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Theory of mind skills 1 year after traumatic brain injury in 6- to 8-year-old children

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Abstract

This study examined the longer-term effects of traumatic brain injury (TBI) on theory of mind (ToM) skills of children who were between the ages of 5 and 7 years at the time of injury. Fifty-two children with orthopaedic injury, 30 children with moderate TBI, and 12 children with severe TBI were evaluated approximately 1 year post-injury (mean age = 6.98 years, *SD* = 0.59, range = 6.02–8.26). Children with severe TBI did not engage in representation of first- and second-order mental states at a developmental level comparable to their peers, suggesting stagnation or lack of development, as well as regression of putatively existing ToM skills. Age, task-specific cognitive demands, and verbal abilities were strong predictors of ToM performance. However, even after taking those factors into account, children with severe TBI had poorer ToM performance than children with orthopaedic injuries.

Much of the research on social-cognitive skills of young children has focused on the construct of perspective-taking or mentalizing abilities, often referred to as 'theory of mind' (ToM) skills. ToM tasks purport to measure a child's ability to take another's point of view or to think about the mental states of others and to use this perspective to understand and predict behaviour. Most developmental research has focused on the emergence and mastery

of first-order ToM skills during the preschool years. A first-order ToM task presents a child with a discrepancy between what the child expects and reality and then asks them to reflect on one's mental state prior to discovery. For example, the child might be presented with a crayon box that is filled with cotton balls (i.e., false contents) or a situation where a toy is unknowingly moved to another place (i.e., false location). While many 3-year-olds will fail first-order ToM tasks, most 5-year-olds have reached mastery. In an effort to study ToM skills beyond 5 years of age, with particular focus on 6- to 7-year-olds, researchers have developed increasingly complex social perspective-taking tasks (i.e., second- and third-order ToM).

Second-order ToM tasks are embedded mental state tasks (e.g., she *thinks* that he *thinks*) requiring the recursive application of mental state reasoning used in first-order belief tasks (e.g., Perner & Wimmer, 1985; Sullivan, Zaitchik, & Tager-Flusberg, 1994). Second-order ToM tasks typically consist of a story that is acted out by an examiner using toys and dolls to depict the key locations and characters. In one of the most widely used second-order ToM stories, two children (John and Mary) see an ice cream truck at the park while they are playing. Later, each child is independently informed that the ice cream truck has moved from the original spot to the school, but neither child knows that the other person knows. Participants 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). Less research has focused on second-order reasoning, despite the potential importance of these types of attributions for social functioning. Much of the work has focused on determining at what age typically developing children have mastered second-order tasks and investigating the role of information-processing demands and cognitive skills in task mastery. For example, Sullivan *et al.* (1994) developed and evaluated whether performance on a second-order ToM task improved in typically developing preschool aged children when it was simplified cognitively and linguistically. In general, research has shown that children master second-order tasks by about age 6 or 7 (Perner & Wimmer, 1985).

Success on third-order or advanced ToM tasks requires accurate interpretation of more complex aspects of social interaction. Advanced ToM tasks are typically designed to reflect naturalistic situations that require skills such as non-literal interpretation of social communication or empathic accuracy (e.g., Dennis, Purvis, Barnes, Wilkinson, & Winner, 2001; Martin & McDonald, 2005). For example, these tasks assess an individual's ability to understand aspects of social interaction and communication such as jokes, irony, and sarcasm. Much of the research on advanced ToM skills has focused on demonstrating deficits in adolescents and adults with autism. Although little normative developmental research has been completed, these advanced ToM skills are thought to continue to develop throughout middle childhood (e.g., Baron-Cohen, Jolliffe, Mortimore, & Robertson, 1997; Happe, 1994; Roeyers, Buysse, Ponnet, & Pichal, 2001).

Little is known about the impact of paediatric brain disorders or injuries on the development of social-cognitive skills such as mentalizing abilities. Traumatic brain injury (TBI) in young children is a leading cause of lifelong disability. Recent epidemiological data suggest that children under the age of 5 years are at greater risk for TBI-related emergency

department visits and hospitalizations when compared to children aged 5–14 years (Centers for Disease Control and Prevention, 2000; Langlois, Rutland-Brown, & Thomas, 2006). Research on social outcomes of early childhood TBI is scant, despite the importance of examining short- and long-term social outcomes of young children (Janusz, Kirkwood, Yeates, & Taylor, 2002; Yeates *et al.*, 2004, 2007). Development of adequate social skills during the early school years is related to learning readiness (Blair, 2002), later academic success, and emotional well-being (Ladd, 1999; Parker & Asher, 1987). A better understanding of the cognitive and behavioural mechanisms that contribute to social outcomes is needed to design appropriate interventions. Certain neuropsychological abilities, such as ToM skills, are likely to affect social competence. That is, connectedness to others and appropriate social responses require the ability to consider another person's point of view (Dennis, 1991; Yeates *et al.*, 2007).

We are aware of four published studies that have examined ToM skills following paediatric TBI. Snodgrass and Knott (2006) assessed 12 children aged 6–12 years with moderate to severe TBI and frontal lobe damage who were 1–7 years post-injury. The 12 children with a history of TBI were compared to 12 non-injured control children using a range of ToM tasks. They found that the TBI group performed worse than the control group on an advanced ToM task (reading the mind in the eyes task, Baron-Cohen *et al.*, 1997), but not on first-order belief or deception tasks. Turkstra, Dixon, and Baker (2004) assessed the first- and second-order ToM abilities of 22 adolescents aged 13–22 years with a history of TBI who were 1–12 years post-injury. The comparison group included 48 typically developing adolescents. The adolescents with TBI performed more poorly than the typically developing group on a second-order ToM task. However, the groups did not differ on a first-order ToM task. The authors also failed to find significant correlations between performance on first- or second-order ToM tasks and age of injury or injury severity. Dennis, Agostino, Roncadin, and Levin (2009) assessed ToM skills in 43 children aged 7–16 years who were at least 1 year post-injury. They found that the TBI group's performance was significantly below normative data on a speech act measure of ToM (Wiig & Secord, 1985). They did not find performance differences between those injured at age 5 or earlier and those injured at age 6 or later. Finally, Walz, Yeates, Taylor, Stancin, and Wade (2009) examined post-acute effects (range = 8–104 days post-injury, mean = 37.88, *SD* = 19–29) of early childhood TBI on first-order ToM skills in 86 children with orthopaedic injury (OI), 42 children with moderate TBI, and 17 children with severe TBI who were aged 3–5 years at the time of injury. The findings offered tentative support for deleterious effects of TBI in young children on at least some aspects of first-order ToM skills. Age and IQ were strong predictors of ToM performance; however, the relationship between ToM and IQ was not as strong for children with TBI as for those with OI. Group differences on ToM were more pronounced at higher IQs than at lower IQs.

We are not aware of any studies that have investigated longer-term emerging second- or third-order ToM skills in children with a history of TBI during early childhood. To address this need and examine longer-term consequences of TBI in young children, children who were between 5 and 7 years of age at a 1-year postinjury assessment were tested on more advanced ToM tasks. The children were also drawn from the same larger parent study

reported on by Walz *et al.* (2009) previously. We hypothesized that children with a history of TBI would display deficits in second- and third-order ToM tasks compared to children with OI when evaluated 1-year post-injury. Moreover, we hypothesized that ToM deficits would be most pervasive for children with severe TBI. Finally, we explored whether children's age, task-specific cognitive demands, verbal ability, and injury severity were predictors of

ToM skills in our sample. Our purpose in considering these factors was to determine if we would find injury group differences in ToM performance that were not solely a function of verbal skills, task complexity, and/or chronological age. A secondary aim of the study was to determine if a simplified second-order task would enhance ToM performance relative to the standard task, as has been shown in typically developing children (Sullivan *et al.*, 1994).

Method

Participants

The study was approved by the institutional review boards of all participating hospitals and informed consent was obtained in writing prior to participation. Children were recruited from consecutive in-patient admissions from 2003 to 2006 of children with TBI or OI at three tertiary care children's hospitals and a general hospital, all of which had Level 1 trauma centres. Eligibility criteria included age at injury between 3 years and 6 years, 11 months, age at least 6 years, 0 months at the 1 year post-injury assessment, no documentation in the medical record or in parent interview of child abuse as a cause of the injury, and English as the primary spoken language in the home. Children with a history of autism, mental retardation, or a neurological disorder prior to injury were excluded. Eligibility for the TBI group included a blunt trauma to the head requiring overnight admission to the hospital and either a Glasgow Coma Scale (GCS; Teasdale & Jennett, 1974) score < 13 or a GCS of 13–15 with evidence for TBI-related brain abnormalities from computed tomography or magnetic resonance imaging. Consistent with previous investigations (Anderson *et al.*, 2006; Taylor *et al.*, 1999), severe TBI was defined as one resulting in a GCS score of 8 or less, and moderate TBI was defined as a GCS score of 9–12 or a higher GCS score in the presence of abnormal neuroimaging. The GCS score assigned to the child was the lowest one recorded post-resuscitation. To provide an estimate of the effects of TBI that accounted for both pre-injury risk exposure and the experience of hospitalization, children admitted to hospitals for OI but without TBI were included as a comparison group. Thus, inclusion in the OI group required a documented bone fracture in an area of the body other than the head that required an overnight hospital stay, and the absence of any evidence of loss of consciousness or other findings suggestive of brain injury.

Children participated in a comprehensive assessment of child and family functioning approximately 1 to 1 $\frac{1}{2}$ years post-injury, with an upper limit of around 17 months post-injury (see Table 1 for further details). This time frame was selected to examine the longer-term developmental consequences of the injury on neurobehavioural functioning. The age range was selected because of the developmental expectation that children would have mastered first-order ToM by age 6 but that second- and third- order ToM competence would still be

emerging. The second- and third-order ToM battery described below was administered to 94 children, including 42 children with TBI (12 severe and 30 moderate) and 52 with OI. Reasons for failure to test children included failing to participate in any portion of the 1 year post-injury assessment (15 TBI, 31 OI) or failing to participate in the child assessment (3 TBI). One child with OI was excluded because of a TBI sustained after enrolment in the study. Children who were not assessed did not differ significantly from those assessed on race, sex, or socio-economic status. Sample demographic characteristics are presented in Table 1.

Procedure and measures

ToM tasks were administered as part of a more comprehensive evaluation of the child and family (see Stancin, Wade, Walz, Yeates, & Taylor, 2008; Taylor *et al.*, 2008; Wade *et al.*, 2008; Walz *et al.*, 2009). As part of the larger assessment, children 6 years of age and older completed one first-order false-location ToM task and a companion control task, as well as second- and third-order ToM tasks. The first- and third-order ToM tasks involve two questions: a ToM question and a memory/comprehension question. Each ToM task was scored as correct or incorrect according to standard scoring procedures widely used in developmental psychology (e.g., Carlson & Moses, 2001; Flavell, Flavell, & Green, 1983; Flavell, Green, & Flavell, 1986). To pass a first- or third-order ToM task, the child was required to answer both the ToM question and the memory/comprehension question correctly. Administration and scoring procedures for second-order ToM tasks are detailed below. The Differential Ability Scales (DAS; Elliott, 1990) was administered as part of the larger test battery, and the Verbal IQ composite score was included in the data analysis as a measure of verbal abilities. The entire neuropsychological battery, including the ToM tasks, were independently scored by two research assistants (the one who administered the tests and a research assistant from another site). Discrepancies were reconciled and discussed with the study neuropsychologists as necessary.

First-order ToM—First-order ToM skills were assessed using a false-location task and a companion control task. The false-location task involved a discrepancy between what the child expected and reality. After discovering the reality, the child was asked about a puppet's expectation *before* discovery. This task has been widely used in the developmental psychology literature and was administered using the procedures developed and described in published research. For the false-location task, the child was asked to identify the location of an object (Carlson & Moses, 2001; Wimmer & Perner, 1983). For example, the examiner had a puppet 'Sally' that put candy in a jar and then left. A different puppet 'Anne' came and took the candy and ate it. Then 'Sally' came back and the child was asked, 'Where does Sally think the candy is?' The false-location control task was designed to parallel the false-location task in terms of syntax and content, but did not include references to mental states (Carlson & Moses, 2001; Gopnik & Astington, 1988). The false-location task and the companion control task were both scored pass/fail (score of 0 or 1).

Second-order ToM—Children received two stories designed to test their understanding of second-order mental states. The stories, which are described by Sullivan *et al.* (1994), entailed embedded mental state tasks requiring the recursive application of mental state

reasoning used in first-order false-belief tasks. The appendix to the article by Sullivan *et al.* (1994) provides complete scripts for both the ‘standard’ ice cream story and the ‘new’ birthday puppy story. The stories were acted out by the examiner using toys and dolls to depict the key locations and characters. The first story, labelled ‘standard’ by Sullivan *et al.* (1994), was based on a story used by Perner and Wimmer (1985). In the story, two children (John and Mary) see an ice cream truck at the park while they are playing. Later, each child is independently informed that the ice cream truck has moved from the original spot to the school, but neither child knows that the other person knows. Participants 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). The second story, labelled ‘new’ by Sullivan *et al.* (1994), was designed to be simpler than the revised ‘standard’ story. In the 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). Both stories included probe questions to ensure that the child actively processed the story, as well as linguistic and non-linguistic control questions that had the same linguistic complexity (double embedding) as the test questions. Children received feedback and teaching on the probe and control questions to ensure they were correctly encoding and remembering the key events. No feedback or correction was provided for the second-order ignorance and second-order false belief questions. Responses were scored pass/fail (Sullivan *et al.*, 1994). We created a second-order ToM score by summing the scores on the ignorance and belief questions across the two tasks (score range 0–). We created a second-order control score by summing the scores on the linguistic and non-linguistic control questions across the two tasks (score range 0–4).

Third-order ToM—A battery of three third-order ToM stories and three physical control stories were taken from Happe (1994), with some modifications made for younger children by their research group (R. Booth, personal communication, 2005). Each of the ToM stories provided a simple account of events that required accurate interpretation of non-literal social interactions involving the concepts of white lie, persuasion, or misunderstanding (see Appendix for task scripts). The three physical stories were similar to the ToM stories in cognitive and linguistic complexity, but did not require the child to make mental state inferences. The stories were presented orally by the examiner, while the child viewed a drawing that served as a nonverbal cue. After hearing the story, the child was asked, ‘Why did X say/do that?’ as well as a memory/comprehension question. Children were required to answer both questions correctly to pass an item. We created a third-order ToM score by summing the scores across the three third-order tasks (score range 0–3). We created a third-order control score by summing the scores across the three third-order control tasks (score range 0–3).

Finally, we created an overall ToM total score by summing the scores across the eight ToM tasks completed by children at the 1 year post-injury assessment (score range from 0–8). This score included the first-order false-location task (1 point), the false-belief and

ignorance scores for the two second-order tasks (4 points), and the three third-order tasks (3 points). To address possible concerns about multiple comparisons, we considered the ToM total score as our major outcome measure.

Results

Group differences on demographics and relationship with ToM performance

Severity group differences—Group comparisons (OI, moderate TBI, severe TBI) were conducted using chi-square analyses for dichotomous demographic variables (sex, race) and analysis of variance for continuous variables (census median family income, Verbal IQ, months from injury to assessment, age at injury, age at assessment). None of the group comparisons were significant (see Table 1 for details).

Relationship with ToM performance—Across the entire sample, we examined correlations of the ToM total score with demographic and clinical variables. ToM performance was not correlated with months from injury to assessment, census median family income, gender, race, or abnormal imaging (for the TBI children only). Better ToM performance was correlated with older age at injury, $r = .40, p < .001$, older age at assessment, $r = .43, p < .001$, and higher Verbal IQ, $r = .54, p < .001$.

Frequency and nature of ToM deficits

Pass rates for the first-order ToM and control tasks were compared across the three groups (OI, moderate TBI, and severe TBI) using chi-square analyses. The severe TBI group performed worse on the false-location task than the moderate TBI and OI groups, $\chi^2(2, 92) = 11.97, p < .01$ with 58% (7/12) of the severe TBI group passing the task compared to 93% (28/30) of the moderate TBI group and 92% (48/52) of the OI group. The three groups did not differ on pass rates of the false-location control task (severe TBI = 91%, moderate TBI = 97%, and OI = 98%).

Analyses of variance were conducted to compare the groups on the second-order ToM score, second-order control score, third-order ToM score, third-order control score, and ToM total score with group as the between-subjects factor. *Post hoc* Bonferroni adjusted *t* tests were used to examine significant main effects. Children with severe TBI (mean = 1.92, $SD = 1.51$) performed significantly worse on the second-order ToM score compared to children with moderate TBI (mean = 3.17, $SD = 1.05$) and children with OI (mean = 3.17, $SD = 0.96$), $F(2, 91) = 7.17, p < .01$. Children with severe TBI (mean = 2.92, $SD = 1.08$) also performed worse on the second-order control task compared to children with OI (mean = 3.65, $SD = 0.62$), $F(2, 91) = 4.38, p < .05$. However, the moderate TBI group did not differ significantly from the other groups on this task (mean = 3.30, $SD = 1.06$). There were no significant group differences on the third-order ToM score (severe TBI mean = 1.64, $SD = 1.12$; moderate TBI mean = 2.13, $SD = 0.97$; OI mean = 2.00, $SD = 1.01$) or the third-order control score (severe TBI mean = 1.45, $SD = 0.69$; moderate TBI mean = 1.55, $SD = 0.91$; OI mean = 1.48, $SD = 0.94$). Finally, children with severe TBI (mean = 4.27, $SD = 1.85$) performed significantly worse on the ToM total score compared to children with moderate

TBI (mean = 6.23, $SD = 1.78$) and children with OI (mean = 6.10, $SD = 1.85$), $F(2, 90) = 4.37, p < .05$.

To examine the extent to which children in each injury group benefited from the 'new' second-order story compared to the 'standard' story, each groups performance on the two versions of the task were compared using the Wilcoxon signed rank test. Within the OI group, more children passed the linguistic control (98 vs. 83%, $p < .01$), the second-order ignorance (100 vs. 83%, $p < .01$), and the second-order false belief (75 vs. 60%, $p < .05$) questions on the 'new' story compared to the 'standard' story. Within the moderate TBI group, more children passed the linguistic control (93 vs. 67%, $p < .01$), and the second-order ignorance (97 vs. 77%, $p < .05$) question on the 'new' story compared to the 'standard' story. Within the severe TBI group, there were no significant performance differences between the two tasks (pass rates of 75 vs. 67% on the linguistic control question, 67 vs. 58% on the second-order ignorance question, and 33% on the second-order false belief question for both stories).

Relationship between ToM performance and child characteristics

Hierarchical linear regression was conducted to examine associations of the ToM total score with child and injury characteristics (see Table 2). Age at assessment and dummy variables representing contrasts of each TBI group to the OI group were entered as predictors in the first step. DAS Verbal IQ score was entered in a second step to determine if group differences were a function of verbal abilities. Interactions of group with verbal abilities were entered in the third step, but were eliminated from the model because they were not significant. Age at assessment and the contrasts between the TBI and OI groups entered in step 1 accounted for 24% of the variance, F change (3, 88) = 8.99, $p < .001$. The addition of the DAS Verbal IQ score to the model in step 2 accounted for an additional 18% of the variance, F change (1, 87) = 27.43, $p < .001$. The contrast between the severe TBI and OI groups remained significant after verbal skills were entered into the regression. The total model was also significant, $F(4, 87) = 15.62, p < .001$. Significant effects for age at assessment and verbal skills reflected a positive association of these variables with the ToM score, whereas the significant effect for severe TBI reflected poorer ToM performance in that group.

Hierarchical linear regression was conducted to examine associations of the second-order ToM score with child and injury characteristics (see Table 3). Age at assessment and dummy variables representing contrasts of each TBI group to the OI group were entered as predictors in the first step. The second-order control task score and the DAS Verbal IQ score were entered in a second step to determine if group differences were a function of the cognitive complexity of the task or verbal abilities. Interactions of group with verbal abilities were entered in the third step, but were eliminated from the model because they were not significant. Age at assessment and the contrasts between the TBI and OI groups entered in step 1 accounted for 25% of the variance, F change (3, 89) = 10.00, $p < .001$. The addition of the second-order control score and DAS Verbal IQ score to the model in step 2 accounted for an additional 22% of the variance, F change (2, 87) = 18.54, $p < .001$. The contrast between the severe TBI and OI groups was still significant after task-specific

cognitive skills and verbal abilities were entered into the regression. The total model was also significant, $F(5, 87) = 15.78, p < .001$. Significant effects for age at assessment, task-specific cognitive abilities, and verbal skills reflected a positive association of these variables with the second-order ToM score. The significant effect for severe TBI reflected poorer second-order ToM performance in that group.

Discussion

The primary goal of this study was to examine the effects of TBI on emerging second- and third-order ToM skills in 6- to 8-year-old children who were injured approximately 1 year prior to assessment. As a group, children with a history of severe TBI were not able to engage in representation of first- and second-order mental states at a developmental level comparable to their peers. Our first-order ToM findings suggest regression of putatively developed false-belief skills following severe TBI among young children who were between the ages of 5 and 7 years at the time of injury. That is, whereas the moderate TBI and OI groups essentially mastered the false-belief and control task (over 90% pass), the severe TBI group mastered only the control task. The discrepancy between performance on the control task and the ToM false-belief task for the severe TBI group suggests that the false-belief deficit is domain specific and not due to the linguistic and cognitive complexity of the task. *Post hoc* analyses suggest that the children with severe TBI were more prone to realism errors. That is, these children failed the task because they were not able to acknowledge an expectation that differed from reality. This finding is consistent with our study of ToM skills shortly after injury in children aged 3–5 years in which children with severe TBI exhibited realism errors on first-order false-contents tasks (see Walz *et al.*, 2009). In general, other studies of ToM skills following paediatric TBI did not find group (TBI vs. control) differences on first-order tasks. However, these studies were of children injured after first-order skills are mastered.

The children with severe TBI were impaired on both the second-order ToM and control tasks compared to their peers. However, our regression analyses suggest that the children with severe TBI had poorer second-order ToM performance even after accounting for task-specific cognitive demands and verbal abilities. These findings suggest that the reduced ToM performance of the severe TBI group is not solely attributable to lower verbal or cognitive abilities. The format of both the ‘standard’ and ‘new’ stories featured reduced length, as well as inclusion of probes and feedback to facilitate the ability of all children to process and retain the relevant information. Interestingly, our results suggest a ‘dose-response’ type of relationship between injury severity and enhanced performance on the ‘new’ second-order ToM task in comparison to the ‘standard’ task. The OI group performed better on the linguistic, ignorance, and false-belief aspects of the ‘new’ story; the moderate TBI group performed better on the linguistic and ignorance aspects, and the severe TBI group did not perform better on any portion of the new task. Children with moderate TBI or OI appeared to benefit from the reductions in information-processing load and linguistic complexity (e.g., fewer characters, shorter story episodes), whereas children with severe TBI did not. Moreover, the deception in the story (i.e., characters hiding the truth from Peter to surprise him for his birthday) may have helped to focus the children with moderate TBI or OI on the ignorance of one person for the knowledge of another. Our within- and between-

group findings also lend some credence to the notion that attribution of second-order ignorance is easier than false belief (Coull & Leekam, 2006; Hogrefe, Wimmer, & Perner, 1986; Sullivan *et al.*, 1994). Given the cognitive and linguistic demands required to demonstrate second-order false belief, children with severe TBI may need further task modifications (e.g., further reduction of memory and linguistic demands) to access their mental state knowledge or they may be demonstrating a developmental lag in these skills.

In view of the relatively poor performance of the severe TBI group on the first-order task, it is not surprising that they also had difficulty in second-order mental state attribution. Moreover, performance on both first- and second-order ToM tasks likely was hampered by the cognitive consequences of severe TBI (Taylor *et al.*, 2008). Recent research suggests that poor performance on ToM tasks following paediatric TBI is likely related to deficits in communication skills and executive functions, such as language pragmatics, working memory, and cognitive inhibition (Dennis, 1991; Dennis *et al.*, 2001, 2009; Yeates *et al.*, 2007). Another possibility is that children with impaired ToM skills were somehow more vulnerable to severe TBI (i.e., missing social cues that would alert them to danger). However, in our sample, severe TBI was more likely than moderate TBI or OI to occur in the context of the child being a passenger in a motor vehicle. In other words, for at least a third of the children in the severe TBI group, the TBI was incurred in a circumstance unlikely to reflect any child cognitive or behavioural factors (see Table 1).

Although we did not find group differences on our third-order control or ToM tasks, these differences may emerge on advanced ToM tasks with advancing age. That is, we would anticipate that children with OI (and probably moderate TBI) will be able to master the third-order ToM tasks at an older age, whereas children with severe TBI will continue to lag behind. Indeed, in the present study, a trend was observed for group differences on the easiest of the third-order mental state stories. That is, around 80% of the OI and moderate TBI groups passed the white lie third-order story in comparison to around 55% of the severe TBI group.

Our regression analysis revealed that age at assessment, verbal skills, and task-specific cognitive complexity were strong predictors of ToM performance independent of injury type, a result consistent with the normative developmental literature and our previous findings with 3- to 5-year-olds shortly after injury (Walz *et al.*, 2009). These findings indicate that ToM tasks are linguistically and cognitively complex and that performance is related to children's verbal skills and other task-specific cognitive competencies (Bloom & German, 2000), as well as chronological age. Indeed, at the 1 year post-injury assessment, ToM performance was significantly related to Verbal IQ for all three groups (severe TBI, $r = .67$; moderate TBI, $r = .53$; OI, $r = .48$). Moreover, the second-order control tasks, which were designed specifically to control for serve as a measure of the cognitive and linguistic complexity of ToM tasks, were very strong predictors of second-order ToM performance.

Study limitations include a relatively small sample size (particularly with severe TBI), the absence of more sophisticated and comprehensive acute or 1 year follow-up brain imaging, and lack of information on other severity variables, such as length of post-traumatic amnesia. Because of the especially small sample of children with severe TBI, caution is

indicated in interpreting the representativeness of findings from this group. Further study is needed, for example, to isolate the effect of TBI from background factors that potentially contribute to risk for severe injuries. Larger sample sizes are most critical in studies of the effects of TBI on outcomes such as ToM, as these skills emerge within a relatively narrow age range and vary substantially with post-injury differences in neural reorganization and skill development (Anderson, Catroppa, Morse, Haritou, & Rosenfeld, 2005; Barnes, Dennis, & Wilkinson, 1999; Ewing-Cobbs, Fletcher, Francis, Davidson, & Miner, 1997; Taylor & Alden, 1997).

The results of this study suggest a number of important research directions as we continue to follow this cohort. Most importantly, this initial follow-up suggests that children with severe TBI 'look worse' over time on ToM tasks and that this is strongly related to verbal skills 1 year post-injury. Continuing to monitor the development of these children will help to determine if children with severe TBI during early childhood ever master even basic ToM tasks. The findings suggest that over time, verbal abilities and task-specific cognitive complexity are stronger predictors, but other neurobehavioural skills not considered in the analyses (e.g., executive functions) may be similarly important for long-term social and neurobehavioural outcomes. We will also be able to relate the development of ToM skills to the child's social environment. Given the importance of social and behavioural competence to academic success and emotional well-being, study of the relationship between ToM skills and social competence will be another important future direction. That is, we would hypothesize that ToM deficits are related to poorer functioning in home, school, and community settings. Indeed, in our cohort, ToM skills (ToM total score) were significantly correlated with parent ratings of social competence, $r = .30, p < .01$ (HCSBS social competence score, Merrell & Caldarella, 2002; Merrell, Streeter, & Boelter, 2001). If the development of ToM skills depends in part on adequate social interactions and social communication, we also might hypothesize emergence of larger group differences in ToM performance over time, as severe TBI has a detrimental impact on social outcomes and interactions with peers, particularly as children reach the later elementary and middle school years (Yeates *et al.*, 2004).

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References

- Anderson VA, Catroppa C, Dudgeon P, Morse SA, Haritou F, Rosenfeld JV. Understanding predictors of functional recovery and outcome 30 months following early childhood head injury. *Neuropsychology*. 2006; 20:42–57.10.1037/0894-4105.20.1.42 [PubMed: 16460221]
- Anderson VA, Catroppa C, Morse S, Haritou F, Rosenfeld J. Functional plasticity or vulnerability after early brain injury? *Pediatrics*. 2005; 116:1374–1382.10.1542/peds.2004-1728 [PubMed: 16322161]

- Barnes MA, Dennis M, Wilkinson M. Reading after closed head injury in childhood: Effects on accuracy, fluency, and comprehension. *Developmental Neuropsychology*. 1999; 14:1–24.10.1207/S15326942DN160101
- Baron-Cohen S, Jolliffe T, Mortimore C, Robertson M. A further advanced test of theory of mind: Evidence from very high functioning adults with autism or Asperger syndrome. *Journal of Child Psychology and Psychiatry*. 1997; 38:813–822.10.1111/j.1469-7610.1997.tb01599.x [PubMed: 9363580]
- Blair C. School readiness: Integrating cognition and emotion in a neurobiological conceptualization of children's functioning at school entry. *American Psychologist*. 2002; 57:111–127.10.1037/0003-066X.57.2.111 [PubMed: 11899554]
- Bloom P, German TP. Two reasons to abandon the false belief task as a test of theory of mind. *Cognition*. 2000; 77:B25–B31.10.1016/S0010-0277(00)00096-2 [PubMed: 10980256]
- Carlson SM, Moses LJ. Individual differences in inhibitory control and children's theory of mind. *Child Development*. 2001; 72:1032–1053.10.1111/1467-8624.00333 [PubMed: 11480933]
- Centers for Disease Control and Prevention, National Center for Injury Prevention and Control. *Traumatic brain injury in the United States: Assessing outcomes in children*. Atlanta, GA: Author; 2000.
- Coull GJ, Leekam SR. Simplifying second-order belief attribution: What facilitates children's performance on measures of conceptual understanding? *Social Development*. 2006; 15:548–563.10.1111/j.1467-9507.2006.00340.x
- Dennis M. Frontal lobe function in children and adolescence: A heuristic for assessing attention regulation, executive control, and the intentional states important for social discourse. *Developmental Neuropsychology*. 1991; 7:327–358.
- Dennis M, Agostino A, Roncadin C, Levin H. Theory of mind depends on domain-general executive functions of working memory and cognitive inhibition in children with traumatic brain injury. *Journal of Clinical and Experimental Neuropsychology*. 2009; 16:1–13.10.1080/13803390802572419
- Dennis M, Purvis K, Barnes MA, Wilkinson M, Winner E. Understanding of literal truth, ironic criticism, and deceptive praise following childhood head injury. *Brain and Language*. 2001; 78:1–16.10.1006/brln.2000.2431 [PubMed: 11412012]
- Elliott, C. *Differential Ability Scales: Introductory and technical handbook*. San Antonio, TX: Psychological Corporation; 1990.
- Ewing-Cobbs L, Fletcher JM, Francis DJ, Davidson K, Miner ME. Longitudinal neuropsychological outcomes in infants and preschoolers with traumatic brain injury. *Journal of the International Neuropsychological Society*. 1997; 3:581–591. [PubMed: 9448371]
- Flavell JH, Flavell ER, Green FL. Development of the appearance-reality distinction. *Cognitive Psychology*. 1983; 15:95–120.10.1016/0010-0285(83)90005-1 [PubMed: 6831859]
- Flavell JH, Green FL, Flavell ER. Development of knowledge about the appearance-reality distinction. *Monographs of the Society for Research in Child Development*. 1986; 15:1–68.10.2307/1165866
- Gopnik A, Astington JW. Children's understanding of representational change and its relation to the understanding of false belief and the appearance-reality distinction. *Child Development*. 1988; 59:26–37.10.1111/1467-8624.ep8860955 [PubMed: 3342716]
- Happe FGE. An advanced test of theory of mind: Understanding of story characters' thoughts and feelings by able autistic, mentally handicapped, and normal children and adults. *Journal of Autism and Developmental Disorders*. 1994; 24:129–154.10.1007/BF02172093 [PubMed: 8040158]
- Hogrefe GJ, Wimmer H, Perner J. Ignorance versus false belief: A developmental lag in attribution of epistemic states. *Child Development*. 1986; 57(3):567–582.10.1111/1467-8624.ep7248787
- Janusz JA, Kirkwood MW, Yeates KO, Taylor HG. Social problem-solving skills in children with traumatic brain injury: Long-term outcomes and prediction of social competence. *Child Neuropsychology*. 2002; 8:179–194.10.1076/chin.8.3.179.13499 [PubMed: 12759833]
- Ladd GW. Peer relationships and social competence during early and middle childhood. *Annual Review of Psychology*. 1999; 50:333–359.10.1146/annurev.psych.50.1.333

- Langlois, JA.; Rutland-Brown, W.; Thomas, KE. Traumatic brain injury in the United States: Emergency department visits, hospitalizations, and deaths. Atlanta, GA: Centers for Disease Control and Prevention, National Center for Injury Prevention and Control; 2006.
- Martin I, McDonald S. Evaluating the causes of impaired irony comprehension following traumatic brain injury. *Aphasiology*. 2005; 19:712–730.10.1080/02687030500172203
- Merrell, KW.; Caldarella, P. Home & Community Social Behavior Scales. Eugene, OR: Assessment Intervention Resources; 2002.
- Merrell KW, Streeter AL, Boelter EW. Validity of the Home and Community Social Behavior Scales: Comparisons with five behavior-rating scales. *Psychology in the Schools*. 2001; 38:313–325.10.1002/pits.1021
- Parker JG, Asher SR. Peer relations and later personal adjustment: Are low-accepted children at risk? *Psychological Bulletin*. 1987; 102:357–389.10.1037/0033-2909.102.3.357 [PubMed: 3317467]
- Perner J, Wimmer H. 'John thinks that Mary thinks that ...': Attribution of second-order beliefs by 5- to 10-year-old children. *Journal of Experimental Child Psychology*. 1985; 39:437–471.10.1016/0022-0965(85)90051-7
- Roeyers H, Buysse A, Ponnet K, Pichal B. Advancing advanced mind-reading tests: Empathic accuracy in adults with a pervasive developmental disorder. *Journal of Child Psychology and Psychiatry and Allied Disciplines*. 2001; 42:271–278.10.1111/1469-7610.00718
- Snodgrass C, Knott F. Theory of mind in children with traumatic brain injury. *Brain Injury*. 2006; 20:825–833.10.1080/02699050600832585 [PubMed: 17060149]
- Stancin T, Wade SL, Walz NC, Yeates KO, Taylor HG. Traumatic brain injuries in early childhood: Initial impact on the family. *Journal of Developmental and Behavioral Pediatrics*. 2008; 29:253–261.10.1097/DBP.0b013e31816b6b0f [PubMed: 18454041]
- Sullivan K, Zaitchik D, Tager-Flusberg H. Preschoolers can attribute second-order beliefs. *Developmental Psychology*. 1994; 30:395–402.10.1037/0012-1649.30.3.395
- Taylor HG, Alden J. Age-related differences in outcomes following childhood brain insults: An introduction and overview. *Journal of the International Neuropsychological Society*. 1997; 3:1–13. [PubMed: 9072958]
- Taylor HG, Swartwout M, Yeates KO, Walz NC, Stancin T, Wade SL. Traumatic brain injury in young children: Post-acute effects on cognitive and school readiness skills. *Journal of the International Neuropsychological Society*. 2008; 14:1–12.10.1017/S1355617708081150 [PubMed: 18078527]
- Taylor HG, Yeates KO, Wade SL, Drotar D, Klein SK, Stancin T. Influences on first-year recovery from traumatic brain injury in children. *Neuropsychology*. 1999; 13:76–89.10.1037/0894-4105.13.1.76 [PubMed: 10067779]
- Teasdale G, Jennett B. Assessment of coma and impaired consciousness: A practical scale. *Lancet*. 1974; 2:81–84. [PubMed: 4136544]
- Turkstra LS, Dixon TM, Baker KK. Theory of mind and social beliefs in adolescents with traumatic brain injury. *Neurorehabilitation*. 2004; 19:245–256. [PubMed: 15502257]
- Wade SL, Taylor HG, Walz NC, Salisbury S, Stancin T, Bernard LA, Yeates KO. Parent-child interactions during the initial weeks following brain injury in young children. *Rehabilitation Psychology*. 2008; 53:180–190.10.1037/0090-5550.53.2.180
- Walz NC, Yeates KO, Taylor HG, Stancin T, Wade SL. First-order theory of mind skills shortly after traumatic brain injury in 3- to 5-year-old children. *Developmental Neuropsychology*. 2009; 34:507–519.10.1080/87565640902964490 [PubMed: 20183714]
- Wiig, EA.; Secord, W. Test of Language Competence - Expanded Edition. New York: Psychological Corporation; 1985.
- Wimmer H, Perner J. Beliefs about beliefs: Representation and constraining function of wrong beliefs in young children's understanding of deception. *Cognition*. 1983; 13:103–128.10.1016/0010-0277(83)90004-5 [PubMed: 6681741]
- Yeates KO, Bigler ED, Dennis M, Gerhardt CA, Rubin KH, Stancin T, Vannatta K. Social outcomes in childhood brain disorder: A heuristic integration of social neuroscience and developmental psychology. *Psychological Bulletin*. 2007; 133:535–556.10.1037/0033-2909.133.3.535 [PubMed: 17469991]

Yeates KO, Swift K, Taylor HG, Wade SL, Drotar D, Stancin T, Minich N. Short- and long-term social outcomes following pediatric traumatic brain injury. *Journal of the International Neuropsychological Society*. 2004; 10:412–426.10.1017/S1355617704103093 [PubMed: 15147599]

Table I

Demographics and clinical data for participants completing second- and third-order ToM battery I year post-injury

Group	Severe TBI, <i>N</i> = 12	Moderate TBI, <i>N</i> = 30	OI, <i>N</i> = 52
Age at injury (range)	5.79 (5.08 – 6.63)	5.89 (4.79 – 6.93)	5.84 (4.90 – 6.95)
Age at 1 -year post-injury assessment (range)	6.92 (6.15 – 7.77)	7.04 (6.05 – 8.12)	6.97 (6.02 – 8.26)
Months from injury to assessment, mean (range)	14.07 (1 1.63 – 16.40)	14.32 (12.38 – 16.77)	14.09 (12.24 – 17.08)
DAS verbal IQ, mean (<i>SD</i>)	93.00 (18.60)	100.14 (13.61)	105.06 (16.60)
Abnormal imaging, <i>N</i> (%)	9 (75%)	24 (80%)	na
Cause of injury, <i>N</i> (%)			
Passenger in motor vehicle	4 (33%)	1 (3%)	1 (2%)
Other transportation	2 (17%)	11 (37%)	9 (17%)
Fall	5 (42%)	18 (60%)	41 (79%)
Other	1 (8%)	0 (0%)	1 (2%)
Males, <i>N</i> (%)	5 (42%)	17 (57%)	27 (52%)
White race, <i>N</i> (%)	9 (75%)	20 (67%)	41 (79%)
Census median family income, <i>M</i> (<i>SD</i>)	\$55,817 (\$11,201)	\$57,3964 (\$29,007)	\$64,645 (\$20,879)

Note. DAS, Differential Ability Scales; mean = 100; *SD* = 15.

Table 2Hierarchical linear regression analysis of predictors of performance on the ToM total score ($N = 92$)

Predictor	β
Step 1	
Age at assessment**	0.39
Moderate TBI versus OI	0.01
Severe TBI versus OI**	-0.28
Step 2	
Age at assessment**	0.30
Moderate TBI versus OI	0.07
Severe TBI versus OI*	-0.18
Verbal IQ**	0.45

*
 $p < .05$;**
 $p < .01$.

Table 3

Hierarchical linear regression analysis of predictors of performance on the second-order ToM score ($N = 93$)

Predictor	β
Step 1	
Age at assessment **	0.34
Moderate TBI versus OI	-0.02
Severe TBI versus OI **	-0.36
Step 2	
Age at assessment	0.15
Moderate TBI versus OI	0.09
Severe TBI versus OI *	-0.19
Second-order control task **	0.42
Verbal IQ **	0.23

*
 $p < .05$;

**
 $p < .01$.