrally presented fixation cross between 1500ms and 2500ms, which was followed by a visual mask for 250ms. The participants were instructed to identify the expression by clicking on one of the six forced-choice emotion labels by using a computer mouse. Accurate emotion recognition is characterised by a high hit rate (i.e., the ability to correctly identify an expression) and a low false-alarm rate (i.e., reduced tendency to mislabel particular emotion). Following an established method (Wagner, 1993), the accuracy scores were calculated for each emotion and time-point that reflect the difference between hit and false-alarm rates: *p*(hits) minus *p*(false alarms). Positive scores (tending to 1) denote greater accuracy.

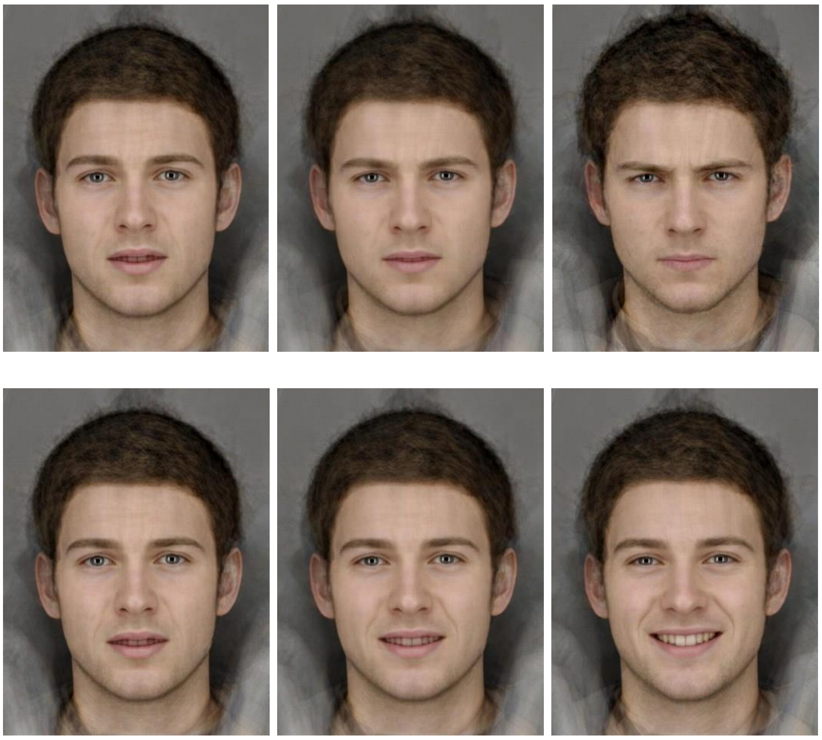

Figure 1. Examples of "angry" and "happy" facial expression stimuli used in FER task

Stop-IT Task.

This computer-based, response inhibition task (Godron, Stevens, & Verbruggen, 2008[2]), operated on MATLAB-software was completed by 21 participants in the current study. The task consisted of a practice phase of 32 trials and an experimental phase of three blocks of 64 trials. When presented with a white arrow, participants were instructed to press either right or left arrow key corresponding with the direction of the arrow, and to withhold responses on presentation of blue arrow. The stop signal (blue arrow) occurred after a variable interval, the stop-signal delay (SSD), which was determined by dynamic tracking procedure. At the beginning of the experiment, SSD was set to a specific value (e.g., 250ms) and was then constantly adjusted after stop-signal trials depending on the outcome of the race between a “go” process (white arrow) and a “stop” process (blue arrow). When the inhibition was successful, SSD increased by 50ms, but when the response inhibition was unsuccessful, SSD decreased by 50ms. This one-up/one-down tracking procedure typically results in a *p*(respond|signal) of approximately .50, which means that the race between the stop and go processes is tied (Verbruggen, Chambers, & Logan, 2013).

The integration method is used to gain an estimation of the covert latency of the stop process, the stop-signal reaction time (SSRT). The point at which the stop process finishes is estimated by integrating the reaction time distribution and finding the point at which the integral equals the probability of responding, *p*(respond|signal), for a specific delay (Verbruggen, Chambers, & Logan, 2013, p. 353). SSRT is then calculated by subtracting the SSD from the finishing time.

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[2] See web-link: https://ore.exeter.ac.uk/repository/handle/10871/13860?show=full

Wechsler Abbreviated Scale of Intelligence (WASI).

In order to determine level of verbal knowledge and visuospatial functioning, all 46 participants in the VYP sample were administered two subtests of the WASI: the Vocabulary and Block Design (Wechsler,1999). The control group was administered Matrix Design subtest of the WASI-II (Wechsler, 2011) measuring perceptual organisation. The 42-item Vocabulary subtest measures verbal and general intelligence, language ability and memory by asking participants to define the meaning of words. The 13-item block design subtest required participants to replicate thirteen 2D geometric patterns using a set of blocks, within the given time limit. This subtest measures perceptual and spatial organisation, visual-motor coordination and abstract conceptualization (Wechsler, 1999). Matrix Design measures fluid and visual intelligence, spatial ability, knowledge of part-whole relationships and simultaneous processing.

The Comprehensive Health Assessment Tool (CHAT).

The neurodisability section of the CHAT (Appendix B; Chitsabesan et al., 2015) was used with all the 46 VYP and 59 control participants to obtain information about history of TBI. The participants were asked: “Have you ever had an injury to the head that caused you to be knocked out and/or dazed and confused?” If the answer was “yes”, then follow-up questions were asked regarding frequency, age at injury, cause, medical treatment and duration of loss of consciousness (LoC). The duration of LoC at the worst injury was used as a measure of TBI severity. The following classification system was used: no history of TBI, dazed and confused without LoC (concussion), LoC between 0-10 minutes (mild TBI), LoC between 10-30 minutes (mild complicated TBI), LoC between 30-60 minutes (moderate TBI), and LoC of 60 minutes or longer (severe TBI). This system is the same with regards to duration of LoC on CHAT manual, but category labels vary slightly[3] (Shaw et al., 2014).

Reactive Proactive Questionnaire (RPQ).

The RPQ (Raine et al., 2006; Appendix C) is a 23-item self-report measure assessing the frequency of reactive (11 items) and proactive aggression (12 items) on a scale (0= never, 1= sometimes, 2= often). The questionnaire can be read by 8-year-olds and adolescents with limited reading ability. This measure is reported to have good internal reliability for reactive (alpha= .84) and proactive aggression (alpha= .86), as well as good convergent and discriminant validity (Raine et al., 2006). Calculating internal consistency for the present study sample found an alpha of .71 for proactive and alpha of .78 for reactive subscales.

Procedure

This study was approved by the University of Exeter's School of Psychology Ethics Board (Appendix D) and by the County Council's Research Governance Board (Appendix E). University ethics was also granted for the MSc and control group studies (Appendix F). Figure 2 outlines the procedure for this study. Based on the inclusion and exclusion criteria, approximately 36 young people were identified as suitable by the YOT service leads. However, only 10 completed the experiment. Four P2I providers were invited to take part in the study, but only two centres agreed to host the research. In total, 11 young people were recruited from the P2I through opportunistic sampling.

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[3] CHAT manual proposes that LoC < 10 minutes is categorized as "minor TBI" and LoC between 10-30 minutes as "mild TBI".

The participating YOTs and P2Is were provided with recruitment packs that consisted of practitioner's abstract, cover letter for parents and guardians, information sheets, and consent forms (Appendix G). All participants completed the research in one-hour individual sessions either at the YOT or P2I premises. The measures were presented in an interview format due to the participant's variable reading ability, and were administered in the same order to ensure comparability. An interview format was also used in the MSc project. However, the control sample participants were tested in a computer laboratory hosting up to 30 participants. The control participants were firstly asked to complete a screening questionnaire to ensure eligibility followed by further paper and pen as well as online-based questionnaires. These participants completed self-report measures independently. The control participants were then directed to the computer-based online emotion recognition task. Written consent was obtained prior to testing and full debrief was offered to all participants across the different studies. At completion of the experiment, the YOT and P2I participants were awarded a £5 voucher, which were funded by the YOT service.

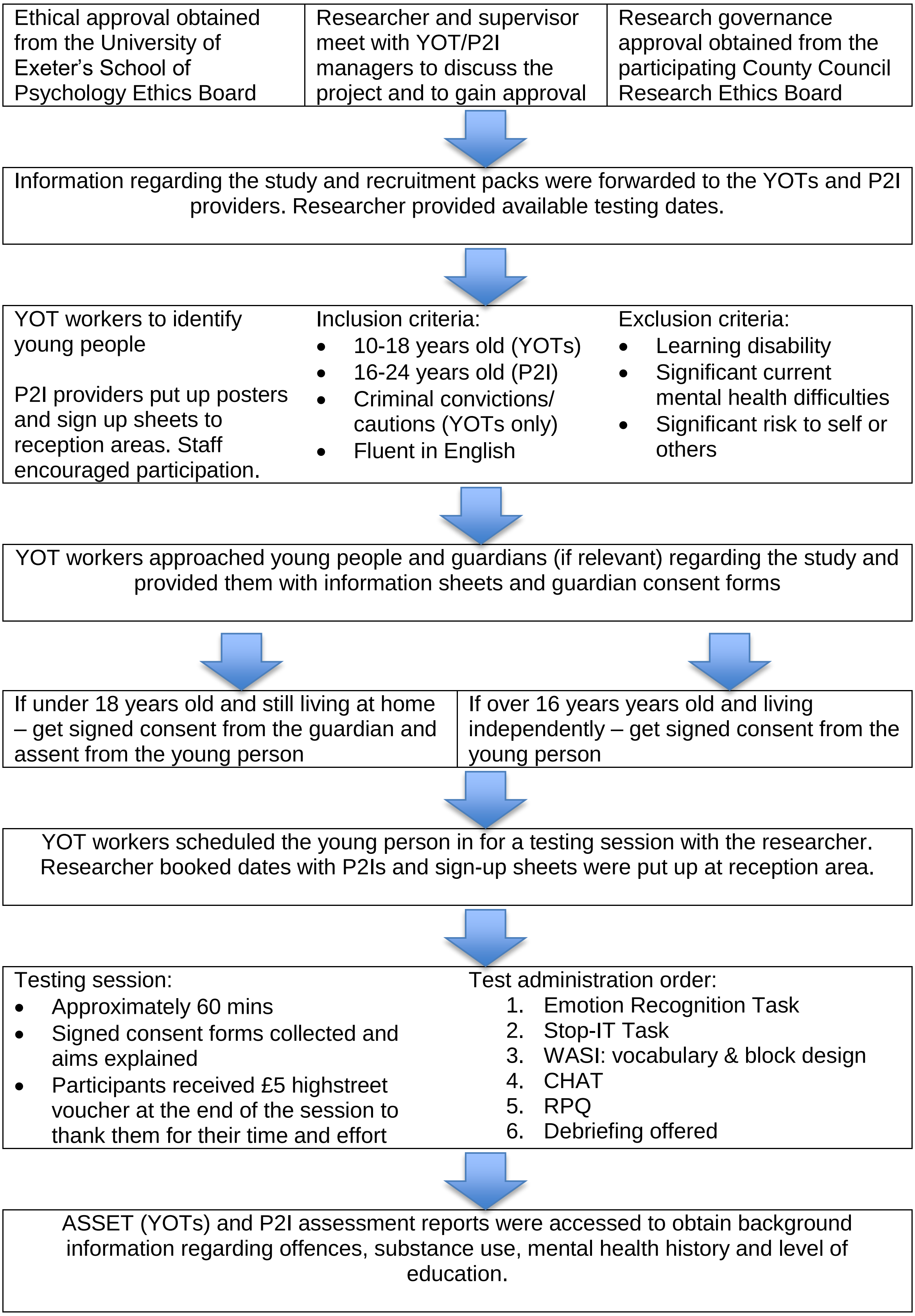

Figure 2. Study procedure

Data Analysis

Data was analysed using IBM SPSS version 22. One data file for FER task was corrupt from the MSc project and excluded from the sample. Sample characteristics and analysis are described separately for Study 1 and Study 2.

Preliminary analyses.

Parametric assumptions were checked by examining histograms, Levene's and Kolmogorov-Smirnov tests. Further examination of box-plots identified six outliers on the FER task that were more than 3 *SD*s from the group mean. In order to reduce the skew and/or kurtosis of the data, these outliers were transformed by converting the score from a z-score of 3.29[4] (Field, 2009, pp. 153). Analyses were carried out on the transformed data. The total sample size of 104 provides in excess of 80% power at an alpha level of 5% to detect a medium effect size for the aforementioned tests (Cohen, 1992). Alpha level was set at .05. Effect sizes for *r* were interpreted as small .1, medium .3 and large .5, and partial eta squared ($\eta 2$) values were interpreted as small .01, medium .06, and large .14 (Cohen, 1992).

[4] The outlier scores were replaced by scores that would give rise to a z-score of 3.29 by first calculating the mean and *SDs* of the data, and then adding 3.29 times the *SD* to the mean.

Results

Study 1

Sample characteristics.

The sample consisted of a VYP-group (*N* = 45), with an age range of 14 to 24 (*M*age = 17.33, *SD* = 2.46) and a control group of 59 students, with an age range of 15 to 18 (*M*age = 16.98, *SD* = .75). Majority of the VYP group was male (68.9%) and White British (93.3%), whereas the control group was mainly female (71.2%). No details regarding ethnicity were available for the control group. Information regarding education and mental health difficulties was only collected for the VYP group at current study (*N*=21) from the ASSET and P2I assessment reports. Of these, 19% were still in education and were yet to take exams, 61.9% had achieved GCSEs, 9.5% had achieved A-levels, and 9.5% had achieved some other qualifications (e.g., BTEC, or vocational qualifications). The VYP group had a mean WASI block design T-score of 45.76 (*SD* = 9.93) and vocabulary mean T-score of 38.18 (*SD* = 10.78). Respectively, these equate to 99 (average) and 85 (low average) population averages. The control group was tested on WASI-II matrix design and had a group mean of 59.98 (*SD* = 7.32), equating to population average of 115 (high average).

Formal mental health diagnoses were not reported in the ASSET or P2I assessments, but 42.3% of the sample was recorded to either have previous or current involvement with mental health professionals. Of this sample (*N*=21), 14.3% was described to either engage in self-harm and/or to have attempted or threatened suicide. One was reported to have historical episode of psychosis, and two were noted to experience depression. Of the total VYP sample (*N*=46), 63.0% were reported to use alcohol or other substances. The category of most severe substance use was only recorded for current study (*N*=21). Of these, 23.8% were using Class A drugs, 28.6% Class B drugs, 28.6% used only alcohol, and 19% were not using any substances. No mental health or substance use details were available for the control group.

Offence characteristics.

Majority (68.7%) of the VYP sample held either a previous and/or current criminal conviction (see Table 2 for details), and 15.7% had received cautions rather than formal convictions. The remaining 15.6% of the sample did not have any convictions or cautions. For one person, there was a mention of past criminal activity in his record, but no details were available. Of those with formal convictions, 32.5% also had a history of previous convictions. None of the control group participants had referrals to the Youth Justice System.

Table 2. Summary of Primary Offences Committed by the VYP Sample

Primary Offence	***n***	***Percentage of Sample***	***Seriousness Score (SS)****
Assault by beating	11	24.4	3 or 4
Theft	5	11.1	3
GBH	3	6.7	6
Rape	3	6.7	8
Burglary	2	4.4	6
Robbery	1	2.2	6
Supply	1	2.2	4
Possession	1	2.2	2
Assault with criminal damage	1	2.2	-**
Other/unspecified criminal damage	1	2.2	3
Common assault	1	2.2	3
Indecent assault on a man aged over 16	1	2.2	5

* SS column refers to a score given to a particular offence type on a scale of 1-8 as defined by the Youth Justice Board. The most serious offence of the individual was included in the table. **- = none recorded.

TBI characteristics.

Evident from Table 3, 60.0% of the VYP sample reported experiencing some degree of TBI, with 48.9% reporting LoC. Of the control group, 32.2% had experienced either a concussion or LoC for less than 10 minutes. Cause and number of previous injuries were not recorded for the control group.

Table 3. Summary of Self-Reported Severity of Worst TBI

TBI Severity	**Definition**	**VYP group (*n*=45)**		**Control group (*n*=59)**	
		n	**Percentage**	***n***	**Percentage**
No history		17	37.8	40	67.8
Minor concussion	Dazed & confused without LoC	6	13.3	4	6.8
Mild TBI	LoC <10 minutes	8	17.8	15	25.4
Mild Complicated	LoC 10-30 minutes	6	13.3	-	-
Moderate TBI	LoC 30-60 minutes	1	2.2	-	-
Severe TBI	LoC > 60 minutes	7	15.6	-	-

The most common causes for the worst injuries were fall when sober (*N*= *7,* 15.6%), fights (*N*=*7,* 15.6%), other non-criminal activity (*N*=3*,* 6.7%), road traffic accidents (*N*=3*,* 6.7%), abuse (*N*=2, 4.4%), and fall when under influence of drugs or alcohol (*N*=1*,* 2.2%). The cause of TBI was unknown for two cases.

Characteristics of the TBI and non-TBI group.

The participants were allocated to TBI or non-TBI groups based on the severity and frequency of their reported injuries. Emerging evidence suggests that 3 or more mild TBIs with LoC can lead to cumulative effect resulting in lasting brain changes (e.g., Davies et al., 2012; Gardner, Shores, Batchelor, 2010; Williams et al., 2010). The non-TBI group (*N*= 30) consisted of participants with either no history of TBI, concussions (without LoC), or up to 2 mild or complicated mild TBIs. Whereas the TBI-group (*N*=15) consisted of participants with a minimum of 3 mild- or complicated mild TBIs, or an incident of moderate, or severe TBIs. Within the TBI group, 12 were male, and within the non-TBI group 19 male. The groups were not significantly different on the demographic variables outlined in Appendix G.

Potentially confounding variables.

Two-tailed Pearson's correlation coefficients were run for age, FER accuracy scores, as well as block design and vocabulary T-scores in the VYP sample. Age was not correlated with any of the measures. However, WASI block design and vocabulary T-scores were significantly correlated with total FER hits, r= .395, p (two-tailed) < .006, and r= .388, p (two-tailed) < .008, respectively. Calculating coefficients revealed that 15.6% and 15.05% of variability in FER performance was accounted for by these two measures. As the control group was not measured on these same variables, these were not added as covariates in further analyses, but are considered as potential confounding factors in the VYP sample.

Hypothesis 1: Compared to the control group, the VYP group (with and without TBI) will demonstrate poorer overall accuracy on the FER task. The VYP TBI- group is predicted to demonstrate poorer overall accuracy compared to the non-TBI and the control groups.

One-way ANOVA was conducted to explore differences between the groups[5] on overall FER accuracy. This revealed a significant main effect of Group, $F(2,103) = 17.35$, p<.001, partial $\eta2 = .256$, with the VYP groups demonstrating lower mean accuracy scores compared to the control group. See Appendix H for means and standard deviations. Planned *post hoc* Bonferroni

[5] VYP non-TBI and TBI-groups and the control group

comparisons revealed that there were significant mean differences between control- and non-TBI group (*M*diff = 8.85, *SE* = 2.08, *p*< .001, 95% CI [3.79, 13.91]) and between control- and TBI-group (*M*diff = 13.51, *SE* = 2.68, *p*< .001, 95% CI [6.99, 20.4]). There were no significant differences between the VYP groups.

Hypothesis 2: Compared to the control group, the VYP groups, especially the TBI-group, will demonstrate poorer accuracy for recognising negative emotions (disgust, fear, angry, sad) than positive emotions (happy, surprise).

A 3 x 6 ANOVA was conducted to examine the between subjects factor of Group (as above) and within subjects factor of Emotion (e.g. six emotions). This revealed a significant within-subjects main effect of Emotion, *F(*5, 505) = 69.22, *p*<.001, partial η2 = .407, indicating that some emotions were more difficult to recognise than others. There was also a significant between-subjects main effect of Group, *F*(2,101) = 16.23, *p*< .001, partial η2 = .245. The main effect was qualified by a significant Emotion Type X Group interaction, *F*(10, 505) = 7.78, *p*<.001, partial η2 = .134. *Post hoc* Bonferroni pairwise comparisons revealed that the mean differences were significant between the control- and non-TBI group (*M*diff = .11, *SE*= .03, *p*<.001, 95% CI [.05, .18]) and between the control- and TBI-group (*M*diff = .17, *SE* = .03, *p*< .001, 95% CI [.09, .26]), but not between the VYP groups.

To investigate differences in performance between groups for each emotion further, five one-way ANOVAs were conducted on the emotions that met parametric assumptions (e.g., angry, disgust, sad, happy and surprise), with planned *post hoc* Bonferroni comparisons. The VYP groups demonstrated significantly poorer accuracy for anger, disgust, sad and surprise, as follows:

Angry, $F(2,103) = 16.61$, $p<.001$, partial $\eta 2 = .248$, with significant mean difference between control- and non-TBI group (*M*diff = .18, *SE* = .04, $p< .001$, 95% CI [.09, .27]), and between control- and TBI-group (*M*diff = .19, *SE* = .05, $p< .001$, 95% CI [.08, .30]); Sad, $F(2,103) = 11.50$, $p<.001$, partial $\eta 2 = .186$, with significant mean differences between control- and non-TBI group (*M*diff =.11, *SE* = .03, $p=.004$, 95% CI [.03 - .20]) and between control- and TBI-group (*M*diff = .19, *SE* = .04, $p<.001$, 95% CI [.08, .30]); Disgust, $F(2,103) = 37.77$, $p<.001$, partial $\eta 2 = .428$, with significant mean differences between control- and non-TBI group (*M*diff= .26, *SE* = .04, p<.001, 95% CI [.17, .35]) and between control- and the TBI-group (*M*diff = .34, *SE* = .05, $p< .001$, 95% CI [.22, .46]); Surprise, $F(2,103) = 5.75$, $p=.004$, partial $\eta 2 = .102$, with significant mean differences between control- and TBI- group (*M*diff = .12, *SE* = .04, $p=$ .008, 95% CI [.02,.21]), but not between control- and non-TBI group. None of the above comparisons were significant between non-TBI and TBI groups. The groups did not differ on recognising happy and the non-parametric Kruskall-Wallis test found no significant differences between the groups on fear. See Figure 3 for accuracy rates.

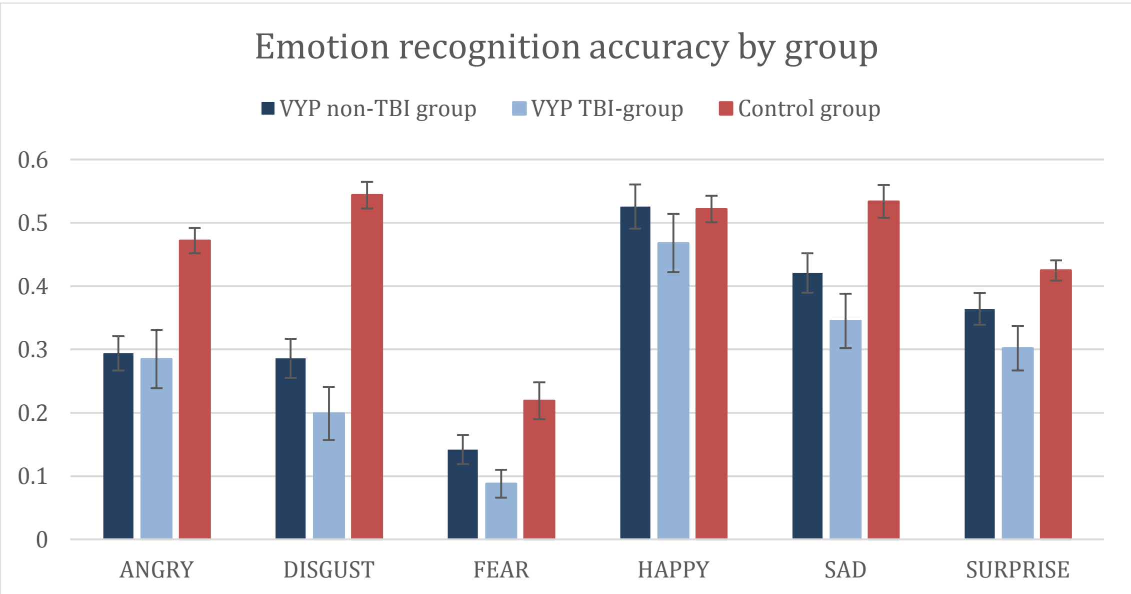

Figure 3. Display of emotion recognition accuracy for each group.

Study 2

Sample characteristics.

Study 2 consisted of 21 VYP participants from Study 1. Majority (71.4%) were male and everyone was White British. The average age was 18.57 years (*SD* = 2.9, age range: 14 – 24 years). Majority of the sample (57.1%) reported a history of TBI. Of these, 28.6% had sustained minor concussions, 23.8% had mild or complicated mTBIs, and 4.8% had moderate to severe TBI. See Appendix I for further demographic details regarding substance use, level of education, history of TBI and criminal offences for this sample. See Appendix J for a summary of the measures used in Study 2.

Hypothesis 3: Poorer performance on impulse control task is associated with worse accuracy on emotion recognition task and higher scores on self-reported measure of reactive-proactive aggression. Individuals with any degree of TBI are predicted to perform worse.

The data for the overall FER accuracy, SSRTs and RPQ subscales did not violate parametric assumptions. Cohen (1992) suggests that sample of 22 is required to detect a large correlation (power = .80, alpha = .01). One-tailed bivariate correlations were conducted for the aforementioned variables based on the a priori predictions of the hypothesis. However, no significant correlations were found between any of the variables.

A sample of 20 per group is suggested to have sufficient power to detect large effect at alpha level .01 (power .80; Cohen, 1992). Therefore, this study was underpowered. Due to the small sample size and the exploratory nature of Study 2, any self-reported TBI was included in the TBI group (*N* = 12). As the severity of TBI characteristics violated parametric assumptions, Mann Whitney U test was carried out to examine differences between the groups on impulse control (SSRT), overall FER accuracy, and RPQ. No statistically significant differences were found between the groups on any of these variables.

Discussion

This study explored the associations between TBI, facial emotion recognition ability, impulse control and self-reported aggression in delinquent and vulnerable young people (VYP) at risk of offending. This study supported the hypothesis that compared to the control group, the VYP groups (with and without TBI) were less accurate in overall performance on the FER task. However, the findings did not support the prediction that the TBI-group would demonstrate significantly poorer accuracy than the non-TBI group. The findings partially supported the prediction that VYP groups demonstrated poorer accuracy for negative than positive emotions. The VYP groups were significantly different from controls in recognising the negative emotions of anger, disgust and sadness, but not fear, and significantly different from controls in recognising positive emotion of surprise, but not happy. Finally, this study did not find support for the prediction that poorer impulse control on a Stop-IT task would be associated with poorer FER accuracy and higher self-reported levels of aggression.

Other key findings were related to prevalence of TBI. In line with pre-existing literature (e.g. Hughes et al., 2015), a history of TBI was reported by 60% of the VYP group, with 48.9% having experienced LoC, whereas 30% of the control group reported a history of TBI, with 25.4% including LoC. The VYP group also reported longer durations of LoC and greater severity of injuries, whereas the control group mainly reported mild TBIs with LoC of less than 10 minutes. However, the higher prevalence of TBI in the VYP group might reflect a selection or recall bias, as the participants were informed about the study aims in advance.

Facial Emotion Recognition in Vulnerable Youth

This study found that VYP groups showed general deficits in facial emotion recognition, which is vital for effective social communication (e.g., Knox & Douglas, 2009; Watts & Douglas, 2006). For instance, facial expression of anger signals threat and results in “vigilant” style of scanning and avoidant behaviours (Green, Williams, & Davidson, 2003). Distress cues are suggested to elicit approach behaviours, possibly reflecting recognition of submission in others that then elicits empathy and social bonding (Blair, Ambady, & Klek, 2005). Such deficits have been consistently found among antisocial and offender populations that is independent from task difficulty (e.g., Blair & Marsh, 2008) and has been suggested to contribute to antisocial behaviour. Consistent with previous findings, the VYP groups were significantly less accurate compared to controls in overall FER performance, and in recognising anger, sadness and disgust (Hoaken, Allaby, & Earle, 2007; Dolan & Fullam, 2006; Jones, Foster, & Skuse, 2007; Robinson et al., 2012). The VYP groups were not significantly different in recognising fear. They reported higher rates of reactive rather than proactive aggression, suggesting less psychopathic traits, which may account for this.

Differences in emotion recognition could also reflect task difficulty. A review of 43 studies from the TBI literature found that recognition scores are highest for happy expressions (94%) and lowest for fear (70%; Rapcsak et al., 2000). Similarly, a recent study by Rosenberg et al. (2014) found that happy faces were much easier to recognise than fear and surprise for both TBI and control groups – this pattern of findings were supported by the present study. In this study, fear had the lowest accuracy across the groups, which might explain lack of significant difference between the groups.

Research has suggested that individuals with moderate to severe TBIs demonstrate significant impairments in FER abilities (e.g., Babbage et al., 2011). Recent studies showed that moderate to severe childhood TBIs were associated with poorer emotion perception later in adulthood (Ryan et al., 2013, 2014). However, this study did not find evidence to support that the TBI-group was less accurate on FER ability than the non-TBI group. Furthermore, it is not possible to determine from this study whether FER ability contributes to antisocial behaviour.

TBI, Emotion Recognition, Impulse Control and Aggression

This study aimed to test the hypothesis that having TBI will exacerbate emotion recognition deficits in offenders and that this will be associated with greater impairments in impulse control and aggression. However, this assumption could not be confirmed. History of TBI in offenders has been associated with recidivism, more violent crime (e.g., Williams et al., 2010; Kenny & Lennings, 2007), poorer impulse control (Fisbein et al., 2009) and one study also considered TBI as an important background factor in FER deficits (Robinson et al., 2012). Therefore, TBI in offenders is suggested to manifest in more problematic behaviour.

The absence of the expected effects could be explained in several ways. First, this study was underpowered to detect any measurable differences between the VYP groups on impulse control, FER ability and self-reported aggression. Second, as the injuries were mainly mild, it could be that these were not fully representative of the typical injuries reported in offenders. Although mild TBIs, especially repeat injuries, have been associated with neuropsychological sequelae (e.g., Gardner, Shores, & Batchelor, 2010) and distinct biomarkers in the brain (e.g., Bigler, 2013), it is possible that symptoms from the mild injuries in this sample were no longer present, or sufficiently severe, at the time of testing. Thirdly, it could be that the premise for this hypothesis was unfounded and these associations do not exist in this population. Finally, the stop-signal paradigm, which is commonly used in experimental research, may not measure inhibition control effectively in clinical populations. The offending youth, for instance, may express impulsive behaviour under stressful emotional and social circumstances, which may be exacerbated by substance misuse and TBI, as suggested by Kenny and Lennings (2007).

Methodological Implications and Future Directions

Limitations.

This study had several important limitations that make it difficult to generalise from the findings. Firstly, due to the low response rate and opportunistic sampling method, the participants might not be fully representative of the offending and vulnerable youth. Although a control group was used in Study 1, it was not an adequate match to the VYP group with regards to gender, SES and cognitive ability. The second study had a small sample and no control group, thus lacking statistical power and means to determine whether the VYP group was different on impulse control and self-reported aggression. Also, the exclusion criteria regarding high risk of violence, by default, excluded the most impulsive and aggressive youth from this study.

A further problematic issue is the classification of TBI, which makes research in this area challenging. This study used a conservative system to classify TBI severity by both frequency and duration of LoC. This study considered LoC of less than 10 minutes as mild TBI and LoC between 10 and 30 minutes as mild complicated TBI. Conversely, other classification systems categorise these as minor and mild, respectively (e.g., WHO, 2001; Shaw et al., 2014). This study used comparable categories for moderate and severe TBIs, with regards to duration of LoC. What is more, the TBI-group included injuries ranging from mild to severe, which might have diluted the effects of the more severe injuries and inflated type II error. Unfortunately, this study was underpowered to conduct further analyses to examine whether different levels of TBI severity might be associated with greater impairment in FER accuracy, as suggested by Ryan et al. (2014).

Another limitation was to use a self-report questionnaire to determine history and severity of TBI, which might have resulted in inaccurate reporting. However, Schofield, Butler, Hollis, and D'Este (2011) found that self-reported TBI among prison population was reliably associated with head injuries recorded in medical records. Nevertheless, without neuroimaging, it is not possible to establish the presence of lesions or diffuse damage to the neural networks (e.g., Bigler, 2013). Considering these limitations, findings from this study should be interpreted with great caution. Therefore, the implications for future research would be to conduct studies with larger and more representative samples utilising neuroimaging, as well as to include matched control groups.

Furthermore, it is difficult to measure something as complicated as FER ability on a computer task using static images. In the real world FER is a dynamic process that requires simultaneous processing of voice prosody, body language and other context specific social cues. Therefore, future research should proceed to examine FER abilities in offenders by using dynamic displays of emotional expression, such videos of everyday interactions. For instance, the Awareness of Social Inference Test (TASIT; McDonald, Flanagan, & Rollins, 2002) might provide a better alternative.

Additionally, neuropsychological factors such as processing speed, visuospatial abilities, cognitive flexibility as well as word finding are suggested to influence performance on complex FER tasks. In this sample, the VYP group performed within the average range on the WASI block design, which was not that dissimilar to the performance of the control group on WASI-II matrix design (within high average range). Although different measures were used to assess cognitive ability in the VYP- and control groups, these measures provide an indication of the overall ability. However, future studies should include more robust cognitive screening to identify the full neurocognitive profile of strengths and weaknesses. Although further measures might have added more value to this research, ethically it would have been difficult to justify longer testing session with this population. Furthermore, substance use and mental health status were also likely to confound performance on the FER task, however excluding participants on these grounds would have resulted in an unrepresentative sample (e.g., Chitsabesan et al., 2015).

Majority of the participants showed signs of frustration during the computer tasks. Therefore, the data might reflect lack of concentration and perseveration on the participants' part, rather than reflect poorer accuracy in the FER task. Future research should develop materials that are more appealing for youth in order to encourage participation in research. Furthermore, the low incentive (£5 voucher) was a commonly reported refusal reason to take part in this study. Although alluring participants with lucrative rewards may lead to an ethical dilemma, better rewards are necessary to recruit hard-to-engage youth in research.

Strengths.

This study had access to a hard-to-engage population and recruited participants from multiple sites across a large county in South West England. The exclusion criteria were kept to a minimum in order to capture a representative sample. Due to foreseeable difficulties in recruiting for this population, previously collected data on FER task was added to the dataset to achieve a larger sample size. Therefore, the first study had adequate power to detect a medium effect size and used a control group to compare differences in emotion recognition performance between VYP and non-delinquent school-aged children, who also reported some mild dosages of TBIs. Although the control group was not fully matched on age, gender, cognitive ability and socio-economic status, it did offer some means for making comparisons.

Furthermore, this study used a range of measures that included computer-based behavioural experiments, validated cognitive assessment (WASI) and a validated self-report questionnaire regarding aggression (PRQ, Raine et al., 2006). Additionally, background data regarding criminal convictions, mental health history, level of education and substance use was collected from formal assessment reports. Furthermore, the FER task was designed to account for task difficulty by using linear morphed images that changed incrementally from ambiguous to unambiguous emotional expressions.

Conclusions

This study explored the association between TBI, FER ability, impulse control and self-reported aggression. Although there is evidence to suggest that offenders demonstrate specific impairments in recognising emotions, TBI has not been systematically considered in previous research. Therefore, this study was one of first to explore whether history of TBI was associated with impaired FER ability in delinquent youth and vulnerable young people. This study found that the VYP group (with and without TBI) demonstrated a similar pattern of reduced FER accuracy that was significantly different to the control group. However, the groups did not differ on accurate recognition of happy and fear. There were no significant differences between the TBI- and non-TBI groups on FER performance. This study also had an exploratory study that examined whether there were any associations between TBI, FER ability, impulse control and self-reported aggression. However, no associations were found.

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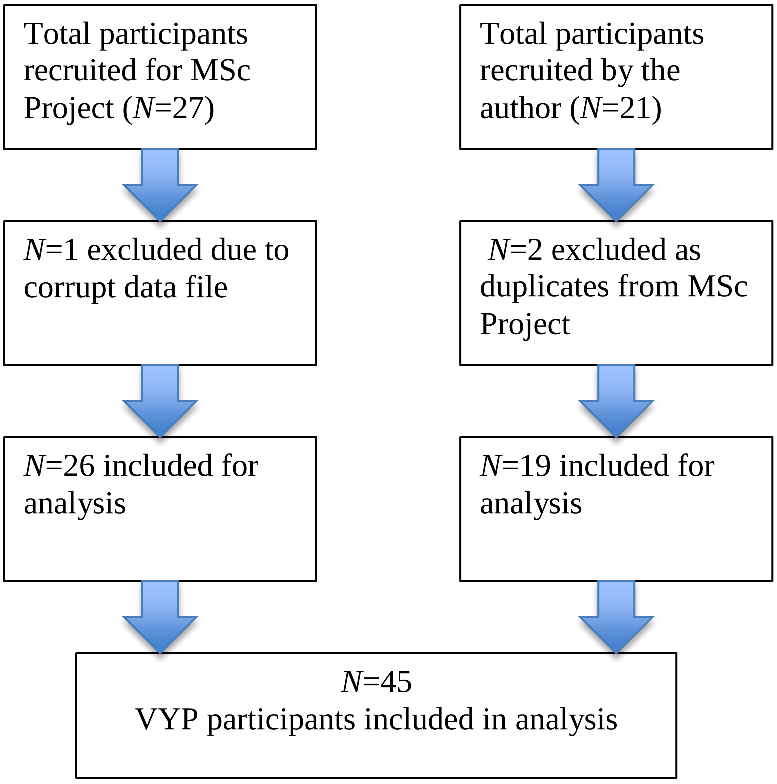
Appendix A. Recruitment Flow Chart and Non-attendance During Recruitment

Recruitment Flow Chart for Study 1



Non-attendance During Recruitment in the Current Study

Recruitment from the YOTs and P2I was highly challenging due to high non-attendance and cancellation rates, as well as difficulties in scheduling participants in. The YOT service leads reported having identified 36 potentially suitable candidates for the research project based on the exclusion and inclusion criteria, and the author was reassured that everyone had been contacted about the research project. However, it was not possible to check whether this had been done. Also, it was not possible to get exact figures with regards to refusal reasons, however the most commonly reported reasons given to the author were the low incentive offered (e.g., £5 voucher) and low motivation to engage with the YOT service and therefore also with the research project. There was one reported parental rejection for the young person to take part.

Recruitment site	**No of booked participants**	**No of participants seen**
Bridgewater YOT	10	3
Taunton YOT	4	2
Shepton Mallet	2	2
Yeovil YOT	4	3
Taunton P2I	4	2
Yeovil P2I	14	9

Each person was asked if they had taken part in previous research projects in Exeter. Two participants were identified having taken part in the previous Master’s project and therefore they were removed from the sample in Study 1.

As the recruitment sites where located in a different county to where the author is based, this resulted in excess of 1200 miles of driving to recruit 21 participants.

Appendix B. Comprehensive Health Assessment Tool (CHAT)

Questionnaire

Demographics

1. What is your age? ☐

2. What is your ethnic group? ☐

3. What is your gender? (M/F) ☐

Head Injury Information

4. Have you ever had a head injury to the head that caused you to be knocked out and/or dazed and confused, for a period of time? (E.g. from a fall, blow to the head, road traffic accident?)

☐Yes ☐No

If Yes,

5. How many times have you been knocked out and/or dazed and confused?

☐ Once
☐ Twice
☐ Three times
☐ Four times
☐More than four times

If more than four times then how many?

☐

Please give details of the time(s) you have been knocked out and/or dazed and confused. (Tick the boxes for duration and cause and provide age at injury). For multiple injuries of same cause, label (1 = worst, 2, 3 etc.) and record all injuries. For age and hospital visit information please reference the related injury)

	Dazed or confused	Unconscious for up to 5 minutes	Unconscious for 5 to 10 minutes	Unconscious for 10 to 20 minutes	Unconscious for 20 – 30 minutes	Unconscious for 30 to 60 minutes	Unconscious for over 60 minutes (please indicate	Age at injury	Were you admitted to hospital?	If yes, how long was duration of hospital visit?
Road Accident										
Road accident in stolen car										
Fall when sober										
Fall when under the influence of drugs/alcohol										
Sports injury										
Fight										
Other non-criminal activity										
Other criminal activity										

Appendix C. Reactive Proactive Questionnaire (RPQ)

The Reactive Proactive Aggression Questionnaire (RPQ) – Raine et al. (2006)

Instructions
There are times when most of us feel angry, or have done things we should not have done. Rate each of the items below by putting a circle around 0 (never), 1 (sometimes), or 2 (often). Do not spend a lot of time thinking about the items—just give your first response. Make sure you answer all the items (see below).

How often have you…

	Never	Some times	Often
1. Yelled at others when they have annoyed you	0	1	2
2. Had fights with others to show who was on top	0	1	2
3. Reacted angrily when provoked by others	0	1	2
4. Taken things from other students	0	1	2
5. Gotten angry when frustrated	0	1	2
6. Vandalized something for fun	0	1	2
7. Had temper tantrums	0	1	2
8. Damaged things because you felt mad	0	1	2
9. Had a gang fight to be cool	0	1	2
10. Hurt others to win a game	0	1	2
11. Become angry or mad when you don’t get your way	0	1	2
12. Used physical force to get others to do what you want	0	1	2
13. Gotten angry or mad when you lost a game	0	1	2
14. Gotten angry when others threatened you	0	1	2
15. Used force to obtain money or things from others	0	1	2
16. Felt better after hitting or yelling at someone	0	1	2
17. Threatened and bullied someone	0	1	2
18. Made obscene phone calls for fun	0	1	2
19. Hit others to defend yourself	0	1	2
20. Gotten others to gang up on someone else	0	1	2
21. Carried a weapon to use in a fight	0	1	2
22. Gotten angry or mad or hit others when teased	0	1	2
23. Yelled at others so they would do things for you	0	1	2

The Reactive–Proactive Questionnaire (RPQ) scores (0, 1 or 2) for proactive aggression items (2, 4, 6, 9, 10, 12, 15, 17, 18, 20, 21, 23) and reactive items (1, 3, 5, 7, 8, 11, 13, 14, 16, 19, 22) are summated to form proactive and reactive scales. Proactive and reactive scale scores are summated to obtain total aggression scores.

Appendix D. University Ethics Approval

Dr Cris Burgess

Psychology
College of Life & Environmental
Sciences

Washington-Singer Laboratories
Perry Road
Exeter EX4 4QG

Direct line +44 (0)1392 724627
Office +44 (0)1392 724625
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22nd August 2014

Applicant: **Sanna Tanskanen**

Ethics application **2014/549**

"Exploring the impact of Traumatic Brain Injury (TBI) on neurocognitive and socio-emotional processes in young offenders"

We are pleased to confirm that we have reviewed your planned research, reference above, and have reached a favourable opinion. On this basis, you are free to commence data collection and we wish you all the best with your project.

If you have any further queries, please don't hesitate to contact me, details above.

Yours sincerely,

Dr Cris Burgess
Chair, Psychology Research Ethics Committee

Appendix E. County Council Research Governance Ethics Approval

Somerset Centre for
SCIL
Integrated Learning

Ethics Approval Form
(Part a or Part b to be completed by CYPD Ethical Committee Representative)

Part a

The researcher has undergone CYPD ethical review and has demonstrated that the ethical issues have been satisfactorily addressed. We thus confirm that the project has CYPD ethical approval.

Signature of CYPD Ethical Committee Representative

Christine Pyke

Date 15th September 2014

Please give details of how the researcher was able to demonstrate that he/she had satisfactorily addressed the ethical issues:

- Breaks can be provided if participants are unable to sit in the room for up to an hour as the exclusion criteria are moderate to severe mental illness, learning disability and high risk of violence to self or others.
- Debriefing will be offered to all participants at the end of the study
- Issues regarding confidentiality and anonymity will be explained to participants prior to taking part in the study, and participants will be required to provide written consent following an opportunity to ask questions.
- Written consent will only be included in the study if consent has been approved. Parent/guardian consent will be sought for participants where they are under the age of 18 who live at home or in care. Those participants who are 16+ and live independently can consent on their own, as long as there are no other capacity issues.
- Anonymity of participants will be protected by coding the data and storing consent forms separately. Electronic data will be passport protected and paper based data will be stored at lockable cabinets at the University.
- Confidentiality will be breached in the event of disclosures of clear and present, or indicators of possible harm to themselves or others. In these cases, the project worker or service manager will be notified and the participant will also be informed of this.
- The experiment will be discontinued if the participants start showing signs of distress or report feeling uncomfortable. The participants have a right to withdraw from the study at any time without giving a reason. Although it is unlikely that the experiment would cause psychological distress, the project worker/support worker will be notified if this is the case.
- Study information sheet to staff and participants, as well as participant and guardian/parent consent forms are enclosed to this application.

Appendix F. Proof of University Ethics Approval for the MSc project and the Control Group

Proof of university ethics for the MSc study:

From: apache@exeter.ac.uk [mailto:apache@exeter.ac.uk]
On Behalf Of Ethics Approval System
Sent: 12 April 2013 15:21
To: Williams, Huw
Subject: Notification of ethical approval decision: accepted

Ethical Approval System

This is to inform you that the application (2013/289) by Miriam Cohen **Entitled** An investigation of the consequences of traumatic brain injury on emotional processing in juvenile offenders has been accepted.

Proof of ethical approval for the control group:

Acad ref	Researchers	Title	Status	Project Leader	Assessor	Date Submitted	Track
2014/622	Claire Harries, Anna Adlam, Henrietta Roberts, Huw Williams, Edward Watkins, Ian Penton-Voak, Marcus Munafo	Emotion recognition, working memory, and mood in adolescents	accepted	(PL): Anna Adlam	Nick Moberley	1 Jul 2014	Track B

Appendix G. Recruitment Pack for YOTs and P2Is

RECRUITMENT PACK:

Study information leaflet: Practitioner's abstract	For staff only
Cover letter to parent/guardian	For guardians/parents of participants under the age of 18 who live at home or in care. Not required for participants over the age of 16 living independently.
Participant information sheet about the study	For all participants
Young person consent form	For all participants
Parental/Guardian consent form	For guardians/parents of participants under the age of 18 living at home or in care. Not required for participants over the age of 16 living independently.

Researcher contact details:

Sanna Tanskanen, Trainee Clinical Psychologist, University of Exeter
Washington Singer Building
Perry Road
Exeter EX4 4QG

Email: st384@exeter.ac.uk

Somerset YOT Teams &
Pathways to Independence Project

UNIVERSITY OF EXETER

Study: Exploring the impact of Traumatic Brain Injury (TBI) on socio-emotional and cognitive processes in young people

PRACTITIONER'S ABSTRACT

Purpose: Traumatic Brain Injury (TBI) is the leading cause of death and disability in children and working age adults. Recent research has shown that TBI is highly prevalent in offending populations and increasing severity, or "dosage", of TBI has been linked to earlier age of incarceration, repeat offending and more violent crimes. However, little is understood about how TBI affects socio-emotional processing, such as recognition of emotions from facial expressions, or how TBI affects impulse control and reactive aggression. This study will hopefully add valuable insight and inform the development of more effective screening and interventions for young offenders.

Method: We are aiming to recruit 50 young offenders and young people in care for this study. The session takes about an hour to complete. The participants are asked to complete a selection of brief assessments measuring cognitive functions, emotion recognition and impulse control. The participants are also asked to fill in a few short questionnaires with the researcher.

Where: The study will take place in a private interview room at the YOT service. The participant will receive a £5 high street voucher after completing the experiment. The participant will also be entered into a price draw worth £10.

How to get involved: If you are currently working with young people, between the ages of 10-25, who might be interested in participating, then please provide them with a participant information sheet. Please contact the researcher to arrange a convenient time for the testing session (contact details below).

Thank you for your time and assistance!

If you have any questions, or would be interested in receiving more information about the study, please contact:

Sanna Tanskanen, Trainee Clinical Psychologist.
Email: st384@exeter.ac.uk

Cover letter to parents/guardians
Under 18 year olds

UNIVERSITY OF EXETER

School of Psychology

RE: RESEARCH STUDY

Exploring the impact of Traumatic Brain Injury (TBI) on socio-emotional and cognitive processes in young people

Dear Parent/Guardian,

We are writing to you as your child, or the young person under your care, has been invited to take part in a research project conducted by the University of Exeter. It is important that you and the young person understand why this research is being done and what it involves, in order to help you to decide whether to take part.

Therefore, please read the enclosed **Participant Study Information Sheet** that explains further details about this research. If you are happy for your child or the young person under your care to take part, then please sign the enclosed **Parent/Guardian consent form**. The researcher will ask for this signed form before the young person can take part in the study.

S/he will meet with a female researcher, Sanna Tanskanen, who is a Trainee Clinical Psychologist from the University of Exeter. She is carrying out this research project as a part of her doctorate in clinical psychology. She has an enhanced background clearance (CRB certificate) and works under close supervision of Professor Huw Williams, at the University of Exeter.

Should you have any further questions about this study, you can request to speak with the researcher over the phone or in person.

Thank you for your time and assistance.

Sanna Tanskanen

Trainee Clinical Psychologist

Somerset YOT Teams &
Pathways to Independence Project

UNIVERSITY OF EXETER

School of Psychology

Exploring the impact of Traumatic Brain Injury (TBI) on socio-emotional and cognitive processes in young people

PARTICIPANT STUDY INFORMATION SHEET

We are inviting you to take part in a research study run by the School of Psychology at the University of Exeter. To help you decide if you want to take part, please read the information below about why this research is being done and what you will be asked to do.

The purpose of this study

Some studies have shown that young people who have experienced an injury to their head (Traumatic Brain Injury - TBI) find it harder to control their impulses and to recognise other people's emotions by looking at their faces. When people find these things difficult, it can lead to problems in relationships and to socially unacceptable behaviours such as aggression or violence. There is relatively small amount of research investigating how good young people are at recognising emotions from faces and controlling their impulses. Therefore, this research will explore the links between TBI, impulsiveness, recognizing emotions, and aggression.

Risks and benefits of participating

You do not have to take part. However, by taking part you will help us to understand how well young people with and without TBI recognise emotions by looking at faces and how good they are at impulse control. Identifying any difficulties in these areas can help the development of specialist interventions and improve services to young people. Should you decide to take part, you can withdraw from the research at anytime without giving a reason.

What would the study involve?

This study will take about an hour to complete. You will be asked to complete 2 computer-based tasks that take about 30-40 minutes in total. One of the tasks will ask you to identify emotions by looking at different faces. The second computer task will ask you to either press a button or to withhold your response when presented with different stimuli. You will also be asked to do some tasks with the researcher that take about 10-15 minutes. Finally you will be asked to fill in a short questionnaire that asks you about any head injuries you may have had and a questionnaire about aggression. With your permission, additional background information about you will be collected from the Asset assessments and pre-sentence reports. You will be asked to sign a consent form before the study. If you are under the age of 18, you will also need your parent's or guardian's consent to take part.

How and where?

The study will take place at your local young offending service and you will be met at a pre-arranged time in a private interview room. You can attend on your own, with your support worker or with your parent/guardian. You will be asked to complete a couple of computer tasks and questionnaires with the researcher. If you wish to participate you must sign the consent form at the beginning of the study. If you are under 18, your parent or guardian will also be asked to sign a consent form before you can take part.

If you agree to take part in this study, you will meet with a female researcher, Sanna Tanskanen, who is a Trainee Clinical Psychologist from the University of Exeter. She is carrying out this research project as a part of her doctorate in clinical psychology. She also has an enhanced background clearance (CRB certificate) and works under close supervision of Professor Huw Williams, at the University of Exeter.

Will the study be confidential? Will it be possible to identify me?

All information about you will be kept strictly confidential. Data will be coded so that your information will be made anonymous (i.e., your consent form and any personal details such as your name will be separated from the questionnaires and stored separately). It will not be possible to identify you.

We have to note that if you were to tell us that you were seriously intending to harm yourself or another person, or that you were engaged in, or were planning to engage in a criminal act, we would be duty bound to report such activities to your practitioner/YOT manager.

The results of the study

When we have completed our study the results will be written up as part of the researcher's Doctorate of Clinical Psychology Research at the University of Exeter. We will also submit the write-up to an academic journal. However, the information will be reported in a way that it is not be possible to identify you.

What is in it for me?

If you sign the consent form and complete the experiments in the study you will receive a £5 high street gift voucher. You will also be entered into a price draw worth £10. There are five vouchers in total.

What to do if you have any questions?

If you would like any information or advice on head injury and concussion, please see the following links:
http://psychology.exeter.ac.uk/research/centres/ccnr/public/adults/
http://psychology.exeter.ac.uk/research/centres/ccnr/wellbeingadults/

If you have any questions or would like further information about the study, please contact: Huw Williams, Associate Professor in Clinical Neuropsychology:
W.H.Williams@exeter.ac.uk
Thank you for your time and assistance.

Somerset YOT teams

UNIVERSITY OF EXETER

Participant Consent Form

Study: Exploring the impact of Traumatic Brain Injury (TBI) on socio-emotional and cognitive processes in young people

1) I have read and understood the study information sheet. ☐
2) I am satisfied with the amount of information I have been given about this research. ☐
3) Any questions I had have been answered to my satisfaction. ☐
4) I allow the researcher access to my Asset information (understanding all information used will be kept anonymous and confidential). ☐
5) If I have taken part in previous research conducted by the University of Exeter, I allow the researcher access to this previously collected data (understanding that this information will also be kept anonymous and confidential). ☐
6) I understand I am free to withdraw from this study at any time, without giving a reason. ☐
7) I agree to take part in this research. ☐

Name (please print clearly in block capital letters)

....

Signature……………………………………

Date………………………………

If you would like to participate in the research study, but would rather information from the Asset assessment is not included please indicate this by ticking the box provided: ☐

Participant number:

Somerset YOT teams
For under 18-year-olds living at home

UNIVERSITY OF EXETER

Parental/Guardian Consent Form

Study: Exploring the impact of Traumatic Brain Injury (TBI) on socio-emotional and cognitive processes in young people

1) My child and I (caregiver) have read and understood the study information sheet. ☐
2) My child and I are satisfied with the amount of information we have been given about this research. ☐
3) Any questions my child and I had have been answered to my satisfaction. ☐
4) My child and I allow the researcher access to the Asset information (understanding all information will be kept anonymous and confidential). ☐
5) If my child has taken part in previous research conducted by the University of Exeter, my child and I allow the researcher access to this previously collected data (understanding that this information will also be kept anonymous and confidential). ☐
6) My child and I understand they are free to withdraw from this study at any time, without giving a reason. ☐
7) I agree for my child to take part in this research. ☐

Name of child (please print clearly in block capital letters)

....

Name of caregiver (please print clearly in block capital letters)

....

Signature…………………………………… Date………………………………

If you would like to participate in the research study, but would rather information from the Asset assessments is not included, please indicate this by ticking the box provided: ☐

Participant number:

Pathways to Independence
Project

UNIVERSITY OF EXETER

Participant Consent Form

Study: Exploring the impact of Traumatic Brain Injury (TBI) on socio-emotional and cognitive processes in young people

1) I have read and understood the study information sheet. ☐

2) I am satisfied with the amount of information I have been given about this research. ☐

3) Any questions I had have been answered to my satisfaction. ☐

4) I allow the researcher access to my assessment information collected by the Pathways to Independence Project (understanding all information used will be kept anonymous and confidential). ☐

5) I understand I am free to withdraw from this study at any time, without giving a reason. ☐

6) I agree to take part in this research. ☐

Name (please print clearly in block capital letters)

....

Signature……………………………………

Date………………………………

If you would like to participate in the research study, but would rather information from the assessment is not included please indicate this by ticking the box provided: ☐

Participant number:

Appendix H. Demographic Information for the TBI- and non-TBI Groups in the VYP Sample

Demographic Information for the TBI- and Non-TBI Groups in the VYP Sample

Variable	**Non-TBI group**			**TBI-group**						
	n	***Mean***	***SD***	***n***	***Mean***	***SD***	***M*diff**	***t***	***p****	**95% CI**
Age	30	17.00	2.46	15	18.0	2.39	-1.00	-1.29	.101	-2.56, .56
Age at first conviction	22	11.32	6.35	8	10.38	6.52	.943	.36	.362	-6.89, 0.15
Seriousness Score	29	3.52	2.49	11	2.18	1.94	1.34	1.60	.059	-.35, 3.02
Number of previous convictions	26	.85	1.41	9	4.22	8.74	-3.38	-1.13	.141	-10.11, 3.35
WASI non-verbal T Score	30	45.67	10.49	15	45.93	9.05	-.27	-.084	.47	-6.67, 6.14
WASI verbal T Score	30	37.73	10.35	15	39.07	11.91	-1.33	-.387	.35	-8.27, 5.61

Note. CI= Confidence Interval, * Significance at $p<0.05$

Appendix I. Summary of Performance on the FER Task

Facial Emotion Recognition Performance for VYP Groups and Control Groups

FER variable	VYP group total (*n*=45)		VYP: Non-TBI group (*n*=30)		VYP: TBI Group (*n*=15)		Control Group (*n*=59)	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Overall accuracy	47.00	10.25	49.0	10.29	44.33	9.77	57.86	8.65
Hits								
Angry	5.78	2.43	5.87	2.27	5.60	2.80	8.53	2.07
Disgust	7.07	3.09	7.67	3.10	5.87	2.83	11.28	2.45
Fear	4.38	2.97	4.57	2.83	4.00	3.32	5.40	3.94
Happy	10.91	2.52	11.00	2.60	10.73	2.43	9.62	2.73
Sad	9.36	2.62	9.63	2.46	8.80	2.93	11.47	1.91
Surprise	9.96	2.55	10.27	2.48	9.33	2.66	11.57	1.63
False alarms								
Angry	2.51	2.19	2.60	2.37	2.33	1.84	2.28	2.69
Disgust	7.76	4.59	7.63	4.24	8.00	5.37	5.10	3.60
Fear	8.62	5.08	8.20	4.82	9.07	4.65	5.60	3.69
Happy	6.15	5.22	3.75	5.10	7.13	5.51	2.64	2.72
Sad	6.47	3.98	6.10	3.97	7.20	4.04	5.70	3.85
Surprise	10.09	4.31	10.07	4.20	10.13	4.66	10.60	5.18
Recognition accuracy								
Angry	0.29	0.16	0.29	0.15	0.29	0.18	0.47	0.16
Disgust	0.26	0.17	0.28	0.17	0.20	0.16	0.54	0.16
Fear	0.12	0.12	0.14	0.13	0.09	0.09	0.22	0.23
Happy	0.51	0.19	0.53	0.19	0.47	0.18	0.52	0.17
Sad	0.40	0.17	0.42	0.17	0.35	0.17	0.53	0.14
Surprise	0.34	0.13	0.36	0.14	0.30	0.11	0.43	0.13

Appendix J. Summary of Participant Demographics in Study 2

Summary of Participant Demographics in Study 2

ID no.	Age	Sex	Highest level of education	Most severe substance used	Hx of TBI	Severity of worst TBI	No. of TBIs	Treatment sought	Cause of worst TBI	Time since worst TBI (month)	Primary Offense/ Caution	SS
1.	24	male	A-levels	Alcohol use	Yes	Complicated mild TBI	10	Yes	Fight	180	Caution for anger related criminal damage	No info
2.	20	female	A-levels	No substance use	No	No history	-	n/a	-	-	None	-
3.	18	female	GCSEs	Alcohol use	No	No history	-	n/a	-	-	None	-
4.	20	female	GCSEs	Class A	Yes	Minor concussion	1	No	Fight	24	Assault with criminal damage	No info
5.	21	female	GCSEs	No substance use	No	No history	-	n/a	-	-	None	-
6.	20	male	GCSEs	Class B	Yes	Minor concussion	4	Yes	Other non-criminal activity	120	None	-
7.	18	male	GCSEs	Class A	Yes	Mild TBI	3	No	Fight	12	Assault by	3

											beating	
8.	16	male	GCSEs	Class B	Yes	Minor concussion	4	Yes	Fight	48	GBH	6
9.	17	male	GCSEs	Class B	Yes	Complicated mild TBI	3	Yes	Fall when sober	96	No information	-
10.	21	male	Other qualifications	Class B	Yes	Moderate/ Severe TBI	16	No	Fall when under influence of drugs or alcohol	1	None	-
11.	15	female	still in education	Alcohol use	No	No history	-	n/a	-	-	Other/ unspecified criminal damage	3
12.	16	female	still in education	Class A	No	No history	-	n/a	-	-	Theft	3
13.	16	male	Other qualifications	Class B	No	No history	-	n/a	-	-	Theft	3
14.	15	male	still in education	Alcohol use	Yes	Mild TBI	2	Yes	Fall when sober	24	Rape	8
15.	14	male	still in education	Class B	Yes	Minor concussion	2	Yes	Fall when sober	120	Common assault	3
16.	17	male	GCSEs	Alcohol use	No	No history	-	n/a	-	-	Assault by beating	3
17.	18	male	GCSEs	Class A	No	No history	-	n/a	-	-	Assault by beating	3
18.	22	male	GCSEs	No substance use	Yes	Minor concussion	3	Yes	Fall when sober	12	None	-

19.	21	male	GCSEs	Class A	Yes	Complicated mild TBI	23	Yes	Sports injury	60	None	-
20.	24	male	GCSEs	No substance use	No	No history	-	n/a	-	-	GBH	6
21.	17	male	GCSEs	Alcohol use	Yes	Minor concussion	1	Yes	Fall when sober	168	Indecent assault on male aged 16 or over	5

Note: SS= Seriousness Score

Appendix K. Summary of Psychological Tests Used in Study 2

Summary of Psychological Tests Used in Study 2

Measure	**Subscale**	**Measurement unit/Range**	**Sample Mean (*n=21)***	**Sample SD**
WASI	Block design	0 – 71	49.00*	9.08
	Vocabulary	0 – 80	39.10*	9.63
Reactive & Proactive Questionnaire	Reactive aggression	0 – 22	11.76	4.784
	Proactive aggression	0 – 24	4.76	3.145
Stop-IT	Measure of inhibition/ impulse control	SSRT Milliseconds	211.52**	65.86
FER	Overall emotion accuracy	0-100	51.19	9.77

Note: *T-score, ** Average SSRT typically 250ms

Appendix L. Dissemination Statement

Dissemination Statement

The results of this study will be disseminated to interested parties through feedback, journal publication and presentation.

Dissemination to participants, YOT and P2I services.

The YOT and P2I services, as well as the local County Council's Research Ethics Board will be informed of the results of the study. A simplified version of the findings aimed at the participants will be provided to the services for further dissemination.

Journal Publication

I intend on submitting a reduced research paper for publication with the Journal of International Neuropsychological Society (impact factor 2.759).

Presentation

This study will be presented to fellow Trainee Clinical Psychologist, staff and other interested parties at the University of Exeter in June 2014. I will also offer to present the study findings to the participating services, or by writing, depending on the preference of the service leads.